Uncontrolled Pedestrian Crossing Evaluation Incorporating Highway Capacity Manual Unsignalized Pedestrian Crossing Analysis Methodology

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June 2014

Research Project
Final Report 2014-21
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Technical Report Documentation Page


4. Title and Subtitle
Uncontrolled Pedestrian Crossing Evaluation Incorporating Highway Capacity Manual Unsignalized Pedestrian Crossing Analysis Methodology

5. Report Date June 2014

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9. Performing Organization Name and Address
Bolton & Menk, Inc.
12224 Nicollet Avenue
Burnsville, MN 55337

10. Project/Task/Work Unit No.
CTS Project #2014022

11. Contract (C) or Grant (G) No.
(C) 03619

12. Sponsoring Organization Name and Address
Minnesota Department of Transportation
Research Services & Library
395 John Ireland Boulevard, MS 330
St. Paul, MN 55155

13. Type of Report and Period Covered
Final Report

15. Supplementary Notes

16. Abstract (Limit: 250 words)
This report provides a procedure for the evaluation of uncontrolled pedestrian crossing locations that takes into account accepted practice, safety and delay. Safety considerations have been paramount to the analysis of crossings but delay is often not considered. The Highway Capacity Manual (HCM) provides a methodology for determining delay that can be included in the analysis of a crossing location. The analysis procedure takes into account previous research procedures and adds in delay considerations to develop a methodology appropriate for use by jurisdictional agencies in the evaluation of what is needed for treatments at uncontrolled pedestrian crossings.

The evaluation procedure developed runs through a multi-step process from field data review through the consideration of appropriate treatment options. The evaluation procedure takes into account field data collection; safety/crash history; stopping sight distance; HCM Level of Service (LOS); pedestrian sight distance; origins and destinations/alternate routes; access spacing and functional classification; roadway speed and pedestrian use; FHWA guidance for placement based on safety considerations; school crossings; and appropriate treatment options. Treatment options include four different classes: Signing and Marking Treatments; Traffic Calming Treatments; Uncontrolled Crossing Treatments; and High Level Treatments.

17. Document Analysis/Descriptors
Pedestrians, crosswalks, level of service, walking, flashing beacons, yielding, highway capacity, evaluation.

18. Availability Statement

19. Security Class (this report)
Unclassified

20. Security Class (this page)
Unclassified

21. No. of Pages 284

22. Price
Uncontrolled Pedestrian Crossing Evaluation Incorporating Highway Capacity Manual Unsignalized Pedestrian Crossing Analysis Methodology

Final Report

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Published by:

Minnesota Department of Transportation
Research Services & Library
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155

This report documents the results of research conducted by the authors and does not necessarily represent the views or policies of the Minnesota Department of Transportation or Bolton & Menk, Inc. This report does not contain a standard or specified technique.

The authors, the Minnesota Department of Transportation, and Bolton & Menk, Inc. do not endorse products or manufacturers. Trade or manufacturers’ names appear herein solely because they are considered essential to this report.
Acknowledgments

The financial and logistical support provided by the Local Road Research Board (LRRB), the Minnesota Department of Transportation (MnDOT), and the Minnesota Local Technical Assistance Program (LTAP) at the Center for Transportation Studies (CTS), University of Minnesota is greatly acknowledged. The procedures presented in this report were developed based on information from previously published research studies and reports and newly collected field data. The authors would also like to thank the following individuals and organizations for their contributions to this document.

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Executive Summary

Pedestrian crossings are an important aspect of the multi-modal transportation system. While they are essential to get pedestrians across highways and streets, they are a concern for jurisdictional authorities of highways and streets due to the numerous locations and concerns for pedestrian safety. In support of this, state statutes generally support the rights of pedestrians at crossing locations. According to Minnesota State Statutes, the driver of a vehicle shall stop for a pedestrian at all marked crosswalks and at all intersections. While motorists are required to stop for pedestrians in these situations, some pedestrians may indicate that additional measures are needed to be able to safely cross at a specific crossing location, especially as many motorists do not follow the law and stop when required. Additionally, in any crash between a vehicle and pedestrian, the chance of the pedestrian being severely injured or killed is high, leading pedestrians to not take chances and wait for an adequate gap in traffic before even attempting to start to cross.

Traffic signals can provide an adequate gap by controlling when traffic, vehicles and pedestrians alike, are to move or stop, but the traffic volume necessary to justify a signal can be quite high. Of more significance to understand is how to provide adequate gaps and increased safety at uncontrolled pedestrian crossing locations.

When traffic volume is high enough, adequate gaps can be difficult to attain. While marking a crosswalk can provide an indication to vehicle traffic that there is a potential for crossing pedestrians, a crosswalk does not make a motorist stop. Consequentially, marked crosswalks do not necessarily provide any increase in safety for a pedestrian. There is significant research into the safety considerations of uncontrolled pedestrian crossings when they are marked versus unmarked. This research generally indicates that pedestrian crash rates increase when these crossings are marked versus unmarked under most situations. This has been applied by many jurisdictional agencies for the evaluation of pedestrian crossings on their roadways. In support of this, the Manual on Uniform Traffic Control Devices (MUTCD) states that an engineering study should be completed before a marked crosswalk is installed at any location an approach is not controlled by a signal, yield or stop sign. While an engineering study that takes into account only safety research may be appropriate for many crossings, it may also be appropriate to consider operations in addition to safety, as is applied to vehicle traffic analysis.

The Highway Capacity Manual (HCM) provides a procedure for evaluating operations through pedestrian crossing delay. The research used to develop the methodology indicates that as delay increases at a crossing location due to motorists not stopping for the pedestrians, pedestrians take more risks to complete a crossing maneuver, similar to the way vehicles that experience high delay will also complete high-risk maneuvers. This impact should not be ignored. As of this research study, the HCM procedure has not been widely applied to the evaluation of pedestrian crossings but can help to provide an equivalent process to vehicle intersection operational analysis and be applied to the MUTCD engineering study requirement.

This research provides a procedure for the evaluation of uncontrolled pedestrian crossing locations that takes into account both safety and delay. The analysis procedure takes into account previous research to develop a methodology that is appropriate for jurisdictional agencies. As
this research was completed in Minnesota, the policies and standards mentioned in the study are from Minnesota where possible.

The evaluation procedure runs through a multi-step process from field data review through the consideration of appropriate treatment options. The specific steps include

- Field Data Review
- Safety Review
- Stopping Sight Distance Analysis
- HCM Level of Service (LOS) Analysis
- Pedestrian Sight Distance Analysis
- Review of Origins and Destinations and Alternate Routes
- Review of Access Spacing and Functional Classification
- Review of Speed and Pedestrian Use
- Review of FHWA Safety Guidance
- School Crossing Considerations
- Consideration of Appropriate Treatment Options
  - Signing and Marking Treatments
  - Traffic Calming Treatments
  - Uncontrolled Crossing Treatments
  - High-Level Treatments

The background, understanding and analysis methodology of each step in the process is introduced. A summary of appropriate crossing treatments, their advantages and disadvantages, recommended locations, estimated costs, and their impact on pedestrian yield rates as it relates to the HCM analysis are provided. In support of the analysis procedure, real world examples from Minnesota are shown to guide users through the evaluation and analysis process.
Chapter 1
Introduction

Pedestrian crossings are an important feature of the multi-modal transportation system. They enable pedestrians and bicyclists to cross conflicting traffic to access locations on either side of streets and highways. Pedestrian crossings can either be marked or unmarked.

According to 2013 Minnesota State Statutes, the driver of a vehicle shall stop to yield the right-of-way to a pedestrian at all intersections and at all marked crosswalks at unsignalized locations. Additionally, a pedestrian crossing a roadway at any location other than within a marked crosswalk or at an intersection shall yield the right-of-way to all vehicles upon the roadway. [1]

While the state statute says that a motorist shall stop for a pedestrian that is within a marked crosswalk or crossing at an intersection, the opportunities in which a motorist actually stops for a pedestrian and yields the right-of-way may be few. Additionally, when the traffic volumes are high enough that there are few gaps in traffic adequate for a pedestrian to cross a roadway safely, pedestrians may have a difficult time crossing. Consequently, either case can result in pedestrian crossings that are challenging and result in high delay for the pedestrian, which can lead to pedestrians taking higher risks.

Providing safe crossing situations for pedestrians relies on not only placing crosswalks at “safe” locations but also providing facilities where pedestrians are crossing with minimal delay. Placing crosswalk markings, signs, or other treatments at pedestrian crossing locations without understanding the needs of pedestrians in the area may result in the overuse of crossing markings and treatments that are not necessary and actually result in a less safe crossing environment. In support of the need to evaluate crossing locations, 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. [2]

Defining where to place pedestrian crossing facilities including markings and signs depends on many factors including pedestrian volume, vehicular traffic volume, sight lines, and speed. Additionally, there are locations in which pedestrians would like to cross the street, but the traffic volume is so high that there are not adequate gaps in the traffic stream to safely cross. This results in a high delay crossing which then results in a high risk-taking environment, decreasing safety.

The methodology for the evaluation of pedestrian crossings presented here attempts to evaluate the adequacy of uncontrolled pedestrian crossing locations based on both safety and operations. A companion to this evaluation methodology is Minnesota’s Best Practices for Pedestrian / Bicycle Safety which provides information on available pedestrian safety strategies.

This manual presents an engineering methodology that takes into account both safety and operations for the evaluation of uncontrolled pedestrian crossings. This includes crossings at both mid-block and intersections in which the cross-street traffic is not controlled by a stop sign, yield sign, or signal.
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Chapter 2

Background

The Minnesota Manual on Uniform Traffic Control Devices (MN MUTCD) states that crosswalk markings should not be used indiscriminately and that an engineering study should be completed when using crosswalk markings.

Objective and Scope:
The objective of this methodology is to provide a study procedure for the evaluation of uncontrolled pedestrian crossing locations that takes into account accepted practice, safety, and operations.

State of the Practice:
Crossing evaluation methods, best practices, and sources for development of the evaluation procedure will be presented.

Data Collection and Field Review:
A methodology for the field review and data collection will be presented. A Data Collection Worksheet has been developed that can be used to complete the field data collection.

Safety:
The Federal Highway Administration provides extensive research into the safety of pedestrian crossings based on the number of lanes being crossed, vehicle volume, and travel speed. The safety evaluation table will be presented.

Operations:
The Highway Capacity Manual provides a comprehensive evaluation methodology for determining the operations of a crossing location through the calculation of average delay for a pedestrian at a crossing location. The HCM procedure will be presented.

The 2010 HCM updates the previous evaluation procedure in the 2000 HCM to account for the effect of yielding of vehicles to pedestrians based on different crossing treatments beyond pavement markings and signs only.

Evaluation Procedure:
An uncontrolled pedestrian crossing location evaluation procedure and flowchart will be presented.

Examples:
Real world examples of different types of pedestrian crossing locations will be presented. This includes a field review and crossing evaluation.
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Chapter 3
State of the Practice

The information presented here is a summary of the information in each referenced document as it relates to pedestrian crossing evaluations. Please refer to the actual document for the full text and explanations.

Minnesota State Statutes [1]

Minnesota State Statutes regarding the rights of pedestrians at unsignalized pedestrian crossings are defined in section 169.21, subdivision 2a, 3a, 3b, 3c, and 3d. It is not the intention of this summary to be all inclusive to all laws regarding pedestrian crossings. No lawyers or legal representatives have reviewed the material and as such should not be taken to be all-inclusive. Consultation with legal representatives and review of the full state statutes is advised in reference to any and all legal matters.

“169.21 PEDESTRIAN.
Subd. 2. Rights in absence of signal.
(a) 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. The driver must remain stopped until the pedestrian has passed the lane in which the vehicle is stopped. No pedestrian shall suddenly leave a curb or other place of safety and walk or run into the path of a vehicle which is so close that it is impossible for the driver to yield. This provision shall not apply under the conditions as otherwise provided in this subdivision.
Subd. 3. Crossing between intersections.
(a) 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.
(b) Any pedestrian crossing a roadway at a point where a pedestrian tunnel or overhead pedestrian crossing has been provided shall yield the right-of-way to all vehicles upon the roadway.
(c) Between adjacent intersections at which traffic-control signals are in operation pedestrians shall not cross at any place except in a marked crosswalk.
(d) Notwithstanding the other provisions of this section every driver of a vehicle shall (1) exercise due care to avoid colliding with any bicycle or pedestrian upon any roadway and (2) give an audible signal when necessary and exercise proper precaution upon observing any child or any obviously confused or incapacitated person upon a roadway.” [1]

Important Points:
1. All intersections include legal pedestrian crossings whether marked or unmarked.
2. When a crossing is not signalized, the driver of a vehicle shall stop to yield the right-of-way to pedestrians within marked crosswalks and at all intersections with marked or unmarked crosswalks.
3. Pedestrians shall yield right-of-way to all vehicles upon the roadway at any point other than at intersections or marked crosswalks.
Minnesota Manual on Uniform Traffic Control Devices (MN MUTCD); January 2014

The MN MUTCD contains standards for traffic control devices that regulate, warn, and guide users along all roadways within the State of Minnesota. The MN MUTCD standards are to be followed on all roadways, public or private within the state.

Crosswalk Markings

Support, Guidance, and Standards for crosswalk markings are included in Section 3B.18 of the MN MUTCD.

“Support:
Crosswalk markings provide guidance for pedestrians who are crossing roadways by defining and delineating paths on approaches to and within signalized intersections, and on approaches to other intersections where traffic stops.

In conjunction with signs and other measures, crosswalk markings help to alert road users of a designated pedestrian crossing point across roadways at locations that are not controlled by traffic control signals or STOP or YIELD signs.

At non-intersection locations, crosswalk markings legally establish the crosswalk.

Standard:
When crosswalk lines are used, they shall consist of solid white lines that mark the crosswalk. They shall not be less than 6 inches or greater than 24 inches in width.

Guidance:
Crosswalk lines should not be used indiscriminately. An engineering study should be performed before a marked crosswalk is installed at a location away from a traffic control signal or an approach controlled by a STOP or YIELD sign. The engineering study should consider the number of lanes, the presence of a median, the distance from adjacent signalized intersections, the pedestrian volumes and delays, the average daily traffic (ADT), the posted or statutory speed limit or 85th-percentile speed, the geometry of the location, the possible consolidation of multiple crossing points, the availability of street lighting, and other appropriate factors.

New marked crosswalks alone, without other measures designed to reduce traffic speeds, shorten crossing distances, enhance driver awareness of the crossing, and/or provide active warning of pedestrian presence, should not be installed across uncontrolled roadways where the speed limit exceeds 40 mph and either:
A. The roadway has four or more lanes of travel without a raised median or pedestrian refuge island and an ADT of 12,000 vehicles per day or greater; or
B. The roadway has four or more lanes of travel with a raised median or pedestrian refuge island and an ADT of 15,000 vehicles per day or greater.
Guidance:
Because non-intersection pedestrian crossings are generally unexpected by the road user, warning signs should be installed for all marked crosswalks at non-intersection locations and adequate visibility should be provided by parking prohibitions.” [2]

Important Points

1. Crosswalk markings legally establish the location of a crosswalk at non-intersection locations.
2. When used, crosswalks shall consist of solid white lines that mark the crosswalk.
3. New marked crosswalks, in the absence of other measures, should not be installed across uncontrolled roadways where the speed limit exceeds 40 mph and either:
   a. Roadway > 4 travel lanes
      Without a raised median
      ADT > 12,000
   b. Roadway > 4 travel lanes
      With a raised median
      ADT > 15,000
4. An Engineering study should be completed before a marked crosswalk is installed at any location that an approach is not controlled by a signal, yield, or stop sign.

Signs

Support, Guidance, and Standards for signs associated with pedestrian crossing are included in multiple sections of the MN MUTCD. The sections that pertain to the signs presented in this manual include

- 2B.11: Stop Here For Pedestrian Signs,
- 2B.12: In-Street and Overhead Pedestrian Crossing Signs,
- 2C.49: Vehicular Traffic Signs,
- 2C.50: Non-Vehicular Signs,
- 7B.8: School Signs and Plaques,
- 7B.11: School Advance Crossing Assembly, and
- 9B.18: Bicycle Warning and Combined Bicycle/Pedestrian Signs.

Warning Signs

Pedestrian warning signs (W11-2) are considered non-vehicular warning signs. Other warning signs may be used at crossings depending on the facility using the crossing, be it pedestrians only (W11-2), bicyclists (W11-1), or a combination (W11-15). Under most circumstances the W11-1 should be used for bike trail crossings, W11-2 should be used for pedestrian crossings, while W11-15 should be used for multi-use trail crossings. Additionally, school crossings have the S1-1 sign. This manual focuses on pedestrian warning signs, but practitioners should be aware that there are different warning signs available for crossings and the support, guidance, and standards for each depend on the type of crossing facility. [2]
Pedestrian warning signs may be used to alert road users in advance of a pedestrian crossing location where unexpected entries into the roadway might occur or where shared use of the roadway by pedestrians might occur. They may be placed in advance of a crossing location and/or at the crossing location.

“Non-vehicular signs should be used only at locations where the crossing activity is unexpected or at locations not readily apparent.”

“The crossing location identified by a W11-2 sign may be defined with crosswalk markings.”

The S1-1 sign can be used in the same way as a pedestrian warning sign except that it is used to indicate where schoolchildren are crossing the roadway. [2]

**Supplemental Plaques**

“If used in advance of a pedestrian crossing, the W11-2 signs should be supplemented with plaques with the legend AHEAD or XX FEET to inform road users that they are approaching a point where crossing activity might occur.”

While the above plaques are included in the MN MUTCD many jurisdictions do not install them, especially if the crossing location is visible from the advance warning sign location. The plaques do provide additional information to the motorist about where the crossing is located if the crossing cannot be readily seen.

“If a post-mounted W11-2 sign is placed at the location of the crossing point where pedestrians might be crossing the roadway, a diagonal downward pointing arrow (W16-7P) plaque shall be mounted below the sign. If the W11-2 sign is mounted overhead, the W16-7P plaque shall not be used.” [2]

In Minnesota, the W16-7P has been modified with a larger sign consistent in size with other arrow signs (16-7mP).
“A Pedestrian Crossing (W11-2) sign may be placed overhead or may be post-mounted with a diagonal downward pointing arrow (W16-7P) plaque at the crosswalk location where Yield Here To (Stop Here For) Pedestrians signs have been installed in advance of the crosswalk.” [2]

Stop Here For Pedestrians Signs

“If a W11-2 sign has been post-mounted at the crosswalk location where a Stop Here For Pedestrians sign is used on the approach, Stop Here For Pedestrians sign shall not be placed on the same post as or block the road user's view of the W11-2 sign.”

“Stop Here For Pedestrians (R1-5b or R1-5c) signs shall be used if stop lines are used in advance of a marked crosswalk that crosses an uncontrolled multi-lane approach. The Stop Here for Pedestrians signs shall only be used where the law specifically requires that a driver must stop for a pedestrian in a crosswalk.” [2]

“If stop lines and Stop Here For Pedestrians signs are used in advance of a crosswalk that crosses an uncontrolled multilane approach, they should be placed 20 to 50 feet in advance of the nearest crosswalk line (see Section 3B.16 and Figure 3B-17), and parking should be prohibited in the area between the stop line and the crosswalk.” [2]
Figure 3.1 Example of Advance Stop Bar
Bloomington [3]

Figure 3.2 Example of Advance Stop Bar
Burnsville

“An advance Pedestrian Crossing (W11-2) sign with an AHEAD or a distance supplemental plaque may be used in conjunction with a Stop Here For Pedestrians sign on the approach to the same crosswalk.” [2]

“When drivers yield or stop too close to crosswalks that cross uncontrolled multi-lane approaches, they place pedestrians at risk by blocking other drivers' views of pedestrians and by blocking pedestrians' views of vehicles approaching in the other lanes.” [2]
Figure 3.3 Example of Stop Lines at Unsignalized Midblock Crosswalks [2]
The advance stop bars with the pedestrian signs have been shown to improve motorist yielding on multi-lane facilities. [4]

In-Street and Overhead Pedestrian Crossing Signs

“In-Street Pedestrian Crossing signs and Stop Here For Pedestrians signs may be used together at the same crosswalk.”

“The In-Street Pedestrian Crossing (R1-6a or R1-6b) sign or the Overhead Pedestrian Crossing (R1-9b) sign may be used to remind road users of laws regarding right-of-way at an unsignalized pedestrian crosswalk. The legend STATE LAW may be displayed at the top of the R1-6a, R1-6b, and R1-9b signs, if applicable.” [2]

![Image of in-street and overhead pedestrian signs]

R1-6a  R1-6b  R1-6c

R1-9b

The R1-6c is also provided for use at school crossing locations. The R1-6a is recommended over the R1-6b sign as visual symbols are more easily understood by all motorists.

“In order to avoid overuse, the In-Street Pedestrian Crossing sign should only be used at locations having high pedestrian crossings.” [2]

Warning Sign Color

All of the warning signs and supplemental plaques may have a fluorescent yellow-green background with a black legend and border.

“When a fluorescent yellow-green background is used, a systematic approach featuring one background color within a zone or area should be used. The mixing of standard...
yellow and fluorescent yellow-green backgrounds within a selected site area should be avoided.” [2]

Warning Beacons

“A Warning Beacon may be used with any Non-Vehicular Warning sign to indicate specific periods when the condition or activity is present or is likely to be present, or to provide enhanced sign conspicuity.

A supplemental WHEN FLASHING (W16-13P) plaque may be used with any Non-Vehicular Warning sign that is supplemented with a Warning Beacon to indicate specific periods when the condition or activity is present or is likely to be present.” [2]

Important Points

1. Pedestrian crossing signs may be used to alert road users to locations where unexpected entries onto the roadway by pedestrians may occur.
2. Pedestrian crossing signs may be placed in advance of and at the pedestrian crossing location.
3. If pedestrian crossing signs are installed at the crossing location, they shall include a diagonal downward pointing arrow.
4. Pedestrian crossing signs may or may not be installed with crosswalk markings.
5. On multi-lane approaches, if an advance stop bar is used, Stop Here For Pedestrians signs shall also be used.
6. In-Street Pedestrian crossing signs may be used to supplement pedestrian warning signs at high pedestrian volume locations.

Raised Medians

Support for raised medians is included in Section 31.6 of the MN MUTCD.

“Raised islands or medians of sufficient width that are placed in the center area of a street or highway can serve as a place of refuge for pedestrians who are attempting to cross at a midblock or intersection location. Center islands or medians allow pedestrians to find an adequate gap in one direction of traffic at a time, as the pedestrians are able to stop, if necessary, in the center island or median area and wait for an adequate gap in the other direction of traffic before crossing the second half of the street or highway. The minimum widths for accessible refuge islands and for design and placement of detectable warning surfaces are provided in the "Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)”. [2]
MnDOT has set up a procedure to evaluate whether a crossing location is appropriate for treatments such as marked crosswalks or pedestrian crossing warning signs. The guidance uses elements which to make a decision whether to install a crossing or if crossing treatments are appropriate at a particular location. The Traffic Engineering Manual states that an engineering study should be completed to determine the necessity of a pedestrian crosswalk. The engineering study should consider:

- Geometrics,
- Motorist sight distance,
- Traffic volume data including truck traffic and turning movements,
- Daily pedestrian volume estimates,
- Observation of site characteristics that could divert driver attention from the crosswalk,
- Posted speed limit,
- Crash history, and
- Sidewalks and pedestrian pathways. [5]

This analysis performed on potential crosswalk location should result in a more uniform application and it is noted that not all sites warrant a pedestrian crossing or a crosswalk with additional treatments. The non-uniform application, misuse, or overuse of crosswalk safety treatments may result in:

- Noncompliance with traffic control devices,
- Decrease in safety, and/or
- Disregard of traffic control device.

The guidance also lays out a decision flowchart to help decision makers determine whether or not a crosswalk is warranted. The flowchart sets out certain conditions that must be met at all crosswalk locations. This includes:

- Adequate stopping sight distance for motorists,
- Minimal truck traffic,
- Minimal vehicle turning movements, and
- Minimal driver distractions. [5]

While Stopping Sight Distance can be easily calculated and evaluated, the flowchart and documents do not quantify any of the other elements above, and so is left open to interpretation. The flowchart sets up a decision tree that has three potential outcomes:

1. **Condition Red (Relatively High Risk)**
   a. Crosswalk not recommended.
   b. If pedestrian warrants are met, other treatments could be added such as: pedestrian bridge, pedestrian underpass, or pedestrian signal.

2. **Condition Yellow (Relatively Medium Risk)**
   a. Eligible for crosswalk with additional treatments.
   b. Design options that may be considered include
      i. Modify existing lane configurations,
      ii. Raised median (minimum width of four feet and length of eight feet),
      iii. Curb extensions,
iv. Pedestrian Crossing Island,
v. Advanced stop lines and associated signing,
vi. Parking restrictions,
svii. Increased law enforcement, and/or
sviii. Modify and/or add lighting.
c. Some Condition Yellow crossings may be determined sufficient without crosswalk enhancements.

3. Condition Green (Relatively Low Risk)
a. Eligible for crosswalk with no or minimal additional treatments.
b. Typically only require pavement markings.
c. Should be selected to address a specific problem.
d. Evaluate need for advance signing and pavement messages. [5]

Based on this criteria, a condition red would disqualify a crossing location from being signed and striped. The most common reason for this is: having less than 20 pedestrians per hour and no elderly or child facilities nearby; speed limit is greater than 40 mph; ADT is greater than 12,000; and/or there are more than 4 lanes.

Guidelines for placement of school crossings are also mentioned. This includes placement of School Advance Warning assemblies, crosswalks within a school zone, and roadway messages.

Figure 3.4 MnDOT Crosswalk Installation Flowchart
The AASHTO Green Book includes some general considerations for pedestrians but is primarily focused on vehicles. Of interest is a list of suggested measures with the potential to aid older pedestrians.

- Use simple designs that minimize crossing widths and minimize the use of complex elements. Consider 11-foot lane widths.
- Assume lower walking speeds
- Provide median refuge islands
- Provide lighting and eliminate glare sources
- Provide adequate guide signs
- Use enhanced traffic control devices
- Provide enhanced markings and delineation
- Use repetition and redundancy in design and signing

Pedestrians have a wide range of walking speeds at which they will cross a street. Typical pedestrian walking speeds range from approximately 2.5 to 6.0 ft/s. Advanced age is the most common cause for slower walking speeds, and in areas with older people, a speed of 2.8 ft/s should be considered for use in design.

Another item especially important in the planning of pedestrian crossings, is Stopping Sight Distance (SSD). In assessing and determining the location of a pedestrian crossing it is important that a vehicle be able to see a pedestrian crossing at the location and be able to stop in adequate time.

Stopping Sight Distance is the length of roadway ahead that is needed for stopping and includes both brake reaction time and braking distance.

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

where:
- SSD = Stopping Sight Distance
- \( V \) = design speed (mph)
- \( t \) = brake reaction distance, 2.5 s
- \( a \) = deceleration rate, ft/s²
- \( G \) = grade, rise/run, ft/ft

The second part of the equation is the braking distance. It may be important to consider the vertical grades in some areas which can increase or decrease the braking distance.

“The purpose of the guide is to provide guidance on the planning, design, and operation of pedestrian facilities along streets and highways.” [7] While this is an extensive document, specific sections are of direct interest to this study.

Walk decisions are primarily based upon three factors: travel distance; personal safety and security; and personal comfort and attractiveness. [7]

Pedestrian walking speeds range from 2.5 to 6.0 ft. per sec. The busier a crossing is, the slower the speed of pedestrians. Wheelchair and scooter users require wider paths and ramps for travel. Cross grades should not be steeper than 2%. [7]

Transit networks rely on pedestrian access. [7]

During project planning crossing measures are needed to ensure frequent and safe opportunities to cross a corridor. “Crossing distances should be kept to a minimum. New construction or altered walkways and street crossing shall be accessible to the maximum extent possible.” Extra care is necessary when developing street crossing near schools. Children are smaller and motorists may have difficulty seeing them. Ensure objects do not inhibit the ability to see children. [7]

The design details on crossings should be followed and evaluated when completing a field review of crossings.

- Crosswalks, landing areas, corners and other parts of the pedestrian route should be clear of obstructions.
- Pedestrians should have a clear view of travel lanes and motorists.
- Symbols, signs, and markings should clearly indicate what actions a pedestrian should take.
- Curb ramps are required to have adequate maneuvering space and detectable warnings. Detectable truncated dome warnings must be provided for the full width of ramps to mark the street edge. Curb ramps to be a minimum of four feet wide but should match the width of the pedestrian route.
- Adequate lighting should be included if pedestrians are present during nighttime hours. In areas of heavy growth, lighting may need to be evaluated when there is full growth.

Midblock crossings have additional considerations when compared to corner crossings. Midblock crossings are located according to a number of factors including pedestrian volume, desired paths for pedestrians, roadway width, or the volume of pedestrians or vehicles. They should not be installed where sight distance or sight lines are limited for either the motorist or pedestrian. The design details on crossings should be followed and evaluated when completing a field review of mid-block crossings. [7]

The guidance provide attributes where midblock crossings can be most effective. Some of the attributes include:

- Location is already a source for substantial midblock crossings
- Land use is such that pedestrians are unlikely to cross at the next intersection
- Safety and capacity of adjacent intersections or large turning volumes creates a difficult crossing situation
- Spacing between adjacent intersections exceeds 660 ft. [7]

Medians or crossings islands are recommended at mid-block crossing locations. Midblock pedestrian crossings should be supplemented with warning signs. Overhead warning signs can improve motorist awareness of the crossing. Parking should be reviewed for impacts to sight distance. [7]

If grade-separated crossings are an alternative at a crossing location, the use of the grade separated crossing depends on the time to use each alternative route. If the crossing time of the “safe” route (underpass or overpass) is generally more than the crossing time at ground level, there is a high probability that pedestrians will not use the “safe” route. [7] The document uses the word “safe” to describe an underpass or overpass but at-grade options can also be designed “safe.”

<table>
<thead>
<tr>
<th>Travel Times</th>
<th>Bridge</th>
<th>Tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equal</td>
<td>15 to 60%</td>
<td>95%</td>
</tr>
<tr>
<td>30% Longer on Safe Route</td>
<td>0%</td>
<td>25 to 70%</td>
</tr>
<tr>
<td>50% Longer on Safe Route</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

This may also be of consideration when evaluating the effectiveness of an alternative route versus just waiting at the existing at-grade crossing.

**Minnesota’s Best Practices for Pedestrian/Bicycle Safety** [8]

The Best Practices Guide is a resource to assist agencies in the effort to safely accommodate pedestrians and bicyclists on roads and highways. The information is primarily presents the guidance prepared by the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), and the National Cooperative Highway Research Program (NCHRP). The strategies focus on the best practices to reduce the number of severe crashes involving pedestrians and bicyclists. The guide provides information on different strategies to reduce the number of pedestrian and bicyclist crashes based on a proven, tried, or experimental basis. The guide explanations of each type of strategy, the crash reduction, operational effects, candidate locations, design features and estimated construction costs. Specific strategies mentioned in the guide as it is related to uncontrolled pedestrian crossings include:
- Crosswalks and Crosswalk Enhancements,
- Medians and Crossing Islands,
- Curb Extensions,
- Pedestrian Hybrid Beacon System,
- Rectangular Rapid Flashing Beacon,
• Crosswalk Lighting,
• Traffic Signals,
• Grade Separated Crossing, and
• Crossing Guards.

This guide should be used a go to source to understand specific safety strategies in more detail. Some of this information is included in Chapter 8.

**Best Practices Synthesis and Guidance in At-Grade Trail Crossing Treatments [9]**

The document presents best practices observed in Minnesota, as well as nationally, for guidance on safety treatment applications at trail crossings. The guide provides a standardized procedure to determine options based on the needs of the individual trail crossings. An extensive decision tree is provided to determine possible options for individual crossings. The roadway crossing features needed for the decision tree include urban/rural, two-lane/multi-lane, undivided/divided, speed limit, traffic volume, and crossing location. The treatments presented are not intended for crossings other than trail crossings and do not include intersection crossings. Many of the treatment options are also presented in detail to understand what the treatment options contain. Some of this information is included in Chapter 8.

**Improving Pedestrian Safety at Unsignalized Crossings [10]**

The study developed guidelines that can be used to select pedestrian crossing treatments for unsignalized intersections and midblock locations. The procedures in the guidelines use variables such as pedestrian volume, street crossing width, and traffic volume to recommend one of four possible crossing treatment categories. The research provided recommendations to revise the MUTCD pedestrian warrant for traffic control signals to the National Committee on Uniform Traffic Control Devices.

The research also provided information on walking speed and motorist compliance. Pedestrian walking speed recommendations were 3.5 ft/s for the general population and 3.0 ft/s for the older or less able population. Motorist compliance was the primary measure of effectiveness for engineering treatments at unsignalized roadway crossings. The study found that the type of crossing treatment affects motorist compliance; other factors influencing the treatment effectiveness were the number of lanes being crossed and posted speed limit.

The document does present a flowchart for guidelines for pedestrian crossing treatments. It also provides worksheets which are a precursor to the methodology presented in the Highway Capacity Manual for evaluation based on pedestrian delay.
WORKSHEET 1: PEAK-HOUR, 35 MPH (55 KM/H) OR LESS

Analyst and Site Information

<table>
<thead>
<tr>
<th>Analyst:</th>
<th>Major Street:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis Date:</td>
<td>Minor Street or Location:</td>
</tr>
<tr>
<td>Data Collection Date:</td>
<td>Peak Hour:</td>
</tr>
</tbody>
</table>

Step 1: Select worksheet (speed reflects posted or statutory speed limit or 85th percentile speed on the major street):

- a) Worksheet 1 – 35 mph (55 km/h) or less
- b) Worksheet 2 – exceeds 35 mph (55 km/h), communities with less than 10,000, or where major transit stop exists

Step 2: Does the crossing meet minimum pedestrian volumes to be considered for a TCD type of treatment?

- Peak-hour pedestrian volume (ped/h), $V_p$
- If $2a > 20$ ped/h, then go to Step 3.
- If $2a < 20$ ped/h, then consider median refuge islands, curb extensions, traffic calming, etc. as feasible.

Step 3: Does the crossing meet the pedestrian volume warrant for a traffic signal?

- Major road volume, total of both approaches during peak hour (veh/h), $V_{maj,a}$
- Minimum signal warrant volume for peak hour (use 3a for $V_{maj,a}$), SC
  - $SC = (0.00021 V_{maj,a}^2 - 0.74072 V_{maj,a} + 734.125)/0.75$
  - OR $[0.00021 3d - 0.74072 3a + 734.125]/0.75$  
- If $3b < 133$, then enter 133. If $3b \geq 133$, then enter $3b$.
- If $15th$ percentile crossing speed of pedestrians is less than 3.5 ft/s (1.1 m/s), then reduce $3c$ by up to 50 percent; otherwise enter $3c$.
- 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), $L$
- Pedestrian walking speed (ft/s), $S_p$
- Critical gap required for crossing pedestrian (s), $t_c = (L/S_p) + t_c$ OR $[4a/4b + 4c]$  
- Major road volume, total both approaches or approach being crossed if median refuge island is present during peak hour (veh/h), $V_{maj,d}$  
- Major road flow rate (veh/s), $v = V_{maj,d}/3600$ OR $[4a/3600]$
- Average pedestrian delay (s/person), $d_p = (e^{4d} - v L - 1) / v$ OR $[e^{4d} - 4d x 4d - 1] / 4f$
- Total pedestrian delay (h), $D_p = (d_p \times V_p)/3600$ OR $[4g-2a/3600]$
  (this is estimated delay for all pedestrians crossing the major roadway without a crossing treatment – assumes 0% compliance). This calculated value can be replaced with the actual total pedestrian delay measured at the site.

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

<table>
<thead>
<tr>
<th>Total Pedestrian Delay, $D_p$ (from 4h) and Motorist Compliance, Comp (from 5a)</th>
<th>Treatment Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>(see Descriptions of Sample Treatments for examples)</td>
<td></td>
</tr>
<tr>
<td>$D_p \geq 21.3$ h (Comp = high or low)</td>
<td>RED</td>
</tr>
<tr>
<td>$5.3 \leq D_p &lt; 21.3$ h and Comp = low</td>
<td></td>
</tr>
<tr>
<td>$1.3 \leq D_p &lt; 5.3$ h (Comp = high or low)</td>
<td>ACTIVE</td>
</tr>
<tr>
<td>$5.3 \leq D_p &lt; 21.3$ h and Comp = high</td>
<td>ENHANCED</td>
</tr>
<tr>
<td>$D_p &lt; 1.3$ h (Comp = high or low)</td>
<td>CROSSWALK</td>
</tr>
</tbody>
</table>

Figure 3.5 Pedestrian Safety Crossing Treatments Worksheet 1: 35 MPH or Less
## WORKSHEET 2: PEAK-HOUR, EXCEEDS 35 MPH (55 KM/H)

### Analyst and Site Information

<table>
<thead>
<tr>
<th>Analyst:</th>
<th>Major Street:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis Date:</td>
<td>Minor Street or Location:</td>
</tr>
<tr>
<td>Data Collection Date:</td>
<td>Peak Hour:</td>
</tr>
</tbody>
</table>

### Step 1: Select worksheet (speed reflects posted or statutory speed limit or 85th percentile speed on the major street):

a) Worksheet 1 – 35 mph (55 km/h) or less
b) Worksheet 2 – exceeds 35 mph (55 km/h), communities with less than 10,000, or where major transit stop exists

### Step 2: Does the crossing meet minimum pedestrian volumes to be considered for a TCD type of treatment?

- Peak-hour pedestrian volume (ped/h), \( V_c \):
- 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), \( V_{mA-p} \):
- Minimum signal warrant volume for peak hour (use 3a for \( V_{mA-p} \)), SC
  \[
  SC = \left( 0.00035 \frac{V_{mA-p}}{0.8} - 0.80083 \frac{V_{mA-p} + 529.197}{0.75} \right)
  \]
- OR \[
  \left( 0.00035 \frac{3a}{0.8} - 0.80083 \frac{3a + 529.197}{0.75} \right)
  \]
  - If \( 3b < 93 \), then enter 93. If \( 3b \geq 93 \), then enter \( 3b \).
- If 15th percentile crossing speed of pedestrians is less than 3.5 ft/s (1.1 m/s), then reduce \( 3c \) by up to 50 percent; otherwise enter \( 3c \).
- 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), \( L \):
- Pedestrian walking speed (ft/s), \( S_p \):
- Pedestrian start-up time and end clearance time (s), \( t_s \):
- Critical gap required for crossing pedestrian (s), \( t_c = (L/S_p) + t_s \) OR \( \left[ \frac{4a}{4b} + 4c \right] \)
- Major road volume, total both approaches or approach being crossed if median refuge island is present during peak hour (veh/h), \( V_{mA-d} \):
- Major road flow rate (veh/s), \( v = \frac{V_{mA-d}}{0.7} \times 3600 \) OR \( \left[ \frac{(4a/0.7) \times 3600}{4d} \right] \)
- Average pedestrian delay (s/person), \( d_p = (e^{v \times t_c} - v t_c - 1) / v \) OR \( \left[ e^{d_{a+d} / 4d - 4f \times 4d - 1} / 4f \right] \)
- Total pedestrian delay (h), \( D_p = (d_p \times V_c) / 3,600 \) OR \( \left[ (4a/2a) / 3600 \right] \)

### 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

<table>
<thead>
<tr>
<th>Total Pedestrian Delay, ( D_p ) (from 4h) and Motorist Compliance, Comp (from 5a)</th>
<th>Treatment Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>( D_p \geq 21.3 ) h (Comp = high or low) OR ( 5.3 \leq D_p &lt; 21.3 ) h and Comp = low</td>
<td>RED</td>
</tr>
<tr>
<td>( D_p &lt; 5.3 ) h (Comp = high or low) OR ( 5.3 \leq D_p &lt; 21.3 ) h and Comp = high</td>
<td>ACTIVE</td>
</tr>
</tbody>
</table>

---

Figure 3.6 Pedestrian Safety Crossing Treatments Worksheet 2: Greater than 35 MPH
Step 1. Select worksheet based on (1) posted or statutory speed limit or the 85th percentile speed on the major street and (2) other conditions present:
   a) Worksheet 1 - 35 mph (55 km/h) or less
   b) Worksheet 2 - Exceeds 35 mph (55 km/h) or locations where the community has a less than 10,000 population or where a major transit stop is present

Step 2. Does the crossing meet minimum peak-hour pedestrian volumes to be considered for a traffic control device type of treatment?

   NO

   Consider median refuge islands, curb extensions, traffic calming, etc. as feasible. No traffic control devices are recommended.

   YES

   Go to Step 3

Step 3. Does the crossing meet the warrant for a traffic signal?

   NO

   Go to Step 4

   YES

   Warrant met, consider traffic signal if site is not within 300 ft (91 m) of another signal.

Step 4. Estimate pedestrian delay.

Step 5. Select treatment based upon total pedestrian delay and expected motorist compliance.

Figure 3.7 Pedestrian Safety Crossing Treatments Flowchart

Results from the study are incorporated into the MUTCD and Highway Capacity Manual (HCM). Some of this information is included in Chapter 8.
Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations [11]

The report is a comprehensive document that covers research into the safety of unmarked versus marked crosswalks. The research recognized that most crossings are unmarked but marked crosswalks can increase the visibility of pedestrians and alerts motorists to the likely presence of pedestrians. Marked crosswalks are also generally accompanied by crosswalk signage. Marked crosswalks may provide a false sense of security. When there are multiple travel lanes on each approach there is a higher occurrence of crashes due to the multiple threat posed.

Figure 3.8 Multiple-Threat Pedestrian Crash Illustration

Sites in the study did not include any traffic-calming treatments or other devices. School crossings were also excluded from the site selection process. As such, the results do not apply to crossings with those attributes.

The 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. [11]
Based on the research marked crosswalks alone are not recommended at uncontrolled crossing locations on multilane roads (i.e., four or more lanes), where traffic volume exceeds approximately 12,000 vehicles per day (with no raised medians), or approximately 15,000 ADT (with raised medians that serve as refuge areas). The recommendation is based on the analysis of pedestrian crash experience, as well as exposure data and site conditions.

Additionally, marked crosswalks should not be installed alone on two lane roads with ADTs greater than 12,000 or on multilane roads with ADTs greater than 9,000 (with no raised median) to add a margin of safety and/or to account for future increases in traffic volume.

The study also recommends against installing marked crosswalks alone on roadways with speed limits higher than 40 mph based on the expected increase in driver stopping distance at higher speeds. Enhanced crossing treatments (e.g., traffic-calming treatments, traffic and pedestrian signals when warranted, or other substantial improvement) are recommended.

“On two-lane roads and lower volume multilane roads (ADTs less than 12,000), marked crosswalks were not found to have any positive or negative effect on pedestrian crash rates at the study sites. It is recommended that crosswalks alone not be installed at locations that may pose unusual safety risks to pedestrians. Pedestrians should not be encouraged to cross the street at sites with limited sight distance, complex or confusing designs, or at sites with certain vehicle mixes (many heavy trucks) or other dangers unless adequate design features and/or traffic control devices are in place.” [11]

The following paragraph includes special consideration:

“At uncontrolled pedestrian crossing locations, installing marked crosswalks should not be regarded as a magic cure for pedestrian safety problems. However, marked crosswalks also should not be considered as a negative measure that will necessarily increase pedestrian crashes. Marked crosswalks are appropriate at some locations (e.g., at selected low-speed, two-lane streets at downtown crossing locations) to help channel pedestrians to preferred crossing locations, but other roadway improvements are also necessary (e.g., raised medians, traffic-calming treatments, traffic and pedestrian signals when warranted, or other substantial crossing improvement) when used at other locations.” [11]

Based on the results of the research of pedestrian crossings throughout the United States the report provides a table for where marked pedestrian crossings should be placed based on the cross-street ADT, travel speed, and number of lanes. It is important to recognize that the research indicates where pedestrian crossing markings alone may or may not be sufficient. The research does not indicate where pedestrian crossings with alternative treatments should or should not be located. In all cases, an engineering study should be completed to determine whether a location is suitable or not, and if additional pedestrian crossing treatments are justified. The table and additional safety considerations are included in Chapter 5.

The Highway Capacity Manual (HCM) provides the methodology for evaluation of pedestrian crossings on an operational basis. The HCM provides an analysis methodology for both signalized and unsignalized crossing locations. This includes an analysis to determine delay and service levels at pedestrian crossings at for pedestrians. The focus of this study is on uncontrolled crossings (i.e. crossings in which vehicle traffic is not controlled by a signal or stop sign and/or pedestrian traffic is not controlled by a signal). This methodology is included in Chapter 6 of this report.
Chapter 4  
Data Collection and Field Review

The first step in understanding the pedestrian needs at a potential pedestrian crossing location is completing a review of the location and adjacent facilities. A Data Collection Field Review Worksheet is provided for the data collection at the end of this chapter. The Field Data Review should consider the following elements and information to be collected.

Geometrics

Crossing Length

The length across the roadway at the crossing location affects how long a pedestrian is exposed to conflicting motorist traffic. A shorter pedestrian crossing length is preferred. The crossing length \( L \) is measured from curb face to curb face and it is the total length a pedestrian is exposed to conflicting traffic. In cases where there is a median, two separate crossing lengths are measured, as shown in Figure 4.2.

Figure 4.1 Pedestrian Crossing Length (1 of 2)

Figure 4.2 Two-Stage Pedestrian Crossing Length

Figure 4.3 Pedestrian Crossing Length (2 of 2)
Median Width

The median can provide for a staged crossing where a pedestrian only needs to cross one side of the street at a time. A median provides a refuge space for pedestrians. A median should be of sufficient size to handle the pedestrians using the crossing. In most cases a sufficiently sized raised pedestrian median refuge includes a minimum median width of 6’ and a minimum 5’ crossing width. This would indicate that there is a sufficient median refuge for pedestrians to allow for a staged crossing, but smaller medians may be sufficient based on the type of pedestrians using the crossing. A wider median is preferred by pedestrians. In the case of smaller medians, the majority of pedestrians would use a different adjacent crossing location that provides close to equal travel time. The median width (W) is measured from curb face to curb face.

Another consideration is that a minimum 4’ x 4’ landing area must be provided at all pedestrian refuges as consistent with Americans with Disabilities Act (ADA) requirements. With the addition of truncated domes (domes usually come in 2’ by 2’ squares) to separate walking spaces from spaces designated for both motor vehicles and pedestrians, this essentially would require a minimum 8’ wide median instead of the 6’ wide median as the minimum width. Best practice is to make the median crossing with the same width as the crosswalk markings. Measure the width of the median and the width of the crossing through the median.

Crosswalk Width

Another important measurement is the crosswalk width. While crosswalks are typically six to eight feet wide, the effective crosswalk width may actually be different. The effective crosswalk width ($W_e$) is the narrowest spot on the entire crossing length. This can be dictated by a number of different aspects including the truncated dome width, the crosswalk marking width, median noses or other obstructions, and/or the median opening width. Striping outside of the crossing
width is essentially unusable space when considering the needs of all pedestrians. That being said, the effective width may be wider than the truncated domes and/or pedestrian ramp if determined to be appropriate based on the crossing users, such as in urban downtown settings with significant pedestrian users that do not use the pedestrian ramp and can effectively use the entire crossing width. A review of actual pedestrian use of the crossing is recommended to verify.
Curb Ramps

The MN MUTCD states that “Crosswalk markings should be located so that the curb ramps are within the extension of the crosswalk markings. Detectable warning surfaces mark boundaries between pedestrian and vehicular ways where there is no raised curb. Detectable warning surfaces are required by 49 CFR, Part 37 and by the Americans with Disabilities Act (ADA) where curb ramps are constructed at the junction of sidewalks and the roadway, for marked and unmarked crosswalks. Detectable warning surfaces contrast visually with adjacent walking surfaces, either light-on-dark, or dark-on-light. The "Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)" contains specifications for design and placement of detectable warning surfaces.” [2], [13]
Access to the crossing by all non-motorized traffic must be provided if the crossing is to be used by pedestrian traffic. This includes providing curb ramps for access to the crossing location. Curb design acceptable for all users is a course unto itself and the details of it are beyond the scope of this study. Guidance on acceptable curb ramp design and parameters are included on the MnDOT Accessibility Webpage.

Curb ramp locations and directionality should be noted. Note where there are truncated domes. Truncated domes do not have to be directional with the crosswalk.

Curb ramps provide equal access to all users. Pedestrian curb ramps are required for all pedestrian crossing locations. Determine if curb ramps are provided. Are they ADA compliant, i.e. include truncated domes, maximum 5% grade if there is no change in direction or maximum 8.3% grade with a 4’x4’ landing?
Roadway Speed

The posted speed limit or 85th percentile speed of the crossed roadway affects the stopping sight distance of vehicles and the safety of the crossing. The higher the vehicle speed, the higher the probability for a fatal crash. This effect is as shown in the following tables, based upon research completed.

Figure 4.12 Risk of Pedestrian Fatality Based on Vehicle Impact Speed [15]

Figure 4.13 Vehicle Impact Speed and Pedestrian Severity [16]
As indicated by the above, slower vehicle speeds have been shown to reduce the possibility of a fatal crash. A pedestrian crossing location that is in an area where speed limits are lower is preferable to placing a crossing on a higher speed roadway segment due to the higher incidence of a fatality. The speed of a vehicle directly impacts the sight distance needed and the braking time of a vehicle. The roadway design 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.

**Average Walking Speed**

The speed of pedestrians using a crossing can have a direct impact on pedestrian sight distance and the Highway Capacity Manual (HCM) Level of Service. The default for pedestrian walking speed is 3.5 ft/s, unless field data on average speed can be collected at the actual crossing. Crossings that serve a significant volume of children, an older population, or people with disabilities may require a slower walk time while crossings with a significant volume of runners and/or teens may have faster walk times. It may be important to determine walking speeds depending on pedestrian composition and traffic volume at different times of day.

Although average walking speed is used in the calculations, the 3.5 ft/s walking speed dictated in the MN MUTCD and other sources, is actually the 15th percentile speed and not the average. This ensures that 85% of pedestrians are able to cross faster than the walking speed accounted for or as in the case of a signalized crossing, ensure that 85% of pedestrians using a crossing are able to get across in the time allotted during a flashing don’t walk. Examples from real-world locations in Minnesota are included in Chapter 6, Table 6.1 for a comparison.

**Roadway Curvature**

The crossing location should be located outside of horizontal and vertical curves to provide adequate stopping sight distance to the crossing location. Motorist attention to the curvature of the roadway can detract motorist attention to any potential crossing location and a pedestrian using the crossing.

Possible obstructions include:
- buildings,
- trees,
- hills, and/or
- landscaping.

Is the crossing location within a horizontal or vertical curve? If so, additional considerations are needed to ensure adequate stopping sight distance.
Figure 4.14 Horizontal Curvature Obstruction

**Sight Distance**

**Stopping Sight Distance**

As defined by AASHTO, the Stopping Sight Distance is the length of roadway ahead that is needed for stopping and includes both brake reaction time and braking distance. [6]

\[
SSD = 1.47Vt + 1.075 \frac{V^2}{30 \left[ \frac{a}{32.2} \pm G \right]}
\]

Where:

- \(SSD\) = Stopping Sight Distance
- \(V\) = roadway speed (mph)
- \(t\) = brake reaction distance, 2.5 s
- \(a\) = deceleration rate, ft/s²
- \(G\) = grade, rise/run, ft/ft

Default values may be used for brake reaction distance and deceleration rate:

- \(t = 2.5\) s from AASHTO
- \(a = 11.2\) ft/s² from AASHTO

All pedestrian crossings shall be placed to provide adequate stopping sight distance. Additional features or roadway geometry changes may be needed to provide adequate sight distance.

**Pedestrian Sight Distance**

Another consideration is the distance in which a pedestrian is able to see a conflicting vehicle and determine if they are able to cross the pedestrian crossing location before the vehicle is at the crossing. This is especially important where there is an absence of warning signs, markings, or other pedestrian crossing treatments. While motorists are required to stop for pedestrians, the pedestrian sight distance takes into consideration when vehicles do not tend to yield right-of-way and also accounts for the pedestrian needs.

Pedestrian Crossing Sight Distance is the length of roadway that must be seen from the crossing that is needed for crossing the roadway in the absence of vehicle yielding and includes both pedestrian start-up and clearance times and the time to cross the roadway.

\[
PedSD = 1.47V \left( \frac{L}{S_p} + t_s \right)
\]

Where:

- \(PedSD\) = Pedestrian Crossing Sight Distance
- \(V\) = roadway speed (mph)
- \(L\) = Crossing distance (ft)
- \(S_p\) = average pedestrian walking speed (ft/s)
- \(t_s\) = pedestrian start-up and end clearance time (s)
Default values may be used for pedestrian walking speed and pedestrian start-up and end clearance time:

\[ S_p = 3.5 \text{ ft/s} \quad \text{from MN MUTCD} \]

\[ t_s = 1.5 \text{ s} \quad \text{from HCM 2010} \]

**Traffic and Pedestrian Data**

**Traffic Volume**

The volume of traffic on the roadway directly affects the available gaps for pedestrians to cross the roadway. Measure the traffic volume in 15-minute increments on the roadway to be crossed. The volume includes all traffic across the crossing location.

**Pedestrian Volume**

The volume of pedestrians using the crossing location can indicate if the pedestrian crossing is necessary or if additional treatment options may be needed. Measure the pedestrian crossing volume in 15-minute increments on the roadway to be crossed.

In most cases, the daily pedestrian volume will not be collected, but can be an indicator of the crossing location use throughout the day.

**Additional Site Characteristics**

**Lighting**

Lighting is important in providing a guide to drivers and pedestrians by lighting both the pedestrian using the crossing and the pedestrian pathway across a roadway. It also provides a visual cue to drivers that there is an intersection or pedestrian crossing location.

Lighting should be placed to provide positive contrast to pedestrians using a crossing. This includes lighting pedestrians from the front other than providing lighting behind the pedestrian. In most cases this means that lighting should be placed prior to the crossing location for each direction of traffic. While this is not possible for all locations, it is especially important on wider roadways with or without medians.

Example lighting configurations to provide positive contrast are provided on the next page.
Is there continuous street lighting, intersection lighting, and/or pedestrian level lighting on pedestrian facilities within the area? Note the placement of the lighting to determine if positive guidance is provided for crossing locations.

Depending on the location, it may be important to field verify that the entire crossing is lighted, especially if there is a high probability of pedestrians using the crossing during dark/nighttime hours. For wide roadways (more than two approach lanes in each direction) or roadways with medians it may be advantageous to evaluate the lighting levels across the crossing. The most important aspects of this evaluation is to ensure that there are no dark spots along the crossing and that the lighting is moderately uniform. Lighting evaluation and guidance should follow the AASHTO Roadway Lighting Design Guide. Pedestrian lighting of crossings should meet the requirements of the roadway being crossed. [17]

Crosswalk Pavement Markings

Crosswalk pavement markings alert and provide visual guidance to drivers and roadway users that there is a designated crossing location and to expect pedestrians. Crosswalk pavement markings also indicates to pedestrians that a specific location is preferred over other unmarked locations along the same roadway. In most cases a marked crosswalk location will also include appropriate crosswalk signage.

The MN MUTCD defines the appropriate marking sizes that must be followed for installation of a marked crosswalk. “When crosswalk lines are used, they shall consist of solid white lines that mark the crosswalk. They shall not be less than 6 inches or greater than 24 inches in width. If transverse lines are used to mark a crosswalk, the gap between the lines should not be less than 6 feet. If diagonal or longitudinal lines are used without transverse lines to mark a crosswalk, the crosswalk should be not less than 6 feet wide. Crosswalk lines, if used on both sides of the crosswalk, should extend across the full width of pavement to the edge of the intersecting crosswalk to discourage diagonal walking between crosswalks.” [2]
High visibility crosswalk markings include: Continental, Zebra, and Ladder. Solid and Dashed markings are not recommended. Solid can result in very slippery surfaces while dashed can be difficult for motorists to see. Markings should be in good to excellent condition and highly visible to approaching traffic. The condition of the markings is important to determine if they should be replaced or not.

- Excellent: No visible wear to markings, “like new”
- Good: Minimal wear to markings
- Fair: Extensive wear in places but can generally be seen by approaching vehicles, replacement may be needed
- Poor: Extensive wear, difficult to determine if the crossing is marked, immediate replacement recommended

Verify if the pedestrian crossing is currently marked. What is the condition of the markings? Are the markings easily defined? Do they need replacement? What is the current crosswalk marking pattern? If at an intersection, which legs are marked? For additional information on crosswalk pavement markings see the MN MUTCD and MnDOT Traffic Engineering Manual (TEM).
Signing

Pedestrian warning signs may be used to alert road users in advance of a pedestrian crossing location where unexpected entries into the roadway might occur or where shared use of the roadway by pedestrians might occur. They may be placed in advance of a crossing location and/or at the crossing location. “Non-vehicular signs should be used only at locations where the crossing activity is unexpected or at locations not readily apparent.” [2]

The MN MUTCD dictates the acceptable signing to be used in conjunction with a pedestrian crossing. Signing may or may not be installed in conjunction with crosswalk markings. Signing shall follow the design and placement as stated in the Minnesota Manual on Uniform Traffic Control Devices. Additional information on signing is included in Chapter 3.

Is the crossing currently signed with the appropriate warning signs at the crossing? Any warning signs in advance of the crossing? At what distance are the signs from the crossing?

Figure 4.24 Pedestrian Crossing Warning Sign (W11-2)
Placed at the Crossing Location
Figure 4.25 Pedestrian Crossing Warning Sign plus In-Road Signs

Figure 4.26 Advanced Pedestrian Crossing Warning Sign
Enhancements

The presence of pedestrian crossing enhancements at the location being studied should be noted. This includes any activated crossing features, pedestrian control devices, and/or traffic calming enhancements.

Adjacent Facilities

The presence of other crossings parallel to the location being studied should be recognized. This includes both marked and unmarked locations that may be used by pedestrians. It is especially important to determine where the nearest currently marked crossing of the same street or highway is located. Evaluation may determine that another crossing may be more appropriate and serve the same origins and destinations with little or no additional delay imposed on the pedestrian.

- How far is the nearest adjacent marked crossing?
- What facilities are present at the nearest adjacent marked crossing?
- Does the crossing have warning signs, a flasher system, etc. that may make it an easier crossing to use?
- How far is the nearest all-way stop, roundabout, or traffic signal? The presence of these types of traffic control in conjunction with a pedestrian crossing provide a different level of pedestrian safety and recognition of pedestrian movements by motorists.
- Could another location serve the same pedestrian crossing movement? It is important to understand if another crossing location nearby can serve the same pedestrian movements
that can be provided at the studied location. If there is missing sidewalk or connection
between the locations, the same movements may not be served effectively at another
location.
• Could another location serve the movement more effectively? This requires a
determination of the origins and destinations near the study site. Another location may
more effectively connect the origins and destinations that is not readily apparent. What is
the most direct route between origins and destinations? If route is actually shorter,
determining why this route is preferred is an important aspect to answer.
• If there is a nearby pedestrian crossing facility that can serve the same movements, 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.

Site Sketch or Aerial

Concurrent with a field review, a site sketch or aerial view and notes on the potential crossing
location should be completed. This brings context to the location and helps to provide a record of
what is currently in the field. It may also provide justification for whether changes may or may
not be needed.

Specific items to note on the sketch or aerial if not readily apparent in the picture.

• Pavement Markings: The current pavement markings at the crossing location should be
recorded. This includes the presence of crosswalk markings, edge lines, center lines, lane
lines, stop lines, or any other markings.

• Signing: This includes signing at and near the crossing including pedestrian signs and any
other signs, as the location of signing may impact how drivers view the area. Reduced
signing in the area reduces visual clutter, making pedestrians easier to see.

• Lighting: Note the location of lighting to check positive guidance. If needed, lighting
levels may also be checked if mounting height and fixtures are known.

• Curb Ramps and Truncated Domes: curb ramp locations and directionality should be
noted. Note where there are truncated domes and general directionality of the domes.

• Parallel and nearby crosswalk locations: Measure distances to nearest crosswalk locations
that serve the same roadway being crossing.

• Adjacent Intersections with All-Way Stop, Signal, or Roundabout: Measure distances to
nearest intersection with any of the above traffic controls.
• Origins and Destinations: Review the area for origins and destinations to determine the need for the crossing at the location. All marked crossings should serve a needed origin-destination connection. Typical origins and destinations of importance include:
  o Bus stops to businesses and residences
  o High density residential to bus stops and commercial/retail
  o Hospitals and medical centers to bus stops and parking
  o Retirement communities to bus stops and commercial/retail
  o Schools/colleges/universities to residential housing and parking
  o Parks to residences
  o Recreational/community centers to residences and parking
  o Theatres and museums to parking
  o Trails to parks and other trails
  o Commercial/retail space to parking

Look at origins and destinations that are connected, such as parking on one side of a roadway and an office building or restaurant on the other side. Note the location of office building and restaurant entrances.

It is important to remember that pedestrians will take the shortest route if at all possible. This relates 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 where pedestrians are using them if the understanding of origins and destinations has changed over time or is incorrect to begin with.
### Uncontrolled Pedestrian Crossing
#### Data Collection Worksheet

**Location:**

**City, State:**

**Reviewer(s):**

**Agency:**

**Project #:**

---

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. | Crossing 1 | ft. |
| Crossing 2 | ft. |
| 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. |

| Median: width of median at crossing location | 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 (PedSSD) | ft. | provided? | Yes | No |
| Direction 2: Pedestrian Sight Distance (PedSSD) | 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: | Daily | pedestrians: | Daily |
| AM Peak Hourly | Pk 15-min | Hourly | Pk 15-min |
| PM Peak Hourly | Pk 15-min | Hourly | Pk 15-min |

#### 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 |

#### Additional Site Characteristics

| Distance 1 | ft. | direction 1 | ft. |
| Distance 2 | ft. | direction 2 | ft. |

| 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 |

---

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Figure 4.28 Data Collection Worksheet (Page 1)
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 origins and destinations.

**draw or insert map of location being studied**

---

**Notes:**

---

**Sight Distance Calculations:**

Stopping sight distance (SSD), \( d_s = 1.475t + 1.075s^2/a \)

Pedestrian sight distance (PedSD), \( d_p = 1.475(L / S_p + t_s) \)

where:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t )</td>
<td>brake reaction time, s</td>
<td>2.5</td>
</tr>
<tr>
<td>( a )</td>
<td>deceleration rate, ft/s(^2)</td>
<td>11.2</td>
</tr>
<tr>
<td>( S_p )</td>
<td>average pedestrian walking speed, ft/s</td>
<td>3.5</td>
</tr>
<tr>
<td>( t_s )</td>
<td>pedestrian start-up and end clearance time, s</td>
<td>3.0</td>
</tr>
</tbody>
</table>

where: \( s = \) design speed, mph

\( L \) = length of crossing, ft

---

Page 2 of 2

Figure 4.29 Data Collection Worksheet (Page 2)
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Chapter 5
Safety Evaluation

The Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations by the Federal Highway Administration provides extensive research into safety considerations of crosswalks through an evaluation of field collected and crash data from sites throughout the United States.

A table for where marked pedestrian crossings should be placed and appropriate enhancements is based on the cross-street ADT, travel speed, and number of lanes as shown on the following page.

Table Definitions

**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 improvement to improve crossing safety for pedestrians.

It is important to recognize that the research indicates where pedestrian crossing markings alone may or may not be sufficient. The research does not indicate where pedestrian crossings with alternative treatments should or should not be located. In all cases, an engineering study should be completed to determine whether a location is suitable or not, and if additional pedestrian crossing treatments are justified. [11]
Table 5.1 Recommendations for Installing Marked Crosswalks at Uncontrolled Locations,*

<table>
<thead>
<tr>
<th>Roadway Type (Number of Travel Lanes and Median Type)</th>
<th>Vehicle ADT ≤ 9,000</th>
<th>Vehicle ADT &gt;9,000 to 12,000</th>
<th>Vehicle ADT &gt;12,000-15,000</th>
<th>Vehicle ADT &gt; 15,000</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Speed Limit</strong></td>
<td>48.3 km/h (30 mi/h)</td>
<td>56.4 km/h (35 mi/h)</td>
<td>64.4 km/h (40 mi/h)</td>
<td>48.3 km/h (30 mi/h)</td>
</tr>
<tr>
<td>Two lanes</td>
<td>C</td>
<td>C</td>
<td>P</td>
<td>C</td>
</tr>
<tr>
<td>Three lanes</td>
<td>C</td>
<td>C</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>Multiline (four or more lanes) with raised median**</td>
<td>C</td>
<td>C</td>
<td>P</td>
<td>N</td>
</tr>
<tr>
<td>Multiline (four or more lanes) without raised median</td>
<td>C</td>
<td>P</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

* These guidelines apply to intersections 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 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 hazards, without 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 safety enhancements (e.g., raised median, traffic signal, road 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 whether 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 safety 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.

In some situations (e.g., low-speed, two-lane streets in downtown areas), installing a marked crosswalk may help consolidate multiple crossing points. Engineering judgment should be used to install crosswalks at preferred crossing locations (e.g., at a crossing location at a streetlight as opposed to an unlit crossing point nearby). While excess of marked crossings at uncontrolled locations should be avoided, higher priority should be placed on providing crosswalk markings where pedestrian volume exceeds about 20 per peak hour (or 15 or more elderly pedestrians and/or children per peak hour).

Marked crosswalks and other pedestrian facilities (or lack of facilities) should be routinely monitored to determine what improvements are needed.
Chapter 6
Operational Evaluation

There are two primary methods in determining how the traffic on a roadway affects how long a pedestrian waits to cross the roadway and determines if it is even possible for a pedestrian to cross the roadway at the crossing location given actual traffic levels.

- A gap study is used to determine the number of gaps of adequate size to allow for a pedestrian to cross the roadway at a particular location.
- A Level-of-Service (LOS) evaluation is used to determine how long a pedestrian waits on average and equates this with a service level. The longer a pedestrian is anticipated to wait, the more unacceptable the wait becomes and there is a higher probability of a pedestrian completing a crossing maneuver when it is not safe to do so.

Data collected in the field is used to provide essential information in the evaluation of a pedestrian crossing location.

Gap Study

A gap study is used to determine the number and size of gaps that are available to cross the roadway. The length of the gaps is used to determine if there are gaps of adequate size between vehicles to safely and effectively provide enough time for pedestrians to cross the roadway. Gap studies require the collection of the time between vehicles and can be quite time intensive. Additionally, it is recognized that while traffic levels are different depending on the hour of the day it also does change from day to day and the gaps collected on one day may be different than another depending on the facility.

The gaps that need to be collected are the gaps that are available at a crossing location. This includes not only determining the gap between vehicles, but the actual gap in which the crossing location is not impacted by a vehicle. Essentially this means accounting for the length of the vehicle by determining the time the actual crossing does not have a vehicle on it. On roadway crossings of similar volume, a roadway with a higher volume of truck traffic usually results in shorter gaps due to the longer vehicles.

There are essentially three methods for collecting gap data.

1. Traffic tube counters: counters must be able to provide intervals of at least one second. This method requires that all calculations be rounded up to the nearest one second. This also does not account for the length of vehicles. To mitigate the unknowns, vehicle classification counts are recommended to determine the number of trucks in the traffic stream and account for the average vehicle length that can also affect the actual gap available.
2. Count Boards: Most manual count boards provide the functionality to do gap studies. This provides a very accurate count of the gap length to tenth of a second.
3. Stopwatch: A stopwatch can be used to also determine the gaps between vehicles but requires that the times be transferred manually. The inclusion of stopwatch features into mobile phones and other electronic devices can include ways to more effectively record the gap times.

The collected gaps are then used to compare against how long it takes a pedestrian to cross the roadway. The adequate pedestrian crossing time or critical headway \( t_c \) includes:

1. Start-up and end clearance time \( t_{sc} \): The time for a pedestrian to make a decision that there is an adequate gap and step onto the roadway plus the time for pedestrians to clear the roadway after crossing. The end clearance time is zero if there is a shoulder on the roadway being crossed. The end clearance is provided to ensure that there is some time between a pedestrian and a vehicle as a pedestrian completes the crossing maneuver.

2. Walking time \( t_w \): The time for a pedestrian to actually cross the roadway. This is determined by dividing the length of the crossing by the crossing speed. Observed pedestrian walking speed should be collected. In the absence of collected data a standard pedestrian walking speed is 3.5 feet per second, consistent with the pedestrian walking speed used in the Minnesota Manual on Uniform Traffic Control Devices.

\[
t_w = \frac{L}{S_p}
\]

where:

\[
t_w = \text{pedestrian walking time (s)}
\]

\[
L = \text{crosswalk length (ft)}
\]

\[
S_p = \text{average pedestrian walking speed (ft/s), default = 3.5 ft/s} \ [2], \ [10]
\]

\[
t_c = t_{sc} + t_w
\]

where:

\[
t_c = \text{critical headway (s)}
\]

\[
t_{sc} = \text{pedestrian start-up and end clearance time (s)}
\]

\[
t_w = \text{pedestrian walking time (s)}
\]

The 2010 Highway Capacity Manual provides a default pedestrian start-up and end clearance time of 3 seconds in the absence of field collected data. \[12\]

The adequate gap for crossing the roadway is equal to the crossing time. The crossing location should also be checked to ensure that a pedestrian is able to see a vehicle to provide the crossing time. The pedestrian sight distance required is equal to the crossing time divided by the \( 85^{th} \) percentile travel speed along the roadway.

\[
\text{PedSD} = 1.47 * S * t_c
\]

where:

\[
\text{PedSD} = \text{pedestrian sight distance (ft)}
\]

\[
t_c = \text{critical headway (s)}
\]

\[
S = 85^{th} \text{ %ile speed of the roadway being crossed or speed limit (mph)}
\]
Level of Service Study

A level of service analysis uses the methodology presented in the 2010 Highway Capacity Manual (HCM) to evaluate the potential delay to a pedestrian to cross at an unsignalized or uncontrolled crossing location. An advantage of this methodology over the gap study is that it provides a basis for when the wait becomes too long for a pedestrian and risk-taking is increased. It also uses the traffic volume and number of lanes to be crossed to determine the probability for a delayed crossing to come up with an average delay experienced at the crossing. The LOS methodology can also use yielding data to determine the effects of crossing treatments.

The information presented here is a summary of the process presented in the HCM. The HCM is the official document which provides all of the equations and methodology that is presented within this section of the manual. This manual is not meant to be a replacement of the manual but expands upon the information presented and presents it within the context of a step in the evaluation process of unsignalized and uncontrolled pedestrian crossings.

The Level-of-Service methodology follows six essential steps.

1. **Step 1:** Identify Two-Stage Crossings
2. **Step 2:** Determine Critical Headway
3. **Step 3:** Estimate Probability of a Delayed Crossing
4. **Step 4:** Calculate Average Delay to Wait for Adequate Gap
5. **Step 5:** Estimate Delay Reduction due to Yielding Vehicles
6. **Step 6:** Calculate Average Pedestrian Delay and Determine LOS

**Figure 6.1 Level of Service Methodology** [12]
Step 1: Identify Two-Stage Crossings

A two-stage pedestrian crossing is a crossing that can be completed in two stages as a pedestrian crosses a roadway. A two-stage crossing is usually provided through the use of a raised median that separates the crossing into two or more stages. A two-stage crossing most commonly splits the two directions of traffic so a pedestrian crossing the roadway only has to account for one direction of traffic at a time. [12]

Considerations

Is there a raised pedestrian median refuge available? If the crossing is defined as a two-stage crossing, each stage of the crossing is to be calculated separately through each of the subsequent steps.

A raised pedestrian median refuge should be of sufficient size to accommodate the pedestrians that are expected to use the crossing. In evaluation of a two-stage crossing, if a currently raised median is being used as a stop over during a crossing, it can be evaluated as a two-stage crossing. If the majority of pedestrians are crossing in one stage, it is a one stage crossing. In most cases, the minimum median width is 6’ with a minimum 5’ crossing width for a two-stage crossing. This indicates that there is a sufficient median refuge for pedestrians to allow for a two-stage crossing for most pedestrians. Best practice is to provide a 6’ wide crossing width to match the width of the pavement markings.

Another consideration is that a minimum 4’ x 4’ landing area should be provided at all pedestrian refuges as consistent with Americans with Disabilities Act (ADA) requirements. With the addition of truncated domes (domes usually come in 2’ by 2’ squares) to separate walking spaces from spaces designated for both motor vehicles and pedestrians, this essentially could require a median that is 8’ wide instead of the 6’ wide median as defined above.

Figure 6.2 One-Stage Crossing [14]
Minneapolis

Figure 6.3 Potential Two-Stage Crossing [14]
St. Louis Park
Step 2: Determine Critical Headway

The critical headway is calculated in the same way critical headway is determined for the gap study. The critical headway calculation uses crosswalk length, average pedestrian walking speed, and pedestrian start-up and clearance times.  \[ t_c = \frac{L}{S_p} + t_s \]

Where:
- \( t_c \) = critical headway for a single pedestrian (s),
- \( S_p \) = average pedestrian walking speed (ft/s),
- \( L \) = crosswalk length (ft), and
- \( t_s \) = pedestrian start-up time and end clearance time (s).

The default for pedestrian walking speed is 3.5 ft/s unless field data on average speed can be collected at the actual crossing. Crossings that serve a significant volume of children or people with disabilities that may require a slower walk time while crossings with a significant volume of runners or teens may have faster walk times. The default for start-up and end clearance times is 3 sec unless field data can be collected.

Examples from real-world locations in Minnesota both from this study and other studies provide some collected pedestrian walking speeds at uncontrolled pedestrian crossings with a mix of no markings, marked and signed, flashing beacons, and Rectangular Rapid Flashing Beacons. It should be noted that although average walking speed is used in the HCM calculations, the 3.5 ft/s
walking speed dictated in the MN MUTCD and other sources, is actually the 15th percentile speed and not the average. This ensures that 85% of pedestrians are able to cross faster than the walking speed accounted for or as in the case for a signalized crossing, ensure that 85% of pedestrians using a crossing are able to get across in the time allotted during a flashing don’t walk.

Table 6.1 Field Collected Walking Speeds

<table>
<thead>
<tr>
<th>Crossing</th>
<th>City, State</th>
<th>Existing Crossing Treatment</th>
<th>Average Collected Walking Speed (ft/s)</th>
<th>15th %ile Collected Walking Speed (ft/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSAH 101 &amp; Lake Dr E</td>
<td>Chanhassen, MN</td>
<td>Unmarked</td>
<td>5.6</td>
<td>5.3</td>
</tr>
<tr>
<td>Powers Blvd &amp; Park Rd</td>
<td>Chanhassen, MN</td>
<td>Flashing Beacons</td>
<td>5.6</td>
<td>4.7</td>
</tr>
<tr>
<td>3rd St &amp; Norm McGrew Plc</td>
<td>Minneapolis, MN</td>
<td>Overhead Flasher w/ Advance RRFB (one-way street)</td>
<td>4.4</td>
<td>3.7</td>
</tr>
<tr>
<td>CR 112 &amp; Mill St</td>
<td>Long Lake, MN</td>
<td>Unmarked</td>
<td>too few pedestrians</td>
<td>too few pedestrians</td>
</tr>
<tr>
<td>CSAH 150 &amp; S. School Crossing</td>
<td>Rogers, MN</td>
<td>Markings/Signs</td>
<td>4.2</td>
<td>3.8</td>
</tr>
<tr>
<td>CSAH 150 &amp; N. School Crossing</td>
<td>Rogers, MN</td>
<td>Markings/Signs/In-Street Sign</td>
<td>4.3</td>
<td>3.6</td>
</tr>
<tr>
<td>England Way &amp; 17th Ave E</td>
<td>Shakopee, MN</td>
<td>Unmarked</td>
<td>4.7</td>
<td>4.2</td>
</tr>
<tr>
<td>Center Ave &amp; TH 12</td>
<td>Montrose, MN</td>
<td>Flashing Beacons</td>
<td>4.5</td>
<td>2.2</td>
</tr>
<tr>
<td>TH 47 &amp; CR 81</td>
<td>Saint Francis, MN</td>
<td>Overhead RRFB</td>
<td>7.0</td>
<td>5.2</td>
</tr>
<tr>
<td>Bank St &amp; University Ave</td>
<td>Minneapolis, MN</td>
<td>Unmarked</td>
<td>5.7</td>
<td>4.6</td>
</tr>
<tr>
<td>Lafayette &amp; 8th St</td>
<td>St. Paul, MN</td>
<td>Unmarked</td>
<td>4.2</td>
<td>3.7</td>
</tr>
<tr>
<td>Rice St at Sears (S. of Aurora Av)</td>
<td>St. Paul, MN</td>
<td>Markings/Signs</td>
<td>4.5</td>
<td>3.9</td>
</tr>
<tr>
<td>Rolling Acres Rd &amp; Rolling Acres Ln</td>
<td>Victoria, MN</td>
<td>Markings/Signs</td>
<td>6.2</td>
<td>3.7</td>
</tr>
<tr>
<td>York Ave &amp; Parklawn Ave</td>
<td>Edina, MN</td>
<td>Markings/Signs</td>
<td>4.8</td>
<td>4.1</td>
</tr>
<tr>
<td><strong>Average of All Sites</strong></td>
<td></td>
<td></td>
<td><strong>5.0</strong></td>
<td><strong>4.1</strong></td>
</tr>
</tbody>
</table>

Table 6.1 Field Collected Walking Speeds

In most of the cases, whether the crossing was marked or unmarked, the average walking speed collected was faster than the 3.5 ft/s walking speed used as a default in the HCM calculations. Additionally, the 15th percentile walking speed collected for many of the sites was faster than 3.5 ft/s. While the above data provides a snapshot of some sites in Minnesota, additional research should be collected before drawing too many conclusions as the data appears to contradict other studies that have collected slower walking speeds. Overall, the above data indicates that collected data should always be used if available, as the defaults may give different results.
Additional data is needed when there is observed platooning. This includes crosswalk width, pedestrian flow rate, and vehicular flow rate. [12]

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

Where:
- \( N_p \) = spatial distribution of pedestrians (ped),
- \( N_c \) = total number of pedestrians in the crossing platoon,
- \( W_c \) = crosswalk width (ft), and
- 8.0 = default clear effective width used by a single pedestrian to avoid interference when passing other pedestrians (ft).

In the absence of an actual painted crosswalk the default crosswalk width is eight feet or as wide as the curb ramps leading to the crossing location.

To compute spatial distribution, the number of pedestrians in the crossing platoon should be collected in the field or the platoon size can be estimated. [12]

\[ N_c = \frac{v_p e^{v_p t_c} + v e^{-vt_c}}{(v_p + v) e^{(v_p-v)t_c}} \]

Where:
- \( N_c \) = total number of pedestrians in the crossing platoon (ped),
- \( v_p \) = pedestrian flow rate (ped/s),
- \( v \) = vehicular flow rate (veh/s), and
- \( t_c \) = single pedestrian critical headway (s).

Group critical headway is:

\[ t_{c,G} = t_c + 2(N_p - 1) \]

Where:
- \( t_{c,G} \) = group critical headway (s),
- \( t_c \) = critical headway for a single pedestrian (s), and
- \( N_p \) = spatial distribution of pedestrians (ped).

Step 3: Estimate Probability of a Delayed Crossing

The probability of a blocked lane due to a vehicle interfering with the pedestrian crossing results in a higher probability of the pedestrian being delayed. This essentially is used to determine the likelihood of the gaps in a given lane being of sufficient time to accommodate the critical headway assuming random arrivals of vehicles. This calculation is dependent on the number of lanes being crossed and the number of vehicles using the roadway in addition to the critical headway. [12]
The probability of a delayed crossing assumes random vehicle arrivals and consequentially may not provide adequate probabilities when calculating crossing delays across a street that is along a signalized corridor. [12]

\[
P_b = 1 - e^{-\frac{t_c G v}{L}}
\]

\[
P_d = 1 - (1 - P_b)^L
\]

Where:
\(P_b\) = probability of a blocked lane,
\(P_d\) = probability of a delayed crossing,
\(L\) = number of through lanes crossed,
\(t_c, G\) = group critical headway (s), and
\(v\) = vehicular flow rate (veh/s).

**Step 4: Calculate Average Delay to Wait for Adequate Gap**

The average pedestrian gap delay is calculated assuming that no motor vehicles yield and a pedestrian is forced to wait for an adequate gap. This uses the critical headway, vehicular flow rate, and probability of delayed crossing. [12]

\[
d_g = \frac{1}{v} \left( e^{v t_{c,G}} - v t_{c,G} - 1 \right)
\]

Where:
\(d_g\) = average pedestrian gap delay (s),
\(t_{c,G}\) = group critical headway (s), and
\(v\) = vehicular flow rate (veh/s).

The average delay for any pedestrian who is unable to cross immediately upon reaching the intersection is a function of the probability of a delayed crossing and the average pedestrian gap delay. [12]

\[
d_{gd} = \frac{d_g}{P_d}
\]

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

After Step 4, if there are no crossing treatments, skip to Step 6.

**Step 5: Estimate Delay Reduction due to Yielding Vehicles**

Pedestrian crossing treatments can affect the rate in which a motorist yields to a pedestrian. The average pedestrian delay is calculated using average headway for each through lane, probability of yielding, and average gap delay.
This step can be used to determine the effect of a potential crossing treatment to vehicle yielding and consequentially average pedestrian delay.

Determine if there is a crossing treatment used that could provide vehicle yielding. Crossing treatments with researched yield rates are included in Table X. This then provides possible reduction in actual delay. [12]

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

and

\[ n = \text{INT} \left( \frac{d_{gd}}{h} \right) \]

Where:
\( d_p \) = average pedestrian delay (s),
\( i \) = crossing event (\( i = 1 \) to \( n \)),
\( h \) = average headway for each through lane,
\( P(Y_i) \) = probability that motorists yield to pedestrian on crossing event \( i \),
\( \text{INT} \) = integer, and
\( n \) = average number of crossing events before an adequate gap is available, must be 1 or more.

The probabilities \( P(Y_i) \) that motorists will yield for different lane crossings are: [12]

One-Lane Crossing

\[ P(Y_i) = P_d M_y (1 - M_y)^{i-1} \]

Two-Lane Crossing

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

Three-Lane Crossing

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

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

Where:
\( P(Y_i) \) = probability that motorists yield to pedestrian on crossing event \( i \),
\( i = \) crossing event (\( i = 1 \) to \( n \)),
\( P_d \) = probability of a delayed crossing,
\( P_b \) = probability of a blocked lane,
\( M_y \) = motorist yield rate (decimal),
\( P(Y_j) \) = probability that motorists yield to pedestrian on crossing event \( j \),
\( j = \) crossing event (\( j = 0 \) to \( i - 1 \)), and
\( P(Y_0) = 0 \).

Potential crossing treatments and the motorist yield rates shown on the next page.
<table>
<thead>
<tr>
<th>Crossing Treatment</th>
<th>Staged Pedestrian Motorist Yield Rate</th>
<th>Unstaged Pedestrian Motorist Yield Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crosswalk Markings and Signs Only $^{(1)}$</td>
<td>7%</td>
<td>7%</td>
</tr>
<tr>
<td>Median Refuge Islands $^{(1)}$</td>
<td>34%</td>
<td>29%</td>
</tr>
<tr>
<td>Pedestal Mounted Flashing Beacon (2-Lane, 35 mph) $^{(3)}$</td>
<td>N/A</td>
<td>57%</td>
</tr>
<tr>
<td>Overhead Flashing Beacon (push-button activation) $^{(1)}$</td>
<td>47%</td>
<td>49%</td>
</tr>
<tr>
<td>Overhead Flashing Beacon (passive activation) $^{(1)}$</td>
<td>31%</td>
<td>67%</td>
</tr>
<tr>
<td>Pedestrian Crossing Flags $^{(1)}$</td>
<td>65%</td>
<td>74%</td>
</tr>
<tr>
<td>School Crossing Guards $^{(5)}$</td>
<td>N/A</td>
<td>86%</td>
</tr>
<tr>
<td>In-street Crossing Signs (25-30 mph) $^{(1)}$</td>
<td>87%</td>
<td>90%</td>
</tr>
<tr>
<td>Warning Sign with Edge Mounted LEDs $^{(6)}$</td>
<td>N/A</td>
<td>28%</td>
</tr>
<tr>
<td>In-road warning lights $^{(1)}$</td>
<td>N/A</td>
<td>66%</td>
</tr>
<tr>
<td>High-visibility Signs and Markings (35 mph) $^{(1)}$</td>
<td>17%</td>
<td>20%</td>
</tr>
<tr>
<td>High-visibility Signs and Markings (25 mph) $^{(1)}$</td>
<td>61%</td>
<td>91%</td>
</tr>
<tr>
<td>Rectangular Rapid-Flash Beacon (RRFB) $^{(2)(4)}$</td>
<td>84%</td>
<td>81%</td>
</tr>
<tr>
<td>School Crossing Guards with RRFB $^{(6)}$</td>
<td>N/A</td>
<td>91%</td>
</tr>
<tr>
<td>Pedestrian Hybrid Beacon (HAWK) $^{(1)}$</td>
<td>97%</td>
<td>99%</td>
</tr>
</tbody>
</table>

N/A: No Research Found on Effect to Yielding Rate

Crossing treatment motorist yield rate sources provided on the next page.

Table 6.2 Crossing Treatment Yield Rates
Crossing treatment yield rate sources:
(3) Bolton & Menk Field Data Collection
(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.

Step 6: Calculate Average Pedestrian Delay and Determine LOS

Sum the delay for each stage of a two stage crossing or use the delay from a one-stage crossing and use the following table to determine the level of service (LOS) for the crossing movement. [12]

<table>
<thead>
<tr>
<th>LOS</th>
<th>Control Delay (sec/pedestrian)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0-5</td>
<td>Usually no conflicting traffic</td>
</tr>
<tr>
<td>B</td>
<td>5-10</td>
<td>Occasionally some delay due to conflicting traffic</td>
</tr>
<tr>
<td>C</td>
<td>10-20</td>
<td>Delay noticeable to pedestrians, but not inconveniencing</td>
</tr>
<tr>
<td>D</td>
<td>20-30</td>
<td>Delay noticeable and irritating, increased likelihood of risk taking</td>
</tr>
<tr>
<td>E</td>
<td>30-45</td>
<td>Delay approaches tolerance level, risk-taking behavior likely</td>
</tr>
<tr>
<td>F</td>
<td>&gt;45</td>
<td>Delay exceeds tolerance level, high likelihood of pedestrian risk-taking</td>
</tr>
</tbody>
</table>

Table 6.3 Pedestrian Mode Level of Service

LOS F indicates that there are not enough gaps of suitable size to allow pedestrians to cross through traffic on the major street safely. LOS F may result in pedestrians selecting smaller than usual gaps, indicating a safety concern that warrants further study.

Evaluation Worksheets are provided on the following pages.
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 practitioners. 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**

<table>
<thead>
<tr>
<th>Crossing Location:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>City, State:</td>
<td>Scenario:</td>
</tr>
<tr>
<td>Reviewer(s):</td>
<td>Agency:</td>
</tr>
<tr>
<td>Project Number:</td>
<td>ID #:</td>
</tr>
</tbody>
</table>

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:**

- **L** = crosswalk length (ft)
- **$S_p$** = average pedestrian walking speed (ft/s)
- **$t_s$** = pedestrian start-up and end clearance time (s)
- **$V$** = vehicular hourly volume (veh/hr)
- **$V_p$** = pedestrian flow rate (ped/s)
- **$V$** = vehicular flow rate (veh/s) = $V/3600$
- **$W_c$** = crosswalk width (ft)
- **N** = number of through lanes crossed (Integer)

**Input Table:**

<table>
<thead>
<tr>
<th>defaults</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>L</strong> =</td>
<td><strong>$S_p$</strong> =</td>
</tr>
<tr>
<td><strong>$S_p$</strong> = 3.5</td>
<td><strong>$S_p$</strong> =</td>
</tr>
<tr>
<td><strong>$t_s$</strong> = 3.0</td>
<td><strong>$t_s$</strong> =</td>
</tr>
<tr>
<td><strong>$V$</strong> =</td>
<td><strong>$V$</strong> =</td>
</tr>
<tr>
<td><strong>$V_p$</strong> = 0*</td>
<td><strong>$V_p$</strong> =</td>
</tr>
<tr>
<td><strong>$V$</strong> = $V/3600$</td>
<td><strong>$V$</strong> =</td>
</tr>
<tr>
<td><strong>$W_c$</strong> = 8.0</td>
<td><strong>$W_c$</strong> =</td>
</tr>
<tr>
<td><strong>N</strong> = INT(L/11)</td>
<td><strong>N</strong> =</td>
</tr>
</tbody>
</table>

*no platooning observed*

#### Crossing 2:

**Evaluation inputs:**

- **L** = crosswalk length (ft)
- **$S_p$** = average pedestrian walking speed (ft/s)
- **$t_s$** = pedestrian start-up and end clearance time (s)
- **$V$** = vehicular hourly volume (veh/hr)
- **$V_p$** = pedestrian flow rate (ped/s)
- **$V$** = vehicular flow rate (veh/s) = $V/3600$
- **$W_c$** = crosswalk width (ft)
- **N** = number of through lanes crossed (Integer)

**Input Table:**

<table>
<thead>
<tr>
<th>defaults</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>L</strong> =</td>
<td><strong>$S_p$</strong> =</td>
</tr>
<tr>
<td><strong>$S_p$</strong> = 3.5</td>
<td><strong>$S_p$</strong> =</td>
</tr>
<tr>
<td><strong>$t_s$</strong> = 3.0</td>
<td><strong>$t_s$</strong> =</td>
</tr>
<tr>
<td><strong>$V$</strong> =</td>
<td><strong>$V$</strong> =</td>
</tr>
<tr>
<td><strong>$V_p$</strong> = 0*</td>
<td><strong>$V_p$</strong> =</td>
</tr>
<tr>
<td><strong>$V$</strong> = $V/3600$</td>
<td><strong>$V$</strong> =</td>
</tr>
<tr>
<td><strong>$W_c$</strong> = 8.0</td>
<td><strong>$W_c$</strong> =</td>
</tr>
<tr>
<td><strong>N</strong> = INT(L/11)</td>
<td><strong>N</strong> =</td>
</tr>
</tbody>
</table>

*no platooning observed*

#### Crossing Treatment Yield Rate

**$M_y$** = motorist yield rate (decimal)

**Input Table:**

| **$M_y$** = |

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

### Results:

<table>
<thead>
<tr>
<th>Average Delay</th>
<th>LOS</th>
<th>sec/ped</th>
</tr>
</thead>
</table>

**Figure 6.6 Highway Capacity Manual Evaluation Worksheet (Page 2)**
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 ADO requirements (4’ x 6’ landing)? [ ] Yes [ ] No
If yes, do pedestrians treat this as a two-stage crossing location? [ ] Yes [ ] No

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 sufficient 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)

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

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

\[ N_c = \frac{v_p e^{t_p c} + v e^{t_r c}}{(v_p + v)e^{(t_p + t_r)c}} \]

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)
- \( t_p \) = single pedestrian critical headway (s)

2. Compute spatial distribution:

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

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)

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)

**Step 2: Determine Critical Headway**

**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.

\[ P_e = 1 - e^{-t_c/G} \]

Where:
- \( P_e \) = 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)

Developed by Bolton & Menk, Inc. for the LRRB.  
HCM Calculations Sheet 1  Page 3 of 5

Figure 6.7 Highway Capacity Manual Evaluation Worksheet (Page 3)
### Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

**Step 4: Calculate Average Delay to Waive for Adequate Gap**

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

\[
d_d = \frac{1}{\nu} \left( e^{t_{c,\text{Q}}} - \frac{\nu}{t_{c,\text{Q}}} - 1 \right)
\]

where:
- \(d_d\) = average pedestrian gap delay (s)
- \(t_{c,\text{Q}}\) = critical headway (s)
- \(\nu\) = vehicular flow rate across crossing (veh/s)

**Average delay for a pedestrian who is unable to cross immediately upon reaching the intersection**

(e.g., any pedestrian experiencing nonzero delay)

\[
d_{p,d} = \frac{d_d}{P_g}
\]

where:
- \(d_{p,d}\) = average gap delay for pedestrians who incur nonzero delay
- \(d_d\) = average pedestrian gap delay (s)
- \(P_g\) = probability of a delayed crossing

**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

\[
d_p = \sum_{i=1}^{n} (t_i - 0.5) P(Y_i) + \left( \frac{d_d}{\nu} - \sum_{i=1}^{n} P(Y_i) \right) \frac{d_{p,d}}{P_g}
\]

where:
- \(d_p\) = average pedestrian delay (s)
- \(t_i\) = crossing event [i = 1 to n]
- \(n\) = average headway for each through lane = N/\(h\)
- \(P(Y_i)\) = probability that motorists yield to pedestrian on crossing event i
- \(r_i = \text{int}(d_{p,d}/\nu), \text{average number of crossing events before an adequate gap is available, } >0\)
- \(j = \text{crossing event } j = \text{crossing event } j \in [0 \text{ to } n - 1]\)
- \(P(Y)\) = probability that motorists yield to pedestrian on crossing event j

1. One-Lane Crossing

\[
P(Y) = P_a M_p (1 - M_p)^{t - 1}
\]

\(M_p\) = motorist yield rate (decimal)

2. Two-Lane Crossing

\[
P(Y) = \left[ P_a - \sum_{i=1}^{n} P(Y_i) \right] \left[ (2P_a(1 - P_a)M_p) + (P_a^2 M_p^2) \right]
\]

3. Three-Lane Crossing

\[
P(Y) = \left[ P_a - \sum_{i=1}^{n} P(Y_i) \right] \left[ P_a^3 M_p^3 + 3P_a^2(1 - P_a)M_p^2 + 3P_a(1 - P_a)^2 M_p ight]
\]

4. Four-Lane Crossing

\[
P(Y) = \left[ P_a - \sum_{i=1}^{n} P(Y_i) \right] \left[ P_a^3 M_p^3 + 3P_a^2(1 - P_a)M_p^2 + 3P_a(1 - P_a)^2 M_p + 3P_a(1 - P_a)^3 M_p \right]
\]

### Summary

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

---

Figure 6.8 Highway Capacity Manual Evaluation Worksheet (Page 4)
Determine if there is a crossing treatment used that could provide vehicle yielding. This then provides a possible reduction in delay.

<table>
<thead>
<tr>
<th>Crossing Treatment</th>
<th>Staged Pedestrian Yield Rate</th>
<th>Unstaged Pedestrian Yield Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crosswalk Markings and Signs Only (1)</td>
<td>7%</td>
<td>7%</td>
</tr>
<tr>
<td>Median Refuge Islands (1)</td>
<td>34%</td>
<td>29%</td>
</tr>
<tr>
<td>Pedestrian Mounted Flashing Beacon (2 Lane, 35 mph) (3)</td>
<td>N/A</td>
<td>57%</td>
</tr>
<tr>
<td>Overhead Flashing Beacon (push-button activation) (4)</td>
<td>47%</td>
<td>49%</td>
</tr>
<tr>
<td>Overhead Flashing Beacon (passive activation) (1)</td>
<td>N/A</td>
<td>67%</td>
</tr>
<tr>
<td>Pedestrian Crossing Flags (1)</td>
<td>65%</td>
<td>74%</td>
</tr>
<tr>
<td>School Crossing Guards (3)</td>
<td>N/A</td>
<td>86%</td>
</tr>
<tr>
<td>In-street Crossing Signs (25-30 mph) (1)</td>
<td>87%</td>
<td>90%</td>
</tr>
<tr>
<td>Warning Sign with Edge Mounted LEDs (5)</td>
<td>N/A</td>
<td>28%</td>
</tr>
<tr>
<td>In-road warning lights (1)</td>
<td>N/A</td>
<td>66%</td>
</tr>
<tr>
<td>High-visibility Signs and Markings (35 mph) (1)</td>
<td>17%</td>
<td>20%</td>
</tr>
<tr>
<td>High-visibility Signs and Markings (25 mph) (1)</td>
<td>61%</td>
<td>91%</td>
</tr>
<tr>
<td>Rectangular Rapid-Flash Beacon (RRFB) (5)(6)</td>
<td>84%</td>
<td>81%</td>
</tr>
<tr>
<td>School Crossing Guards with RRFB (3)</td>
<td>N/A</td>
<td>91%</td>
</tr>
<tr>
<td>Pedestrian Hybrid Beacon (HAWK) (1)</td>
<td>97%</td>
<td>99%</td>
</tr>
</tbody>
</table>

Sources:
3. Bolton & Menk Field Data Collection
5. Brewer, Marcus A., Kay Fitzpatrick, Before-and-After Study of the Effectiveness of Rectangular Rapid-Flash Beacons Used with School Sign in Garland, Texas. Texas Transportation Institute, College Station, TX, April 2012.
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Chapter 7
Evaluation Procedure

The location details, evaluation, decisions, and design process should be thoroughly documented. This includes any stakeholder involvement and public comments. The jurisdictional authority has the final decision on the control and design of pedestrian crossing features on their roadways.

Using the information provided in Chapters 2 through 6, a crossing evaluation procedure has been developed to take into consideration safety and operations. The procedure is based on previous research and evaluation methodologies.

The evaluation methodology guidance is shown in the flowchart, Figure 7.1.

**Step 1. Field Data Review**

The Field Data Review should consider the elements defined under Chapter 4 of this report.

Information to be collected should include

- **Geometrics**
  - Crossing Length
    - pedestrian exposure is reduced on shorter crossings
  - Median Width
    - if used by pedestrians the median should be sufficient in size to handle the pedestrians using it
  - Curb Ramps
    - curb ramps are required for all pedestrian crossing locations
  - Americans with Disabilities Act (ADA) Requirements
    - ADA requirements for pedestrian crossings including grades, tactile surfaces/truncated domes, and landing areas.
  - Roadway Speed
    - for a pedestrian/vehicle crash slower speeds have been shown to reduce the possibility of a fatal crash
  - Roadway Curvature
    - vertical and horizontal curvature can impact sight lines
  - Sight Distance
    - Stopping Sight Distance
      - must be provided at pedestrian crossings
    - Pedestrian Sight Distance
      - should be provided at unmarked and unsigned crossings

- **Traffic and Pedestrian Data**
  - Vehicle Traffic Volume
  - Pedestrian Traffic Volume
Figure 7.1 Uncontrolled Pedestrian Crossing Evaluation Flowchart
• Additional Site Characteristics
  o Lighting
    ▪ should be provided at marked crossings used at night and provide positive contrast
  o Crosswalk Pavement Markings
    ▪ must follow the designs as stated in the Manual on Uniform Traffic Control Devices
  o Signing
    ▪ must follow the design and placement as stated in the Manual on Uniform Traffic Control Devices
  o Enhancements
    ▪ enhancements installed at the crossing location may or may not be appropriate and provide effective yielding
  o Distance to Adjacent Pedestrian Crossing Facilities
    ▪ an adjacent crossing location may provide a shorter travel time, less delay, a safer crossing environment, and/or a more direct route between origins and destinations
  o Distance to Adjacent Intersections with All-Way Stop, Signal, or Roundabout Control
    ▪ an adjacent controlled crossing location may provide a shorter travel time
  o Origins and Destinations
    ▪ all marked crossings should serve a needed origin-destination connection
    ▪ Typical origins and destinations of importance include:
      • Bus stops
      • High density residential
      • Hospitals and medical centers
      • Retirement communities
      • Schools, colleges, and universities
      • Parks
      • Recreational and community centers
      • Theatres and museums
      • Trails

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 into the issues and concerns at a crossing location. The field review can assist with determining potential issues. This includes an inspection of potential hazards and may include a visual view of operations.

Rear-end crashes at a location may indicate that motorists are stopping for pedestrians but 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 may 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 onto the roadway. If SSD cannot be met, pedestrian barriers and pedestrian routing to an alternative location should be considered. Pedestrian barriers can include fencing, concrete barriers, and/or bushes. The pedestrian barrier should be continuous between acceptable crossing locations to guide pedestrians to the locations to be used. Any breaks in the barrier, such as for a driveway or street access, will likely result in the pedestrian crossing at that location. Pedestrian routing may include wayfinding signage to guide pedestrians to the acceptable alternative crossing locations.

**Step 4. Level of Service**

Determine the Level of Service (LOS) of the current crossing condition following the procedure as outlined in the 2010 Highway Capacity Manual and Chapter 6 of this report.

LOS is generally deemed acceptable at A to D and unacceptable at E or F. Local agency direction on acceptable service levels should be verified. If the Level of Service is acceptable and the location already has treatments such as signing and/or striping, consider no changes at the existing crossing. If the crossing location has acceptable service levels without any treatments, consider removal of the treatments.

If LOS is unacceptable, skip to Step 6. If this is completed after Step 11, consider applying appropriate treatment option(s) if LOS is acceptable.

**Step 5. Pedestrian Sight Distance**

If adequate service levels are provided, Pedestrian Sight Distance (PedSD) should be checked if the crossing does not have any treatments (i.e. is unmarked and unsigned). If adequate PedSD is provided, consider no changes at the existing crossing.

**Step 6. Review Origins and Destinations**
The potential origins and destinations in the area should be reviewed for the most likely path to determine how it lines up with the crossing being analyzed. The most important thing to remember is that pedestrians will take the shortest route if at all possible. Understanding this is of essential importance in 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 where pedestrians are using them if the understanding of origins and destinations is incorrect.

Studies have shown that many pedestrians will take the fastest route and the most direct route irrespective of the safety potential of the crossing location. [18] The percentage of pedestrians using the most direct route and fastest route are higher for younger people than older. Additionally if traffic is sparse, the percentage of pedestrians crossing at a given location, irrespective of the crossing treatments, is 40 to 60% and is generally equal between younger and older people. [19]

Check to see if an alternative route is available that can serve the same origin-destination pair (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.

Additionally, the alternative crossing route location should be visually seen from the location being studied. If the crossing cannot be seen there is no way for the pedestrian to know if it is available, unless there is route signage. Even with route signage, the potential trip length may not be known to a pedestrian if the crossing cannot be seen. This can affect the potential use of the alternative crossing location.

If the primary origin-destination movements can be accomplished effectively at another crossing without much backtracking, has a shorter travel time and can be seen from the location being studied, there should be consideration for no change at the existing crossing. The alternative crossing location should be evaluated separately to determine the needs at that crossing location.

**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. 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 at least 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 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. If the crossing location is on a coordinated signalized corridor or a grade-separated facility, pedestrian barriers and pedestrian routing to an alternative location should be considered. Pedestrian barriers can include fencing, concrete barriers, and/or bushes. The pedestrian barrier should be continuous between acceptable crossing locations to guide pedestrians to the locations to be used. Any breaks in the barrier, such as for a driveway or street access, will likely result in the pedestrian crossing at that location. Pedestrian routing may include wayfinding signage to guide pedestrians to the acceptable alternative crossing locations.

**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 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 speed 35 mph or less there should be a minimum of 20 pedestrians using the crossing during one hour of the day.

The above pedestrian volumes thresholds can be reduced by 0.33 if more than 50% of the pedestrian traffic using the crossing is elderly or children.

If the thresholds cannot be met, skip to Step 10.

**Step 9. FHWA Safety Guidance**

The Federal Highway Administration (FHWA) guidance in the Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations and as shown in Chapter 5 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 and provides the basis for the guidance in the table.

It is important to recognize that the research indicates where pedestrian crossing markings alone may or may not be sufficient. The research does not indicate where pedestrian crossings with
alternative treatments should or should not be located. In all cases, an engineering study should be completed to determine whether a location is suitable or not, and if additional pedestrian crossing treatments are justified.

The FHWA recommendations for installing marked crosswalks and other treatments is included in Table 7.1.

Table Definitions

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 improvement to improve crossing safety for pedestrians. It is important to recognize that the research indicates where pedestrian crossing markings alone may or may not be sufficient. The research does not indicate where pedestrian crossings with alternative treatments should or should not be located. In all cases, an engineering study should be completed to determine whether a location is suitable or not, and if additional pedestrian crossing treatments are justified. [11]
### Table 7.1 Recommendations for Installing Marked Crosswalks at Uncontrolled Locations

<table>
<thead>
<tr>
<th>Roadway Type (Number of Travel Lanes and Median Type)</th>
<th>Vehicle ADT ≤ 9,000</th>
<th>Vehicle ADT &gt;9,000 to 12,000</th>
<th>Vehicle ADT &gt;12,000-15,000</th>
<th>Vehicle ADT &gt; 15,000</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Speed Limit</strong> <strong>(km/h)</strong></td>
<td><strong>≤ 48.3 km/h</strong></td>
<td><strong>56.4 km/h</strong></td>
<td><strong>64.4 km/h</strong></td>
<td><strong>64.4 km/h</strong></td>
</tr>
<tr>
<td>Two lanes</td>
<td>C</td>
<td>C</td>
<td>P</td>
<td>C</td>
</tr>
<tr>
<td>Three lanes</td>
<td>C</td>
<td>C</td>
<td>P</td>
<td>C</td>
</tr>
<tr>
<td>Multilane (four or more lanes) with raised median***</td>
<td>C</td>
<td>P</td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>Multilane (four or more lanes) without raised median</td>
<td>C</td>
<td>P</td>
<td>N</td>
<td>P</td>
</tr>
</tbody>
</table>

* These guidelines include intersections 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 hazards, 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 medians, traffic signals, pedestrian facilities). A final decision should be made after consulting with relevant stakeholders and experts.

** When 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 conducted 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 improvements to improve crossing safety for pedestrians.

In some situations (e.g., low-speed, two-lane streets in downtown areas), installing a marked crosswalk may help consolidate multiple crossing points. Engineering judgment should be used to install crosswalks at preferred locations (e.g., at a crossing location at a streetlight as opposed to an unlighted crossing point nearby). While overuse of marked crossings at uncontrolled locations should be avoided, higher priority should be placed on providing crosswalk markings where pedestrian volume exceeds about 20 per peak hour (or 15 or more elderly pedestrians and/or children per peak hour).

Marked crosswalks and other pedestrian facilities (or lack of facilities) should be routinely monitored to determine what improvements are needed.
Step 10. School Crossings

The safety of children to get to and from school is of special consideration that 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 consistent with school start and dismissal times, making the crossing use noticeable to motorists. Consider appropriate treatment options including crossing guards. At higher traffic speed crossings, this includes appropriate traffic calming treatments in addition to other treatments.

If this step is completed directly after Step 8, and the location is not a school crossing location, go to Step 9.

Step 11. Consider Appropriate Treatment Options

Appropriate treatment options should be considered for crossing locations as based on the evaluation flowchart. In many cases, the most appropriate option is to keep the location unmarked and unsigned (i.e. “Do Nothing”), as any treatment may increase the crash potential at the location.

The treatment options have been organized into four separate categories as shown in Table 7.2 to 7.5 depending on their primary function in serving pedestrian crossings.

- Signing and Marking Treatments
- Uncontrolled Crossing Treatments
- Traffic Calming Treatments
- High Level Treatments

Some of the options have not been shown to have any noticeable impact to motorist yielding and service levels, but are provided as examples that have been implemented by some agencies. Many of the traffic calming treatments may not directly impact motorist yielding but do result in shorter crossing distances and a potential for lower traffic speeds. For ADA compliant versions of the treatment summary tables, please see Appendix A.

In all cases, when speed limits are over 40 mph and/or the FHWA guidance indicates an N designation, it may be appropriate to consider traffic calming treatments, no matter the other treatments recommended.
Signing and Marking Treatments

Signing and Marking Treatments (Table 7.2) 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.

Figure 7.2 Standard Crosswalk Markings

Figure 7.3 Advance Pedestrian Crossing Warning Sign

Figure 7.4 In-Street Crossing Sign

Figure 7.5 Pedestrian Crossing Warning Sign with Down Arrow

Figure 7.6 High Visibility Continental Crosswalk Markings
## Table 7.2 Signing and Marking Treatments

*Treatments Should be Justified Through an Engineering Study*

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Recommended Locations</th>
<th>Motorist Yield Rate</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crosswalk Markings Only</strong></td>
<td>Inexpensive</td>
<td>Very little effect at night*2</td>
<td>Not usually recommended alone</td>
<td>Staged Pedestrian: 7% Unstaged Pedestrian: 7%</td>
<td>$500 to $2,000</td>
</tr>
<tr>
<td></td>
<td>Helps define a crossing location</td>
<td>Speeds increase over time</td>
<td>Low volume and low speed roadways</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indicates to drivers that a crossing location is present</td>
<td>Not been shown to reduce crashes</td>
<td>With justification</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Warning Signs</strong></td>
<td>Inexpensive</td>
<td>Tend to be ignored unless pedestrians use the crossing consistently</td>
<td>Where unexpected entries into the roadway by pedestrians may occur</td>
<td>NR NR</td>
<td>$300 to $1,200</td>
</tr>
<tr>
<td></td>
<td>Helps define a crossing location</td>
<td>Proven to be ineffective at reducing crashes at uncontrolled intersections</td>
<td>Either at or before the crossing location</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Warning to drivers that a crossing location is present</td>
<td></td>
<td>Either with or without a marked crosswalk</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Overhead Warning Signs</strong></td>
<td>Visual distance increased</td>
<td>Requires overhead structure</td>
<td>Multi-lane roadways</td>
<td>NR NR</td>
<td>$60,000 to $75,000</td>
</tr>
<tr>
<td></td>
<td>Warning to drivers that a crossing location is present</td>
<td>Tend to be ignored unless pedestrians use the crossing consistently</td>
<td>Midblock crossing locations</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Signs easier to see when have multiple lanes of approach</td>
<td></td>
<td>Usually coupled with other measures such as RRFBs or beacons</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Colored Concrete/Brick Pavers</strong></td>
<td>May decrease vehicle speed</td>
<td>Can be expensive</td>
<td>Downtown/Urban conditions</td>
<td>NR NR</td>
<td>$10,000 to $75,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not been shown to reduce crashes</td>
<td>Traffic signal locations</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Speeds increase over time</td>
<td>In conjunction with pavement markings</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Crosswalk Markings and Signs</strong></td>
<td>Inexpensive</td>
<td>Very little effect at night</td>
<td>Where justified</td>
<td>NR NR</td>
<td>$800 to $3,200</td>
</tr>
<tr>
<td></td>
<td>Warning to drivers that a crossing location is present</td>
<td>Not been shown to reduce crashes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>May decrease vehicle speed</td>
<td>Speeds increase over time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>In-Street Crossing Signs (25 to 30 mph)</strong></td>
<td>Inexpensive</td>
<td>May make snow removal more difficult</td>
<td>Downtown/Urban conditions</td>
<td>87% 90%</td>
<td>$500 to $1,000</td>
</tr>
<tr>
<td></td>
<td>Additional Warning to drivers that a crossing location is present</td>
<td>Need consistent maintenance and replacement due to vehicle hits</td>
<td>Supplement warning signs at high pedestrian volume locations</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>In conjunction with pavement markings</td>
<td>In conjunction with pavement markings</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>High Visibility Crosswalk Markings</strong></td>
<td>May decrease vehicle speed</td>
<td>Not been shown to reduce crashes</td>
<td>Where justified</td>
<td>61% (25 mph) 17% (35 mph) 20% (35 mph)</td>
<td>$5,000 to $50,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Speeds increase over time</td>
<td>Urban conditions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*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 generally applied to locations with marked crosswalks to provide an extra level of operational and safety benefit due to higher volume and speeds. Many of the treatments are pedestrian activated.

Figure 7.7 Center Median with Refuge Island

Figure 7.8 School Crossing Guard

Figure 7.9 Pedestal Mounted Flashing Signal Beacons
Figure 7.10 Overhead Flashing Signal Beacons

Figure 7.11 Rapid Rectangular Flashing Beacons (RRFB)

Figure 7.12 In-Road Warning Lights with Edge Lit Warning Sign
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Recommended Locations</th>
<th>Motorist Yield Rate</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Median with Refuge Island</td>
<td>Decreases pedestrian crossing distance Provides higher pedestrian visibility Reduces vehicle speeds approaching the island Reduces conflicts Increases usable gaps Reduces pedestrian exposure time</td>
<td>May make snow removal more difficult May be a hazard for motorists Small islands not recommended on high speed (&gt;40 mph) roadways</td>
<td>Wide two-lane roads and multi-lane roads with sufficient right-of-way</td>
<td>34%</td>
<td>20% Variable</td>
</tr>
<tr>
<td>School Crossing Guards</td>
<td>Inexpensive Provides higher pedestrian visibility to drivers Highlights when a pedestrian crossing is being used</td>
<td>May require trained staff or local law enforcement, especially on high speed and high volume roadways</td>
<td>At school locations</td>
<td>NR</td>
<td>86% Variable</td>
</tr>
<tr>
<td>Pedestrian Crossing Flags</td>
<td>Inexpensive Provides higher pedestrian visibility to drivers assuming the flag is held in a noticeable location</td>
<td>No effect at night Requires pedestrian to actively use a flag Can be easily removed/stolen Shorter crossings are preferred</td>
<td>Downtown/Urban locations High pedestrian volume locations Across low speed (&lt;45 mph) roadways</td>
<td>65%</td>
<td>74% &lt;$500</td>
</tr>
<tr>
<td>Warning Sign with Edge Mounted LEDs</td>
<td>Highlights a crossing both at night and during the day Requires pedestrian activation Minimal to no effect on speed</td>
<td>Requires pedestrian activation In conjunction with In-Road Warning Lights Downtown/Urban conditions</td>
<td>NR</td>
<td>28%</td>
<td>$3,000 to $8,000</td>
</tr>
<tr>
<td>In-Road Warning Lights</td>
<td>Highlights a crossing both at night and during the day Provides higher driver awareness when a pedestrian is present</td>
<td>Snow plows can cause maintenance issues No effect when road surface is covered in snow Requires pedestrian activation</td>
<td>Downtown/Urban conditions</td>
<td>NR</td>
<td>66% $20,000 to $40,000</td>
</tr>
<tr>
<td>Pedestrian Mounted Pedestrian Flashing Signal Beacons</td>
<td>Provides higher driver awareness when a pedestrian is present Requires pedestrian activation Not advisable on multi-lane streets Not been shown to reduce crashes</td>
<td>Low speed school crossings Two lane roadways Midblock crossing locations</td>
<td>NR</td>
<td>57% (2-Lane, 35 mph)</td>
<td>$12,000 to $18,000</td>
</tr>
<tr>
<td>Pedestrian Overhead Flashing Signal Beacons</td>
<td>Provides higher driver awareness when a pedestrian is present Requires pedestrian activation</td>
<td>Multi-lane roadways Midblock crossing locations Lower speed roadways</td>
<td>Multi-lane roadways Midblock crossing locations Lower speed roadways</td>
<td>active 47% passive 31%</td>
<td>active 49% passive 67%</td>
</tr>
<tr>
<td>Rectangular Rapid Flash Beacons (RRFBs)</td>
<td>Provides higher driver awareness when a pedestrian is present Increases yielding percentage Increase in usable gaps Reduces the probability of pedestrian risk taking Can be configured to be seen from 360 degrees Requires pedestrian activation</td>
<td>Supplement existing pedestrian crossing warning signs School Crossings Midblock crossing locations Low and high speed roadways</td>
<td>Supplement existing pedestrian crossing warning signs School Crossings Midblock crossing locations Low and high speed roadways</td>
<td>84%</td>
<td>83% $12,000 to $18,000</td>
</tr>
</tbody>
</table>

NR = No Research Found on Effect to Yielding Rate
Traffic Calming Treatments

Traffic Calming Treatments are generally applied to locations that are experiencing high traffic speeds. Traffic speeds should be lowered to enable any type of at-grade crossing. They 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. This reduced exposure results in safer crossing environments. These treatments may be completed in conjunction with Uncontrolled Crossing Treatments and/or other treatments if determined to be necessary.

Figure 7.13 Center Median with Refuge Island

Figure 7.14 Crossing Location Lighting

Figure 7.15 Pavement Striping/Road Diet

Figure 7.16 Curb Bump-Out

Figure 7.17 Channelized Turn Lane with Raised Crossing
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Recommended Locations</th>
<th>Motorist Yield Rate</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Median with Refuge Island</td>
<td>Decreases pedestrian crossing distance Provides higher pedestrian visibility Reduces vehicle speeds approaching the island Reduces conflicts Increases usable gaps Reduces pedestrian exposure time</td>
<td>May make snow removal more difficult May be a hazard for motorists Small islands not recommended on high speed (&gt;40 mph) roadways</td>
<td>Wide two-lane roads and multi-lane roads with sufficient right-of-way</td>
<td>34%</td>
<td>29%</td>
</tr>
<tr>
<td>Raised Crossings</td>
<td>Provides higher pedestrian visibility to vehicle Can reduce vehicle speeds</td>
<td>May make snow removal more difficult May reduce emergency vehicle response times Only appropriate in low speed/urban environments</td>
<td>Low speed/Urban environments</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Lighting</td>
<td>Can be inexpensive Highlights a crossing at night</td>
<td>No effect during daylight</td>
<td>Targeted crossing locations not located on a street with continuous roadway lighting</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Pavement Striping (Road Diet)</td>
<td>Can be inexpensive May decrease vehicle speed May decrease illegal right side passing Can be an interim solution</td>
<td>Does not provide a physical barrier between modes Pedestrian crossing distance same as existing</td>
<td>Four-lane undivided roadways Locations with very long crossings</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Curb Bump-Outs/Extensions</td>
<td>Can be inexpensive Reduce pedestrian crossing distance Provides higher pedestrian visibility to vehicle Reduce: speed for turning vehicles Decrease in illegal right side passing</td>
<td>May make snow removal more difficult Proximity of curb to through traffic may be a safety concern</td>
<td>Downtown/Urban conditions</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Channelized Turn Lanes (Corner Islands) (Not Usually Recommended as a Pedestrian Crossing Treatment)</td>
<td>Decrease pedestrian crossing distance Provides higher pedestrian visibility Decrease in illegal right side passing</td>
<td>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</td>
<td>Intersections with wide approaches Intersections with right turn lanes and sufficient corner right-of-way Intersections with operational improvement needs</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

NR = No Research Found on Effect to Yielding Rate
High Level Treatments

High Level Treatments are generally 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.

Figure 7.18 Pedestrian Hybrid Beacon

Figure 7.19 Pedestrian Traffic Signal

Figure 7.20 Underpass

Figure 7.21 Overpass
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Recommended Locations</th>
<th>Motorist Yield Rate</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian Hybrid Beacon</td>
<td>Provides higher driver awareness when a pedestrian is present Has been shown to decrease pedestrian crashes</td>
<td>Potential increase in vehicle crashes Can have spotty compliance rates due to lack of driver understanding</td>
<td>Justified locations Midblock crossing locations</td>
<td>97% 99%</td>
<td>$150,000 to $300,000</td>
</tr>
<tr>
<td>Traffic Signal</td>
<td>Provides higher driver awareness when a pedestrian is present Easily understandable</td>
<td>May increase crashes due to the driver expectation of a green signal indication</td>
<td>High pedestrian volume crossings Justified locations, meets signal warrants</td>
<td>NA NA</td>
<td>$100,000 to $300,000</td>
</tr>
<tr>
<td>Underpass Grade Separation</td>
<td>Removes pedestrian/vehicle conflicts</td>
<td>Location with compatible grades Very location specific Very expensive Drainage within an underpass can be problematic Underpass would require lighting</td>
<td>High pedestrian volume crossings High volume roadways High speed roads</td>
<td>NA NA</td>
<td>$800,000+</td>
</tr>
<tr>
<td>Overpass Grade Separation</td>
<td>Removes pedestrian/vehicle conflicts</td>
<td>Location with compatible grades Very location specific Very expensive Snow removal on overpass may be difficult</td>
<td>High pedestrian volume crossings High volume roadways High speed roads</td>
<td>NA NA</td>
<td>$1,200,000+</td>
</tr>
</tbody>
</table>

NA = Not Applicable or No Research Found on Effect to Yielding Rates
The specific instance in which to use each treatment option is up to engineering judgment, but recommended locations are provided as a starting basis. Additional research into which treatments to use in which situations should be studied further and would provide valuable insight to be used by agencies for consistent application of treatments. For additional information on treatment options, please see:


**Repeat Step 4. Evaluate LOS for Treatment Option(s)**

Step 4 should be repeated after deciding on a potential 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 and Chapter 6 of this report. 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 a different treatment option,
- Consider pedestrian routing to another location, and/or
- Consider High Level Treatments, if justified.
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Chapter 8

Examples

Using the information provided in Chapters 2 through 6, some examples from Minnesota are provided. The names of cities, streets, and other location specific information has been removed as these examples and results have not been approved by the jurisdictional authority.

Examples 1 through 4 include the full analysis, equations, and procedure while examples 5 through 10 include a brief synopsis of the procedure but all analysis is completed in the attached worksheets.
Example 1: Two-Lane Rural Highway Trail Crossing

Site Review
Conduct a field review and take pedestrian/vehicle counts during the peak hours.

The crossing location connects a Regional Trail. The trail crossing extends across the two-lane highway. The crossing has no medians, has pavement markings and pedestrian crossing warning signs.
Complete Field Review Worksheet.

<table>
<thead>
<tr>
<th>Location:</th>
<th>Example 1: Two-Lane Rural Highway</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>City, State:</td>
<td>Any City, Minnesota</td>
<td>Scenario:</td>
</tr>
<tr>
<td>Reviewer(s):</td>
<td></td>
<td>Agency:</td>
</tr>
<tr>
<td>Project #:</td>
<td></td>
<td>ID #:</td>
</tr>
</tbody>
</table>

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

**Uncontrolled Pedestrian Crossing**

**Data Collection Worksheet**

**Geometrics**

- **Crossing Length:** Measure the crossing distance from curb to curb.  
  - Crossing 1: 45 ft.  
  - Crossing 2: 0 ft.

- 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.

- **Median:** width of median at crossing location  
  - 0 ft.

- **Crossing Width:** effective crosswalk width  
  - 6 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: 45 mph

- **Roadway Curvature and Sight Distances:**  
  - Average walking speed: 6.2 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.

<table>
<thead>
<tr>
<th>Direction 1:</th>
<th>Stopping Sight Distance (SSD)</th>
<th>360 ft.</th>
<th>provided?</th>
<th>Yes ☑ No ☐</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direction 2:</td>
<td>Stopping Sight Distance (SSD)</td>
<td>ft.</td>
<td>provided?</td>
<td>Yes ☑ No ☐</td>
</tr>
<tr>
<td>Direction 1:</td>
<td>Pedestrian Sight Distance (PedS)</td>
<td>679 ft.</td>
<td>provided?</td>
<td>Yes ☑ No ☐</td>
</tr>
<tr>
<td>Direction 2:</td>
<td>Pedestrian Sight Distance (PedS)</td>
<td>ft.</td>
<td>provided?</td>
<td>Yes ☑ No ☐</td>
</tr>
</tbody>
</table>

**Traffic and Pedestrian Data**

- **Traffic Counts:** vehicles: 8,200
- **Pedestrian Counts:** Daily
  - AM Peak Hourly: 508
  - PM Peak Hourly: 341
  - Pk 15-min: 142 Hourly: 16 Pk 15-min: 94

**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? Continental ☑

**Signs**

- Currently signed at crosswalk? Yes ☑ No ☐

- Currently signed in advance of crosswalk? Yes ☑ No ☐

**Distances**

- direction 1: 547 ft.  
  - direction 2: 458 ft.

**Enhancements**

- What enhancements are currently at the crossing location? Trail Crossing signs (text) Trail Crossing signs (text)

- dir 1: north, dir 2: south

**Adjacent Facilities**

- Distance to nearest marked crosswalk: 2,000 ft.

- What pedestrian control devices are present at the nearest adjacent marked crosswalk? Traffic signal

- Distance to nearest all-way stop, roundabout or signalized intersection: 2,000 ft.

- Could another location serve the same pedestrian crossing movement? Yes ☑ No ☐

- Could another location serve 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, parcel, intersection widths, lane lengths, shoulder widths, sign placement, and nearby origins and destinations.

Draw or insert map of location being studied

Notes:
- No curb, trail meets roadway at-grade, crossing connects a regional trail, in no passing zone
- 12’ lanes, shoulder 6 to 8’ wide
- crosswalk 6’ wide, trail 12’ wide

Sight Distance Calculations:

<table>
<thead>
<tr>
<th>where:</th>
<th>defaults:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s_p$</td>
<td>3.5</td>
</tr>
<tr>
<td>$S_o$</td>
<td>11.2</td>
</tr>
<tr>
<td>$S_u$</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Stopping sight distance (SBD), ft = $1.475s + 1.60s^2/a$

Pedestrian sight distance (PedSD), ft = $1.475(s_p + S_o)$

where: $s = \text{brake reaction time, s}$
$a = \text{deceleration rate, ft/s}^2$

Page 2 of 2
Safety Review
No pedestrian crashes at the location within last ten years. There have been three rear-end crashes at the location within the last ten years.

What does this tell us? Vehicles are stopping, but may be late in stopping. Sight distance may be impaired. Review of location indicates that pedestrians may come out quickly from tree cover.

SSD, PedSD Calculation
The Field Review Worksheet completes this calculation.

\[
SSD = d_{PRT} + d_{MT} = 1.47Vt + 1.075 \frac{V^2}{a}
\]

Where:
- \(d_{PRT}\) = driver perception – reaction distance, (ft)
- \(d_{MT}\) = braking distance (ft)
- \(V\) = design speed (mph)
- \(t\) = brake reaction time (s) [DEFAULT = 2.5 sec]
- \(a\) = deceleration rate (\(\frac{ft}{s^2}\)) [DEFAULT = 11.2 \(\frac{ft}{s^2}\)]

\[
SSD = 1.47 \times 45 \times 2.5 + 1.075 \frac{45^2}{11.2} = 359.7 \text{ ft} \approx 360 \text{ ft}
\]

Evaluation of the crossing indicates that there is sufficient stopping sight distance.

\[
PedSD = 1.47V\left(\frac{L}{S_p} + t_s\right)
\]

Where:
- \(L\) = length of crossing (ft)
- \(S_p\) = average pedestrian walking speed (\(\frac{ft}{s}\)) [DEFAULT = 3.5 \(\frac{ft}{s}\)]
- \(t_s\) = pedestrian start – up and end clearance time (s) [DEFAULT = 3.0 sec]

Actual pedestrian walking speed collected: average 6.2 ft/s

\[
PedSD = 1.47 \times 45 \times \left(\frac{45}{6.2} + 3.0\right) = 679 \text{ ft}
\]

Again, evaluation of the crossing indicates that there is sufficient pedestrian sight distance for this crossing. There is approximately 880 ft available to the south, and approximately 860 ft available to the north.
HCM Analysis

Determine inputs:

\[ V = 508 \text{ in AM, 341 in PM} \]

**Evaluation Inputs:**

<table>
<thead>
<tr>
<th>( L ) = crosswalk length (ft)</th>
<th>( S_p ) = average pedestrian walking speed (ft/s)</th>
<th>( t_s ) = pedestrian start-up and end clearance time (s)</th>
<th>( V ) = vehicular hourly volume (veh/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L = 45 )</td>
<td>( S_p = 3.5 )</td>
<td>( t_s = 3 )</td>
<td>( V = 508 )</td>
</tr>
<tr>
<td>( S_p = 6.2 )</td>
<td></td>
<td>( t_s = 3 )</td>
<td>( V = 142 )</td>
</tr>
<tr>
<td>( t_s = 3 )</td>
<td></td>
<td></td>
<td>( V_p = 0 )</td>
</tr>
<tr>
<td>( t_s = 3 )</td>
<td></td>
<td></td>
<td>( W_c = 6.0 )</td>
</tr>
<tr>
<td>( L = 45 )</td>
<td></td>
<td></td>
<td>( N = 2 )</td>
</tr>
</tbody>
</table>

**Input Table:**

<table>
<thead>
<tr>
<th>( L )</th>
<th>( S_p )</th>
<th>( t_s )</th>
<th>( V )</th>
<th>( V_p )</th>
<th>( W_c )</th>
<th>( N )</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>3.5</td>
<td>3</td>
<td>508</td>
<td>0</td>
<td>6.0</td>
<td>2</td>
</tr>
</tbody>
</table>

**AM Peak Hour**

**Step 1: Identify Two-Staged Crossings**

a. There is no median.
b. There are no curb ramps – There is no curb

**Step 2: Determine Critical Headway**

Pedestrian Platooning is **NOT** observed, so the spatial distribution of pedestrians can assumed to be 1 \( (N_p = 1, \; v_p = 0) \) and the critical headway is determined from the equation below:

Single Pedestrian:

\[
t_c = t_{c,G} = \frac{L}{S_p} + t_s
\]

\[
t_{c,G} = \frac{45}{6.2} + 3.0 = 10.3 \text{ sec}
\]

**Step 3: Estimate Probability of a delayed crossing**

Calculate the flow rate (since we have the data, using peak 15-minutes):

\[
v = \frac{V}{PHF} = \frac{508}{508} = \frac{508}{4 \times 142} = 568 \frac{veh}{hr} = 0.16 \frac{veh}{s}
\]
Calculate the probability of a delayed crossing

\[ P_b = 1 - e^{-\frac{t_c G v}{N}} \]

\[ P_d = 1 - (1 - P_b)^N \]

\[ P_b = 1 - e^{-\frac{10.3(0.16)}{2}} = 0.55 \]

\[ P_d = 1 - (1 - 0.55)^2 = 0.80 \]

**Step 4: Calculate Average Delay to Wait for Adequate Gap**

\[ d_g = \frac{1}{v} (e^{v t_c G} - v t_c G - 1) \]

\[ d_{gd} = \frac{d_g}{P_d} \]

\[ d_g = \frac{1}{0.16} \left( e^{0.16(10.3)} - 0.16(10.3) - 1 \right) = 15.4 \text{ sec} \]

\[ d_{gd} = \frac{15.4}{0.56} = 19.2 \text{ sec} \]

If there are no additional treatments at the crossing, delay = 19.2 sec. (LOS C)

Delay is acceptable. Location does have high visibility markings and signs but they are in poor condition. The roadway has a speed limit of 45 mph. Little to no yielding is likely due to the presence of the markings and signs. Considered to have no treatments. Go to Step 5 of the flowchart.

**Pedestrian Sight Distance**

Pedestrian Sight Distance is provided. Based on available data, the crossing does not need any treatments and does not have to be marked or signed.

**PM Peak Hour**

Same process as AM Peak Hour:

\[ Delay = 12.3 \text{ sec} = LOS \text{ C} \]

Analysis of the crossing indicates that the crossing is experiencing LOS C during the AM Peak Hour and LOS C in the PM Peak Hour. Pedestrian traffic is essentially equal in the AM and PM.

**Result**

Acceptable Service Level in the AM and PM
Because there is an acceptable level of service for this crossing, and the PedSD/SSD are met, no changes are recommended at this crossing. Based on the analysis, the signings and markings could be removed but since they are already in place, that can be difficult politically.

Some recommendations based on the field review.

- The crosswalk markings should be re-applied so that they are effective for traffic.
- The crosswalk markings should be re-marked to match the width of the trail, 12’ instead of the standard 6’.
- Trail crossing warning signs should be updated with the most recent version from the MN MUTCD.

How does this compare to a gap study?

**Gap Study (If Available)**

![AM Gap Study Graph](image-url)
A gap study can show how much time exists between successive vehicles. This can be used to determine if there are available gaps to cross. As can be seen by these graphs, most of the gaps are very small (0-10 sec) for both directions, meaning these are the gaps available to cross both directions of traffic.

\[
\text{Needed Gap} = \text{Crossing Time} + \text{Start/End Time} = \frac{45}{6.2} + 3 = 10.3 \text{ sec}
\]

Check of the data provided in the gap study graph indicates that there are 131 gaps available during the AM peak hour and 137 gaps available during the PM peak hour that meet the needed crossing time of 10.3 seconds. This indicates that there is approximately one acceptable gap every 30 seconds. Generally this would indicate an average wait time of around 15 seconds, close to the results from the HCM analysis.

The HCM evaluation worksheets are provided on the next pages.
Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

Crossing Location: Example 1: Two Lane Rural Highway
City, State: Any City, Minnesota
Reader(s): Agency:

Scenario: Trail Crossing, AM Peak Hour

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, does the median refuge need to meet ADA requirements (4' x 4' landing)? □ Yes □ No

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 sufficient 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)

\[ \begin{align*}
L & = 45 \\
S_p & = 6.2 \\
t_c & = 3 \\
\end{align*} \]

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

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

\[ N_p = \frac{v_p - v}{(v_p - v)(1 - e^{-v/v_c})} \]

where:
- \( N_p \): 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)

\[ \begin{align*}
v_p & = 1.06 \\
v & = 3.5 \text{ ft/s} \\
t_c & = 10.3 \\
\end{align*} \]

2. Compute spatial distribution:

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

where:
- \( N_p \): spatial distributions of pedestrians (ped)
- \( N_p \): total number of pedestrians in crossing platoon (ped)
- \( W_c \): crosswalk width (ft)

\[ \begin{align*}
N_p & = 6 \\
W_c & = 6 \\
N_p & = 1 \\
\end{align*} \]

3. Compute group critical headway:

\[ t_{g,c} = t_c + 2(N_p - 1) \]

where:
- \( t_{g,c} \): group critical headway (s)
- \( t_c \): single pedestrian critical headway (s)
- \( N_p \): spatial distributions of pedestrians (ped)

\[ \begin{align*}
t_c & = 10.3 \\
N_p & = 1 \\
t_{g,c} & = 10.3 \\
\end{align*} \]

Step 2: Determine Critical Headway

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.

\[ P_b = 1 - e^{-\frac{t_c}{v N}} \]

where:
- \( P_b \): probability of blocked lane
- \( t_c \): group critical headway (s)
- \( v \): vehicular flow rate across crossing (veh/s)
- \( N \): number of lanes crossed

\[ \begin{align*}
t_c & = 10.3 \\
v & = 0.16 \\
P_b & = 0.56 \\
N & = 2 \\
P_b & = 0.8 \\
\end{align*} \]
Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

**Step 4: Calculate Average Delay to Wait for Adequate Gap**

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d_1 = \frac{1}{v}(\rho \cdot t_{c,a} - 1/t_{c,a} \cdot 1)$</td>
<td>$d_2 = \frac{1}{v}(\rho \cdot t_{c,a} - 1/t_{c,a} \cdot 1)$</td>
</tr>
</tbody>
</table>

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

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

$$d_{el} = \frac{d_1 - d_2}{P_g}$$

where:
- $d_{el}$ = average gap delay for pedestrians who incur nonzero delay
- $P_g$ = probability of a delayed crossing

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d_1 = 15.42$</td>
<td>$d_2 = 19.22$</td>
</tr>
</tbody>
</table>

**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 marked crossings and either marked or unmarked crossings at intersections, motorist yield rates actually vary considerably.

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

**Average pedestrian delay:**

$$d_p = \sum_{i=1}^{n}(1 - 0.5)P(Y_i) + (n - \sum_{i=1}^{n}P(Y_i))d_{el}$$

where:
- $d_p$ = average pedestrian delay (s)
- $i$ = crossing event (1 to $n$)
- $h$ = average headway for each through lane = $N/N_i$
- $P(Y_i)$ = probability that motorists yield to pedestrian on crossing event $i$
- $n_i = \text{Int}([d_{el}/h]_0)$, average number of crossing events before an adequate gap is available
- $j = \text{crossing event (0 to } n-1\text{)}$
- $P(Y_{ij})$ = probability that motorists yield to pedestrian on crossing event $j$

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d_1 = \ldots$</td>
<td>$d_2 = \ldots$</td>
</tr>
</tbody>
</table>

**Summary**

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

Calculations Sheet 2
### Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

**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, does the median refuge need to meet ADA requirements (4’ x 4’ landing)?  
- [ ] Yes  
- [ ] No

**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 sufficient for a safe crossing.

For a single pedestrian:

\[ t_c = \frac{L}{S_p} + t_e \]

- **L** = crosswalk length (ft)
- **S_p** = average pedestrian walking speed (ft/s)
- **t_e** = pedestrian start-up and end clearance time (s)

<table>
<thead>
<tr>
<th>Crossing</th>
<th>( L )</th>
<th>( S_p )</th>
<th>( t_e )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>45</td>
<td>6.2</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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

\[ N_p = \frac{\mu_p e^{-\lambda_1 \mu_p} + \mu_p e^{-\lambda_2 \mu_p}}{\lambda_1 + \lambda_2} \]

- \( \lambda_1 \) = pedestrian flow rate (ped/s)
- \( \mu_p \) = vehicular flow rate across crossing (veh/s)
- \( t_c \) = single pedestrian critical headway (s)

2. Compute spatial distribution:

\[ N_p = \int \left[ \frac{8.0(N_p - 1)}{W_c} \right] + 1 \]

- \( W_c \) = crosswalk width (ft)
- \( 8.0 \) = default clear width used by a single pedestrian to avoid interference with other pedestrians (ft)

3. Compute group critical headway:

\[ t_{c,g} = t_c + 2(N_p - 1) \]

**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.

\[ P_b = 1 - e^{-t_{c,g}/N} \]

- \( P_b \) = probability of blocked lane
- \( P_d \) = probability of delayed crossing
- \( N \) = number of lanes crossed
- \( t_{c,g} \) = group critical headway (s)
- \( \mu_p \) = vehicular flow rate across crossing (veh/s)

**Calculations Sheet 1**
### 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.

\[ d_{a} = \frac{1}{V} \left( e^{\frac{u}{l_{c}}} - 1 \right) \]

where:
- \( d_{a} \) = average pedestrian delay (s)
- \( l_{c} \) = group critical headway (s)
- \( u \) = vehicular flow rate across crossing (veh/s)

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

\[ d_{n} = \frac{d_{a}}{P_{d}} \]

where:
- \( d_{n} \) = average pedestrian delay for pedestrians who incur nonzero delay
- \( P_{d} \) = probability of a delayed crossing

#### 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 NCDOT at all marked crossings and either marked or unmarked crossings at intersections, motorist yield rates actually vary considerably.

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

Average pedestrian delay

\[ d_{p} = \sum_{i=1}^{n} \left( l_{i} \cdot 0.5 \right) \cdot P(Y_{i}) + \left( P_{d} \cdot \sum_{i=1}^{n} \cdot P(Y_{i}) \right) d_{n} \]

where:
- \( d_{p} \) = average pedestrian delay (s)
- \( l_{i} \) = crossing event \( i \) (1 to \( n \))
- \( h_{i} \) = average headway for each through lane = \( N_{i} \cdot h \)
- \( P(Y_{i}) \) = probability that motorists yield to pedestrian on crossing event \( i \)

\( n_{i} = \lfloor (d_{n}/h) \rfloor \), average number of crossing events before an adequate gap is available

\( j = \) crossing event \( j \) (0 to \( n \))

\( P(Y_{j}) \) = probability that motorists yield to pedestrian on crossing event \( j \)

### Summary

<table>
<thead>
<tr>
<th>LOS</th>
<th>Average</th>
<th>Delay Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0-5</td>
<td>Usually no conflicting traffic</td>
</tr>
<tr>
<td>B</td>
<td>5-10</td>
<td>Occasionally some delay due to conflicting traffic</td>
</tr>
<tr>
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<td>&gt;45</td>
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</tr>
</tbody>
</table>

Developed by Bolton Monk, Inc. for the Local Road Research Board.
Example 2: Two-Lane Urban Street Crossing

Site Review
Conduct a field review and take pedestrian/vehicle counts during the peak hours.

The crossing is currently unmarked and there is a bus stop at the crossing location.
### Complete Field Review Worksheet

**Uncontrolled Pedestrian Crossing Data Collection Worksheet**

**Location:** Two Lane Urban Street  
**City, State:** Any City, Minnesota  
**Reviewer(s):**  
**Date:** Saturday, Noon  
**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

<table>
<thead>
<tr>
<th>Crossing Length: Measure the crossing distance from curb to curb.</th>
<th>Crossing 1: 66 ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>Crossing 2: 0 ft.</td>
</tr>
<tr>
<td>Median: width of median at crossing location</td>
<td>0 ft.</td>
</tr>
<tr>
<td><strong>Crossing Width:</strong> effective crosswalk width</td>
<td>8 ft.</td>
</tr>
<tr>
<td>Raised Median Available?</td>
<td>Yes □  No □</td>
</tr>
<tr>
<td>ADA Compliant Median Available (minimum 4' x 4' landing)?</td>
<td>Yes □  No □</td>
</tr>
<tr>
<td>Curb Ramps Available?</td>
<td>Yes □  No □</td>
</tr>
<tr>
<td>ADA Compliant Curb Ramp Available (width, grades, truncated domes)?</td>
<td>Yes □  No □</td>
</tr>
</tbody>
</table>
| **Speed:**  
| Postcard or 85th percentile speed | 30 mph |
| **Roadway Curvature and Sight Distances:**  
| Average walking speed | 3.5 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)  
197 ft. provided? Yes □  No □

**Direction 2:** Stopping Sight Distance (SSD)  
ft. provided? □ Yes  □ No

**Direction 1:** Pedestrian Sight Distance (PedSSD)  
964 ft. provided? □ Yes  □ No

**Direction 2:** Pedestrian Sight Distance (PedSSD)  
ft. provided? □ Yes  □ No

#### Traffic and Pedestrian Data

<table>
<thead>
<tr>
<th>Traffic Counts</th>
<th>Daily 10,400</th>
<th>Pedestrian Counts: Daily 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM Peak Hourly</td>
<td>Pk 15-min 690</td>
<td>Hourly Pk 15-min 3</td>
</tr>
<tr>
<td>PM Peak Hourly</td>
<td>Pk 15-min 219</td>
<td>Hourly Pk 15-min 3</td>
</tr>
</tbody>
</table>

#### 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 □

#### Enhancements:

- Distance to nearest marked crosswalk?  
  515 ft.

- What enhancements are currently at the crossing location?  

#### Additional Site Characteristics

- Distance to nearest all-way stop, roundabout or signalized intersection  
  515 ft.

- Could another location serve the same pedestrian crossing movement?  
  Yes □  No □

- Could another location serve 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 origins and destinations.

Draw or insert map of location being studied

Notes: Crossing location unmarked, no effective curb ramps, lighting on north corner
no pedestrian crossing signing

Sight Distance Calculations:

Stopping sight distance (SSD), ft = 1.475t + 1.075s^2/a
Pedestrian sight distance (PedSD), ft = 1.475(L / S_p + t)

where:
- \( t \) = brake reaction time, s
- \( a \) = deceleration rate, ft/s^2
- \( S_p \) = average pedestrian walking speed, ft/s
- \( L \) = length of crossing, ft
- \( S \) = design speed, mph

defaults:
- \( t = 2.5 \) s
- \( a = 11.2 \) ft/s^2
- \( S_p = 3.5 \) ft/s
- \( t = 3.0 \) s

Page 2 of 2
**Safety Review**

No pedestrian crashes at the location within last ten years. Two run off road crashes near the intersection in past ten years.

No safety issues indicated by crash data.

**SSD, PedSD Calculation**

\[
SSD = d_{PRT} + d_{MT} = 1.47Vt + 1.075 \frac{V^2}{a}
\]

Where:
- \(d_{PRT}\) = driver perception – reaction distance, (ft)
- \(d_{MT}\) = braking distance (ft)
- \(V\) = design speed (mph)
- \(t\) = brake reaction time (s) [**DEFAULT = 2.5 sec**]
- \(a\) = deceleration rate (\(\frac{ft}{s^2}\)) [**DEFAULT = 11.2 \frac{ft}{s^2}\)]

\[
SSD = 1.47 * 30 * 2.5 + 1.075 \frac{30^2}{11.2} = 197 \text{ ft}
\]

Looking at a map of the crossing, there is sufficient stopping sight distance for this crossing.

\[
PedSD = 1.47V\left(\frac{L}{S_p} + t_s\right)
\]

Where:
- \(L\) = length of crossing (ft)
- \(S_p\) = average pedestrian walking speed (\(\frac{ft}{s}\)) [**DEFAULT = 3.5 \frac{ft}{s}\)]
- \(t_s\) = pedestrian start – up and clearance time (s) [**DEFAULT = 3.0 sec**]

\[
PedSD = 1.47 * 30 * \left(\frac{66}{3.5} + 3\right) = 964 \text{ ft}
\]

Looking at a map of the crossing, there is not sufficient pedestrian sight distance. There is approximately 400 to 500 ft ft available to the east, and approximately 1,200 to 1,400 ft available to the northwest.
HCM Analysis

Determine inputs:

**Evaluation Inputs:**

<table>
<thead>
<tr>
<th>L = crosswalk length (ft)</th>
<th>L = 66</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_p$ = average pedestrian walking speed (ft/s)</td>
<td>$S_p$ = 3.5</td>
</tr>
<tr>
<td>$t_s$ = pedestrian start-up and end clearance time (s)</td>
<td>$t_s$ = 3</td>
</tr>
<tr>
<td>V = vehicular hourly volume (veh/hr)</td>
<td>V = 690</td>
</tr>
<tr>
<td>$v_p$ = pedestrian flow rate (ped/s)</td>
<td>$v_p$ = 0*</td>
</tr>
<tr>
<td>$W_c$ = crosswalk width (ft)</td>
<td>$W_c$ = 8</td>
</tr>
<tr>
<td>N = number of lanes crossed</td>
<td>N = INT(L/11)</td>
</tr>
</tbody>
</table>

**Input Table:**

<table>
<thead>
<tr>
<th>defaults:</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L$ =</td>
<td>66</td>
</tr>
<tr>
<td>$S_p$ =</td>
<td>3.5</td>
</tr>
<tr>
<td>$t_s$ =</td>
<td>3</td>
</tr>
<tr>
<td>V =</td>
<td>690</td>
</tr>
<tr>
<td>$v_p$ =</td>
<td>0</td>
</tr>
<tr>
<td>$W_c$ =</td>
<td>8</td>
</tr>
<tr>
<td>N =</td>
<td>2</td>
</tr>
</tbody>
</table>

Weekend Midday Peak Hour

**Step 1: Identify Two-Staged Crossings**

There is no median at the crosswalk. This is a one-stage crossing

**Step 2: Determine Critical Headway**

Pedestrian Platooning is **NOT** observed, so the spatial distribution of pedestrians can assumed to be 1 ($N_p=1$, $v_p = 0$) and the critical headway is determined from the equation below:

Single Pedestrian:

$$t_c = t_{c,G} = \frac{L}{S_p} + t_s$$

$$t_{c,G} = \frac{66}{3.5} + 3.0 = 21.9\text{ sec}$$

**Step 3: Estimate Probability of a delayed crossing**

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

$$v = \frac{V}{PHF} = \frac{690}{690} = 876\text{veh/hr} = 0.24\text{veh/s}$$

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

$$P_b = 1 - e^{-21.9(0.24)} = 0.93$$
\[ P_d = 1 - (1 - 0.93)^2 = 0.99 \]

**Step 4: Calculate Average Delay to Wait for Adequate Gap**

\[ d_g = \frac{1}{v}(e^{vt_{cG}} - vt_{cG} - 1) \]

\[ d_{gd} = \frac{d_g}{P_d} \]

\[ d_g = \frac{1}{0.24}(e^{0.24(21.9)} - 0.24(21.9) - 1) = 765 \text{ sec} \]

\[ d_{gd} = \frac{764}{0.99} = 769 \text{ sec} \]

There is no reduction in delay due to yielding vehicles

\[ d_p = d_{gd} = 769 \text{ sec} = \text{LOS F} \]

Analysis of the crossing indicates that the crossing is experiencing LOS F the Midday Peak Hour.

Result: Unacceptable Service Level. **Skip to Step 6 of the evaluation flowchart.**
Uncontrolled Pedestrian Crossing Level of Service
Evaluation Worksheet

Crossing Location: Example 2: Two Lane Urban Street
Date: Any City, Minnesota
Scenario: Saturday, noon
Agency:

Reviewer(s):

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, does the median refuge need to meet ADA requirements (4' x 4' landing)? [ ] Yes [ ] No

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 sufficient 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)

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

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

\[ N_p = \frac{V_p}{(W_c + V) + \frac{V_p}{S_p \cdot W_p}} \]

where:
- \( N_p \) = total number of pedestrians in crossing platoon (ped)
- \( V_p \) = pedestrian flow rate (ped/s)
- \( W_p \) = vehicular flow rate across crossing (veh/s)
- \( t_s \) = single pedestrian critical headway (s)

2. Compute spatial distribution:

\[ N_p = \left\lfloor \frac{8.0(N_c - 1)}{W_c} \right\rfloor + 1 \]

where:
- \( N_p \) = spatial distributions of pedestrians (ped)
- \( N_c \) = total number of pedestrians in crossing platoon (ped)
- \( W_c \) = crosswalk width (ft)

3. Compute group critical headway:

\[ t_{c,G} = t_s + 2(N_p - 1) \]

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

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.

\[ P_b = 1 - e^{-t_{c,G}/V} \]

where:
- \( P_b \) = probability of blocked lane
- \( t_{c,G} \) = group critical headway (s)
- \( V \) = vehicular flow rate across crossing (veh/s)

\[ P_d = 1 - (1 - P_b)^N \]

where:
- \( P_d \) = probability of delayed crossing
- \( N \) = number of lanes crossed

Calculations Sheet 1

Developed by Bolton-Mens, Inc.
for the Local Road Research Board.

HCM Evaluation Worksheet
### 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.

\[
d_{p} = \frac{1}{u} (e^{\frac{u}{d_{g} \cdot t_{cG} \cdot 1}} - 1)
\]

where:
- \(d_{p}\) = average pedestrian delay (s)
- \(t_{cG}\) = group critical headway (s)
- \(d_{g}\) = average pedestrian gap delay (s)
- \(u\) = vehicular flow rate across crossing (veh/s)

**Crossing 1**

\[t_{cG} = 21.86, \quad d_{p} = 764.61\]

**Crossing 2**

\[t_{cG} = 24, \quad d_{p} = \text{Not Provided}\]

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

\[
d_{pel} = \frac{d_{p}}{P_{d}}
\]

where:
- \(d_{pel}\) = average gap delay for pedestrians who incur none zero delay
- \(P_{d}\) = probability of a delayed crossing

**Crossing 1**

\[d_{pel} = 764.61, \quad P_{d} = 0.995\]

**Crossing 2**

\[d_{pel} = 766.66, \quad P_{d} = \text{Not Provided}\]

**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 marked crossings and either marked or unmarked crossings at intersections, motorist yield rates actually vary considerably.

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

Average pedestrian delay

\[
d_{p} = \sum_{i=1}^{n} (\bar{h} - 0.5)P(Y_{i}) + (P_{d} \cdot \sum_{i=1}^{n} P(Y_{i}))d_{pel}
\]

where:
- \(d_{p}\) = average pedestrian delay (s)
- \(\bar{h}\) = average headway for each through lane = N/l
- \(P(Y_{i})\) = probability that motorists yield to pedestrian on crossing event \(i\)
- \(P_{d}\) = average number of crossing events before an adequate gap is available

1. One-Lane Crossing

\[P(Y_{i}) = P_{d}M_{y}(1-M_{y})^{i-1}\]

2. Two-Lane Crossing

\[P(Y_{i}) = 2P_{d}(1-P_{d})M_{y}(1+2M_{y})^{i-1}\]

3. Three-Lane Crossing

\[P(Y_{i}) = (P_{d} \cdot \sum_{i=1}^{n} P(Y_{i})) \cdot \frac{P_{d}(1-P_{d})}{P_{d} + P_{d}(1-P_{d})M_{y} + P_{d}(1-P_{d})M_{y}^{2}} + (1-P_{d})M_{y}^{2}
\]

4. Four-Lane Crossing

\[P(Y_{i}) = (P_{d} \cdot \sum_{i=1}^{n} P(Y_{i})) \cdot \frac{P_{d}(1-P_{d})}{P_{d} + P_{d}(1-P_{d})M_{y}^{2} + 2P_{d}(1-P_{d})M_{y}^{3}} + (1-P_{d})M_{y}^{2} + 4P_{d}(1-P_{d})M_{y}^{3} + 6P_{d}(1-P_{d})M_{y}^{4} + 4P_{d}(1-P_{d})M_{y}^{5}
\]

**Summary**

<table>
<thead>
<tr>
<th>Average Delay Reduction (s)</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>768.7</td>
<td>F</td>
</tr>
</tbody>
</table>

**Step 6: Calculate Average Pedestrian Delay & Determine LOS**

<table>
<thead>
<tr>
<th>LOS</th>
<th>Control Delay (sec/ped)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.5</td>
<td>Usually no conflicting traffic</td>
</tr>
<tr>
<td>B</td>
<td>5-10</td>
<td>Occasionally some delay due to conflicting traffic</td>
</tr>
<tr>
<td>C</td>
<td>10-20</td>
<td>Delay noticeable to pedestrians, but not inconveniencing</td>
</tr>
<tr>
<td>D</td>
<td>20-30</td>
<td>Delay noticeable/irritating, increased chance of risk-taking</td>
</tr>
<tr>
<td>E</td>
<td>30-45</td>
<td>Delay approaches tolerance level, risk-taking likely</td>
</tr>
<tr>
<td>F</td>
<td>&gt;45</td>
<td>Delay exceeds tolerance level, high chance of risk-taking</td>
</tr>
</tbody>
</table>

Developed by Bolton Merik, Inc. for the Local Road Research Board.

HCM Evaluation Worksheet
Review Origins and Destination, Alternate Routes

Origins and Destinations

The crossing is at a location that connects restaurants to a regional recreational park. Crossing also connects multiple restaurants and bus stops.

Alternative Routes

There may be an alternative route to use the signalized intersection based on where pedestrians are in the park, but may not be an alternative for some.

Calculate how much time it would take for a pedestrian to walk to the nearest adjacent marked crossing, cross the roadway, and return to the location where they started.

This total amount of time is compared to the average pedestrian delay (average measured wait time).

Distance to nearest marked crossing = 505 ft to the northwest (Signalized intersection)

Walking Time to Signalized Intersection:

\[
\frac{505 \text{ ft}}{3.5 \text{ ft/s}} = 144 \text{ sec}
\]

Wait Time and Crossing Time at Intersection:
Assume average wait time of 30 sec.

\[
30 + \frac{65 \text{ ft}}{3.5 \text{ ft/s}} = 49 \text{ sec}
\]

Walking Time back to Original Location:

\[
\frac{505 \text{ ft}}{3.5 \text{ ft/s}} = 144 \text{ sec}
\]

Total Time:

\[
144 + 49 + 144 = 337 \text{ sec}
\]

Average Measured Wait Time (Pedestrian Delay) without a crossing

769 sec with current crossing (from HCM Analysis)

The alternative route time is considerably less than the average wait time at the current crossing. Pedestrians should be encouraged to use the crossing at the signalized intersection to cross the roadway. However, there is a direct origin-destination connection between the southeast end of the Park and the shopping center/restaurants.
Result: There could be an acceptable alternative route at the signalized intersection, but there is a direct origin-destination connection at the crossing.

Access Spacing and Functional Classification
The crossing is not located in a signalized corridor or grade-separated facility.

Speed and Pedestrian Use
The speed limit is 30 mph, but the city population is less than 10,000.

There were 3 pedestrians during the peak hour.

Result: **Go to Step 10 of the evaluation flowchart.**

School Crossing
This is not a school crossing, go to Step 9.

FHWA Safety Guidance
Three lanes, speed limit = 30 mph, ADT = 10,400. Results in C designation. **Go to Step 11, Traffic Calming Treatments.**

Traffic Calming Treatment Options
Treatment Options should consider the roadway environment.
  a. Urban section (curb)
  b. Two-Lane Undivided with left turn lanes
  c. Speed Limit = 30 mph
  d. Origin-Destination connection
  e. Clear motorist sight lines (SSD is met)
  f. Pedestrian sight lines impacted (PedSD not met)
  g. Crossing is not currently signed and marked
  h. No pedestrian crashes reported in past 10 years

Review the Traffic Calming Treatment options that are available.
  a. Center Median with Refuge Island – possible, remove shoulder, traffic to curb
  b. Raised Crossing – possible, but difficult with the curve
  c. Lighting – already implemented
  d. Pavement Striping – already two-lane section
  e. Curb Bump-Out/Extensions – possible
  f. Channelized Turn Lanes – not recommended

Due to the low pedestrian volume collected at the site, the biggest need is to increase the pedestrian sight distance, but that would require extensive reconstruction and/or property acquisition. There is an alternative route at the signal that is recommended. Pedestrian walkway enhancements to get people to use that crossing location is recommended.
Based on the traffic calming treatment options, the curb bump-outs would likely be the easiest to implement, would not obstruct the travel lanes, and would reduce the crossing length. Uncontrolled crossing treatments are not recommended due to the low pedestrian count. No other changes should be considered at the existing crossing besides advanced warning signs to alert motorists of the chance of pedestrians crossing.

Curb bump-outs plus lane narrowing and moving the crossing further north could reduce the crossing length to 38’ (2-11’ lanes, 12’ turn lane, 2’ curb reaction).

**Repeat Step 4**

**Determine inputs:**

<table>
<thead>
<tr>
<th>Evaluation Inputs:</th>
<th>defaults:</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td>L = crosswalk length (ft)</td>
<td></td>
<td>L = 38</td>
</tr>
<tr>
<td>$S_p$ = average pedestrian walking speed (ft/s)</td>
<td>$S_p$ = 3.5</td>
<td>$S_p$ = 3.5</td>
</tr>
<tr>
<td>$t_s$ = pedestrian start-up and end clearance time (s)</td>
<td>$t_s$ = 3.0</td>
<td>$t_s$ = 3</td>
</tr>
<tr>
<td>$V$ = vehicular hourly volume (veh/hr)</td>
<td>$V$ = 690</td>
<td>$V$ = 219</td>
</tr>
<tr>
<td>Peak 15-minute volume (veh)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$v_p$ = pedestrian flow rate (ped/s)</td>
<td>$v_p$ = 0*</td>
<td>$v_p$ = 0</td>
</tr>
<tr>
<td>$W_c$ = crosswalk width (ft)</td>
<td>$W_c$ = 8.0</td>
<td>$W_c$ = 8</td>
</tr>
<tr>
<td>N = number of through lanes crossed</td>
<td></td>
<td>N = 2</td>
</tr>
</tbody>
</table>

**Weekend Midday Peak Hour**

**Step 1: Identify Two-Staged Crossings**

There is no median at the crosswalk. This is a one-stage crossing

**Step 2: Determine Critical Headway**

Pedestrian Platooning is **NOT** observed, so the spatial distribution of pedestrians can assumed to be 1 ($N_p$=1, $v_p$ = 0) and the critical headway is determined from the equation below:

Single Pedestrian:

\[
t_c = t_{c,G} = \frac{L}{S_p} + t_s
\]

\[
t_{c,G} = \frac{38}{3.5} + 3.0 = 13.9 \text{ sec}
\]

**Step 3: Estimate Probability of a delayed crossing**
\[ P_b = 1 - e^{-\frac{t_{c,G}v}{N}} \]
\[ P_d = 1 - (1 - P_b)^N \]

\[ v = \frac{V}{PHF} = \frac{690}{\frac{690}{4 \times 219}} = 876 \text{ veh/hr} = 0.24 \text{ veh/s} \]

\[ P_b = 1 - e^{-\frac{13.9(0.24)}{2}} = 0.81 \]
\[ P_d = 1 - (1 - 0.81)^2 = 0.96 \]

Step 4: Calculate Average Delay to Wait for Adequate Gap

\[ d_g = \frac{1}{v} (e^{vt_{c,G}} - vt_{c,G} - 1) \]
\[ d_{gd} = \frac{d_g}{P_d} \]

\[ d_g = \frac{1}{0.24} (e^{0.24(13.9)} - 0.24(13.9) - 1) = 98 \text{ sec} \]
\[ d_{gd} = \frac{98}{0.96} = 102 \text{ sec} \]

There is no reduction in delay due to yielding vehicles

\[ d_p = d_{gd} = 102 \text{ sec} = \text{LOS F} \]

Analysis of the crossing with the curb bump-outs could reduce the crossing delay by 667 seconds or by 85%. The curb bump-outs would also increase the visibility of any pedestrian to oncoming vehicles.

Result

Still unacceptable Service Level. Could consider do nothing, just add the curb bump-outs, or consider appropriate high level treatments. Pedestrian count too low for high level treatments.

Recommendation: Consider curb bump-outs or do nothing.
### Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

**Crossing Location:** Example 2: Two Lane Urban Street  
**Date:** Any City, Minnesota  
**Scenario:** Saturday, noon, Curb Bump-Outs  
**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, does the median refuge need to meet ADA requirements (4' x 4' landing)?  
- [ ] Yes  
- [ ] No

**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 sufficient for a safe crossing:**

For a single pedestrian:

\[ t_c = \frac{L}{S_p} + t_e \]

- **crossing 1**
  - \( L = 38 \) ft
  - \( S_p = 3.5 \) ft/s
  - \( t_e = 3.9 \) sec

- **crossing 2**
  - \( L = \)  
  - \( S_p = \)  
  - \( t_e = \)

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

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

\[ N_p = \frac{U_p e^{-\frac{L}{U_p}} + U_v e^{-\frac{L}{U_v}}}{(1 - e^{-\frac{L}{U_p}})(1 - e^{-\frac{L}{U_v}})} \]

- \( N_p = \) total number of pedestrians in crossing platoon (ped)
- \( U_p = \) pedestrian flow rate (ped/s)
- \( U_v = \) vehicular flow rate across crossing (veh/s)
- \( t_e = \) single pedestrian critical headway (s)

- **crossing 1**
  - \( U_p = 0.24 \) ped/s
  - \( N_p = 13.9 \)

- **crossing 2**
  - \( U_p = \)  
  - \( N_p = \)

2. Compute spatial distribution:

\[ N_p = \text{Int}[\frac{8.0(N_p-1)}{W_c}] + 1 \]

- \( N_p = \) spatial distributions of pedestrians (ped)
- \( N_p = \) 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)

- **crossing 1**
  - \( N_p = 8 \)
  - \( W_c = 13.9 \) ft

- **crossing 2**
  - \( N_p = \)  
  - \( W_c = \)

3. Compute group critical headway:

\[ t_g = t_e + 2(N_p-1) \]

\[ N_p = \] spatial distributions of pedestrians (ped)

- **crossing 1**
  - \( N_p = 13.9 \)
  - \( t_g = \)

- **crossing 2**
  - \( N_p = \)  
  - \( t_g = \)

#### 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.**

\[ P_b = 1 - e^{-0.5U_p/2} \]

\[ P_d = 1 - (1-P_b)^N \]

- \( P_b = \) probability of blocked lane
- \( P_d = \) probability of delayed crossing
- \( N = \) number of lanes crossed
- \( t_g = \) group critical headway (s)

- **crossing 1**
  - \( t_g = 13.9 \) sec
  - \( U_p = 0.24 \) ped/s
  - \( P_b = 0.81 \)
  - \( N = 2 \)
  - \( P_d = 0.96 \)

- **crossing 2**
  - \( t_g = \)  
  - \( U_p = \)  
  - \( P_b = \)
  - \( N = \)  
  - \( P_d = \)

__Calculations Sheet 1__

---

*Developed by Bolton Mall, Inc. for the Local Road Research Board.*

*HCM Evaluation Worksheet*
**Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet**

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

\[
d_e = \frac{1}{v} \left( e^{v t_g} - 1 \right) t_g \quad \text{where:} \quad d_e = \text{average pedestrian gap delay (s)}
\]

\[
t_g = \frac{13.86}{0.24} = 57.75
\]

\[
v = \frac{97.88}{0.24} = 408 \quad \text{veh/s}
\]

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

\[
d_{d1} = \frac{d_e}{P_d}
\]

\[
13.86 = \frac{97.88}{0.564} = 173.07
\]

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 marked crossings and either marked or unmarked crossings at intersections, motorist yield rates actually vary considerably.

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

Average pedestrian delay

\[
d_e = \sum_{i=1}^{n} F(i) \left( \frac{1}{i} \right) P(Y_i) M_i + (P_d - \sum_{i=1}^{n} F(i) P(Y_i) M_i) d_{d1}
\]

\[
h_i = \text{average headway for each through lane} = \frac{N}{i}
\]

\[
P(Y_i) = \text{probability that motorists yield to pedestrian on crossing event } i
\]

\[
F(i) = \text{number of crossing events before an adequate gap is available}
\]

\[
1. \text{One-Lane Crossing}
\]

\[
P(Y_i) = P_d M_i (1 - M_j)^{i-1}
\]

\[
M_j = \text{motorist yield rate (decimal)}
\]

\[
2. \text{Two-Lane Crossing}
\]

\[
P(Y_i) = 2P_d (1- P_d) M_j + 1P_d^2 M_j^2
\]

\[
P(Y_i) = \frac{P_d}{1 - \sum_{i=1}^{n} F(i) P(Y_i) M_i}
\]

\[
M_j = \text{motorist yield rate (decimal)}
\]

\[
3. \text{Three-Lane Crossing}
\]

\[
P(Y_i) = \left( \frac{P_d - \sum_{i=1}^{n} F(i) P(Y_i) M_i}{P_d} \right) M_j^3 + \frac{3P_d^2 (1- P_d) M_j^2}{P_d} + \frac{3P_d^3 (1- P_d)^2 M_j}{P_d} + \frac{4P_d^4 (1- P_d)^3 M_j}{P_d}
\]

\[
P(Y_i) = \frac{P_d}{1 - \sum_{i=1}^{n} F(i) P(Y_i) M_i}
\]

\[
4. \text{Four-Lane Crossing}
\]

\[
P(Y_i) = \left( \frac{P_d - \sum_{i=1}^{n} F(i) P(Y_i) M_i}{P_d} \right) M_j^4 + \frac{4P_d^2 (1- P_d) M_j^3}{P_d} + \frac{6P_d^3 (1- P_d)^2 M_j^2}{P_d} + \frac{4P_d^4 (1- P_d)^3 M_j}{P_d}
\]

\[
P(Y_i) = \frac{P_d}{1 - \sum_{i=1}^{n} F(i) P(Y_i) M_i}
\]

**Summary**

<table>
<thead>
<tr>
<th>Average</th>
<th>101.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
<td>F</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LOS</th>
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<th>Comments</th>
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<td>30-40</td>
<td>Delay approaches tolerance level, risk-taking likely</td>
</tr>
<tr>
<td>F</td>
<td>45+</td>
<td>Delay exceeds tolerance level, high chance of risk-taking</td>
</tr>
</tbody>
</table>

[Developed by Bolton Merk, Inc. for the Local Road Research Board., HCM Evaluation Worksheet]
Example 3: Four-Lane Divided Urban Street Crossing

Site Review
Conduct a field review and take pedestrian/vehicle counts during the peak hours.

The crossing location is currently marked and signed. There is a median along the street but the median does not extend through the crossing location. There are two senior living facilities, a community/recreational center, and bus stops within walking distance of the crossing.
### Uncontrolled Pedestrian Crossing
#### Data Collection Worksheet

**Location:** Example 3: Four-Lane Divided Street  
**Date:**  
**City, State:** Any City, Minnesota  
**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.  
  - Crossing 1: 112 ft.  
  - Crossing 2: ft.  
  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.

- **Median:** width of median at crossing location
- **Crossing Width:** effective crosswalk width: 6 ft.

#### ADA availability

- **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

- **Average walking speed:** 4.8 ft/s
- **posted or 85th percentile speed:** 35 mph
- **Equations to calculate the following are located on the next page.**

#### Roadway Curvature and Sight Distances

- **Is the crossing location within a horizontal or vertical curve?** ☑ Yes ☐ No
- **Direction 1:** Stopping Sight Distance (SSD): 246 ft. provided? ☑ Yes ☐ No
- **Direction 2:** Stopping Sight Distance (SSD): ft. provided? ☑ Yes ☐ No
- **Direction 1:** Pedestrian Sight Distance (PedSSD): 1355 ft. provided? ☑ Yes ☐ No
- **Direction 2:** Pedestrian Sight Distance (PedSSD): ft. provided? ☑ Yes ☐ No

#### Traffic and Pedestrian Data

- **AM Peak:** Hourly 948 Pk 15-min 262 Hourly 6 Pk 15-min 3
- **PM Peak:** Hourly 841 Pk 15-min 227 Hourly 6 Pk 15-min 3

#### 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

- **Signing:** Currently signed at crosswalk? ☑ Yes ☐ No
  - Currently signed in advance of crosswalk? ☑ Yes ☐ No

- **Distances?** direction 1 527 ft. direction 2 478 ft.

- **Enhancements:** What enhancements are currently at the crossing location? Signs and High Visibility Markings

- **Adjacent Facilities:** Distance to nearest marked crosswalk? 905 ft.
  - What pedestrian control devices are present at the nearest adjacent marked crosswalk? Traffic signal
  - Distance to nearest all-way stop, roundabout or signalized intersection 905 ft.
  - Could another location serve the same pedestrian crossing movement? ☑ Yes ☐ No
  - Could another location serve the movement more effectively? ☑ Yes ☐ No

---

Page 1 of 2
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 origins and destinations.

**Notes:**
- Many O-D connections, ped crossings signs present and in good condition.
- Curb ramps have recently been updated.

**Sight Distance Calculations:**

Stopping sight distance (SSD), $ft = 1.475x + 1.075x^2$

Pedestrian sight distance (PedSD), $ft = 1.425x + S_v$

where: $x = \text{distance in feet}$

where:
- $t = \text{brake reaction time, s}$ (default: 2.5)
- $a = \text{deceleration rate, ft/s}^2$ (default: 11.2)
- $S_v = \text{average pedestrian walking speed, ft/s}$ (default: 3.5)
- $t_s = \text{pedestrian start-up and end clearance time, s}$ (default: 3.0)

$L = \text{length of crossing, ft}$
Safety Review
There were two pedestrian crashes at the location within the last ten years (2004 & 2009). The 2004 crash resulted in a pedestrian fatality. There have been a total of 14 crashes at this location over the last ten years. Most having to do with turning vehicles. Many turning movements and lanes to keep track of in addition to the pedestrians.

SSD, PedSD Calculation

\[ SSD = d_{PRT} + d_{MT} = 1.47Vt + 1.075 \frac{V^2}{a} \]

Where:
- \( d_{PRT} \) = driver perception – reaction distance, (ft)
- \( d_{MT} \) = braking distance (ft)
- \( V \) = design speed (mph)
- \( t \) = brake reaction time (s) [DEFAULT = 2.5 sec]
- \( a \) = deceleration rate (\( \frac{ft}{s^2} \)) [DEFAULT = 11.2 \( \frac{ft}{s^2} \)]

\[ SSD = 1.47 \times 35 \times 2.5 + 1.075 \times \frac{35^2}{11.2} = 246.2 \text{ ft} \approx 246 \text{ ft} \]

Looking at a map of the crossing, there is sufficient stopping sight distance for this crossing.

\[ PedSD = 1.47V\left(\frac{L}{S_p} + t_s\right) \]

Where:
- \( L \) = length of crossing (ft)
- \( S_p \) = average pedestrian walking speed (ft/s) [DEFAULT = 3.5 ft/s]
- \( t_s \) = pedestrian start – up and clearance time (s) [DEFAULT = 3.0 sec]

\[ PedSD = 1.47 \times 35 \times \left(\frac{112}{4.8} + 3\right) = 1,355 \text{ ft} \]

Again, looking at a map of the crossing, there is not sufficient pedestrian sight distance. There is approximately 1,000 to 1,200 ft available to the north, and approximately 1,400 to 1,600 ft available to the south.
HCM Analysis

Determine inputs:

\[ V = 948 \text{ in AM peak hour, 841 in PM peak hour} \]

**Evaluation Inputs:**

<table>
<thead>
<tr>
<th></th>
<th>defaults:</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td>L = crosswalk length (ft)</td>
<td></td>
<td>L = 112</td>
</tr>
<tr>
<td>( S_p ) = average pedestrian walking speed (ft/s)</td>
<td>3.5</td>
<td>( S_p ) = 4.8</td>
</tr>
<tr>
<td>( t_s ) = pedestrian start-up and end clearance time (s)</td>
<td>3.0</td>
<td>( t_s ) = 3</td>
</tr>
<tr>
<td>( V ) = vehicular hourly volume (veh/hr)</td>
<td></td>
<td>( V ) = 948</td>
</tr>
<tr>
<td>Peak 15-minute volume (veh)</td>
<td></td>
<td>( V ) = 262</td>
</tr>
<tr>
<td>( v_p ) = pedestrian flow rate (ped/s)</td>
<td>0*</td>
<td>( v_p ) = 0</td>
</tr>
<tr>
<td>( W_c ) = crosswalk width (ft)</td>
<td>8.0</td>
<td>( W_c ) = 6</td>
</tr>
<tr>
<td>N = number of through lanes crossed</td>
<td>( \text{INT}(L/11) )</td>
<td>N = 4</td>
</tr>
</tbody>
</table>

**AM Peak Hour**

*Step 1: Identify Two-Staged Crossings*

There is a median, but it does not extend to the crossing location. This is a one-stage crossing.

*Step 2: Determine Critical Headway*

Pedestrian Platooning is **NOT** observed, so the spatial distribution of pedestrians can assumed to be 1 \((N_p=1, v_p = 0)\) and the critical headway is determined from the equation below:

Single Pedestrian:

\[
 t_c = t_{c,G} = \frac{L}{S_p} + t_s
\]

\[
 t_{c,G} = \frac{112}{4.8} + 3.0 = 26.3 \text{ sec}
\]

*Step 3: Estimate Probability of a delayed crossing*

\[
 P_b = 1 - e^{-\frac{t_{c,G}v}{N}}
\]

\[
 P_d = 1 - (1 - P_b)^N
\]

\( N = \text{4 lanes} \)
$$v = \frac{V}{PHF} = \frac{948}{\frac{948}{4 \times 262}} = 1048 \text{veh/hr} = 0.29 \text{veh/s}$$

$$P_b = 1 - e^{\frac{-26.3(0.29)}{4}} = 0.85$$

$$P_d = 1 - (1 - 0.85)^4 = 1.00$$

**Step 4: Calculate Average Delay to Wait for Adequate Gap**

$$d_g = \frac{1}{v}(e^{vt_{cG}} - vt_{cG} - 1)$$

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

$$d_g = \frac{1}{0.29}(e^{0.29(26.3)} - 0.29(26.3) - 1) = 7,118 \text{sec}$$

$$d_{gd} = \frac{7,118}{1.00} = 7,121 \text{ (rounding error)}$$

Delay = 7,118 seconds, LOS F

**Step 5: Estimate Delay Reduction due to Yielding Vehicles**

$$M_y = 20\%$$ because the crossing has high visibility markings and signs at speed limit of 35 mph.

$$d_p = \sum_{i=1}^{n} h(i - 0.5)P(Y_i) + [P_d - \sum_{i=1}^{n} P(Y_i)] \times d_{gd}$$

$$h = \frac{N}{v} = \frac{4}{0.29} = 13.8$$

$$n = \text{Int}\left(\frac{d_{gd}}{h}\right) = \text{Int}\left(\frac{7,118}{13.8}\right) = 516$$
4-Lane Crossing

\[ P(Y_i) = [P_d - \sum_{j=0}^{i-1} P(Y_j)] \]

\[ \frac{P_b^4 M_y^4 + 4P_b^3 (1 - P_b) M_y^3 + 6P_b^2 (1 - P_b)^2 M_y^2 + 4P_b (1 - P_b^3) M_y}{P_d} \]

\[ P(Y_1) = 0.2679 \]
\[ P(Y_2) = 0.1961 \]

... 

Plug these into equation above to determine average pedestrian delay.

\[ d_p = \sum_{i=1}^{516} 13.8(i - 0.5)P(Y_i) + [1 - \sum_{i=1}^{516} P(Y_i)] \times 7,121 = 44.5 \text{ sec} \]

44.5 sec = LOS E

Delay is unacceptable, go to Step 6 of the evaluation flowchart. There are high visibility markings that are in good condition at the crossing.
### Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

**Crossing Location:** Example 3: Four Lane Divided Street  
**Data:** Any City, Minnesota  
**Scenario:** AM Peak Hour

<table>
<thead>
<tr>
<th>Step 1: Identify Two-Stage Crossings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is there a median available for a two-stage crossing?</td>
</tr>
<tr>
<td>If yes, does the median refuge meet ADA requirements (4’ x 4’ landing)?</td>
</tr>
<tr>
<td>If yes, does the median refuge need to meet ADA requirements (4’ x 4’ landing)?</td>
</tr>
</tbody>
</table>

#### 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 sufficient for a safe crossing.

For a single pedestrian:

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

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

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L = 112$</td>
<td>$L = ____$</td>
</tr>
<tr>
<td>$S_p = 4.8$</td>
<td>$S_p = ____$</td>
</tr>
<tr>
<td>$t_c = ____$</td>
<td>$t_c = ____$</td>
</tr>
</tbody>
</table>

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

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

$$ N_p = \frac{v_p + v_e}{v_p + v_e}$$

where:  
- $N_p$: total number of pedestrians in crossing platoon (ped)
- $v_p$: pedestrian flow rate (ped/s)
- $v_e$: vehicular flow rate across crossing (veh/s)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v_p = ____$</td>
<td>$v_p = ____$</td>
</tr>
<tr>
<td>$N_p = ____$</td>
<td>$N_p = ____$</td>
</tr>
</tbody>
</table>

2. Compute spatial distribution:

$$ N_p = \text{Int}\left[\frac{8.0(N_0 - 1)}{W_c}\right] + 1 $$

where:  
- $N_0$: total number of pedestrians in crossing platoon (ped)
- $N_p$: spatial distributions of pedestrians (ped)
- $W_c$: crosswalk width (ft)
- 8.0: default clear width used by a single pedestrian to avoid interference with other pedestrians (ft)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_0 = ____$</td>
<td>$N_0 = ____$</td>
</tr>
<tr>
<td>$W_c = ____$</td>
<td>$W_c = ____$</td>
</tr>
</tbody>
</table>

3. Compute group critical headway:

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

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_e = ____$</td>
<td>$t_e = ____$</td>
</tr>
<tr>
<td>$N_p = ____$</td>
<td>$N_p = ____$</td>
</tr>
</tbody>
</table>

#### 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.

$$ P_b = 1 - t_{c,G}^{N/N} $$

where:
- $P_b$: probability of blocked lane
- $t_{c,G}$: group critical headway (s)
- $N$: number of lanes crossed
- $N_p$: spatial distributions of pedestrians (ped)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{c,G} = ____$</td>
<td>$t_{c,G} = ____$</td>
</tr>
<tr>
<td>$N = ____$</td>
<td>$N = ____$</td>
</tr>
</tbody>
</table>

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

where:
- $P_d$: probability of delayed crossing
- $N$: number of lanes crossed
- $P_b$: probability of blocked lane

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_b = ____$</td>
<td>$P_b = ____$</td>
</tr>
<tr>
<td>$P_d = ____$</td>
<td>$P_d = ____$</td>
</tr>
</tbody>
</table>
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.

\[ d_e = \frac{1}{u}(e^{v/c_0} - 1) \]

where:
- \( d_e \) = average pedestrian gap delay (s)
- \( c_0 \) = group critical headway (s)
- \( v \) = vehicular flow rate across crossing (veh/s)

\[ t_{c0} = 26.33 \quad \text{crossing 1} \quad d_e = \quad \text{crossing 2} \quad t_{c0} = 0.29 \quad d_e = 7117.9 \quad d_e = \]

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

\[ d_{ed} = \frac{d_e}{P_d} \]

where:
- \( d_{ed} \) = average gap delay for pedestrians who incur nonzero delay
- \( P_d \) = probability of a delayed crossing

\[ d_{ed} = \quad \text{crossing 1} \quad d_{ed} = \quad \text{crossing 2} \quad d_{ed} = \]

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 marked crossings and either marked or unmarked crossings at intersections, motorist yield rates actually vary considerably.

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

Average pedestrian delay

\[ d_p = \sum_{i=1}^{n} t_i(P_i(P_i - \sum_{j=1}^{n} P_jd_{jd})) \]

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

1. One-Lane Crossing

\[ P(Y_i) = P(M_j)(1-M_j)^{i-1} \]

2. Two-Lane Crossing

\[ M_j = \text{motorist yield rate (decimal)} \]

\[ P(Y_i) = 2P(M_j)(1-P(M_j))^{i-1} \]

3. Three-Lane Crossing

\[ P(Y_i) = \left( P(M_j)(1-P(M_j)) \right)^{i-1} + 3P(M_j)^2 \left( 1-P(M_j) \right)^{i-1} + 3P(M_j)^2 \left( 1-P(M_j) \right)^2 \]

4. Four-Lane Crossing

\[ P(Y_i) = \left( P(M_j)(1-P(M_j)) \right)^{i-1} + 4P(M_j)^3 \left( 1-P(M_j) \right)^{i-1} + 4P(M_j)^3 \left( 1-P(M_j) \right)^2 + 4P(M_j)^3 \left( 1-P(M_j) \right)^3 \]

Summary

<table>
<thead>
<tr>
<th>Average</th>
<th>44.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
<td>E</td>
</tr>
</tbody>
</table>

Step 6: Calculate Average Pedestrian Delay & Determine LOS

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

Developed by Bolltei Moni, Inc.
For the Local Road Research Board.

HCM Evaluation Worksheet

Page 4 of 5

123
How does this compare to a gap study?

**Gap Study (If Available)**

A gap study can show how much time exists between successive vehicles. This can be used to determine if there are available gaps to cross. As can be seen by these graphs, most of the gaps are very small (0-10 sec) for both directions, meaning these are the gaps available to cross both directions of traffic.

\[
\text{Needed Gap} = \text{Crossing Time} + \text{Start/End Time} = \frac{112}{4.8} + 3.0 = 26.3 \text{ sec}
\]
Check of the data provided in the gap study graph indicates that there are 4 gaps available during the AM peak hour and 5 gaps available during the PM peak hour that meet the needed crossing time of 26.3 seconds. This indicates that there is approximately one acceptable gap every 15 minutes.

Additionally, the median may provide a stopping point for some pedestrians.

- AM Peak, Southbound, 143 gaps available for a needed gap of 8.2 seconds
- AM Peak, Northbound, 97 gaps available for a needed gap of 13.8 seconds
- PM Peak, Southbound, 127 gaps available for a needed gap of 8.2 seconds
- PM Peak, Northbound, 88 gaps available for a needed gap of 13.8 seconds

Consequently, one adequate gap every 1.5 minutes in the AM and PM.

**Review Origins and Destinations, Alternate Routes**

*Origins and Destinations*

The crossing is at a location connecting high density residential, retirement communities, bus stops and a community/recreational center. This is a direct connection and most pedestrians will not choose a different crossing location.

*Alternative Route Analysis*

Calculate how much time it would take for a pedestrian to walk to the nearest adjacent marked crossing, cross the roadway, and return to the location where they started. This total amount of time will be compared to the average pedestrian delay (average measured wait time).

Distance to nearest marked crossing = 905 ft to the south (Signalized intersection)

Walking Time to Signalized Intersection:

\[
\frac{905 \text{ ft}}{4.8 \text{ ft/s}} = 189 \text{ sec}
\]

Wait Time and Crossing Time at Intersection:

Assume average wait time of 30 sec.

\[
30 + \frac{125 \text{ ft}}{4.8 \text{ ft/s}} = 56 \text{ sec}
\]

Walking Time to Original Location:

\[
\frac{905 \text{ ft}}{4.8 \text{ ft/s}} = 189 \text{ sec}
\]
Total Time:

\[ 189 + 56 + 189 = 434 \text{ sec} \]

Average wait time from HCM analysis is 45 seconds. Crossing time faster at the crossing.

Result: There could be acceptable alternative routes, but most pedestrians will not use them.

Pedestrian Crossing in a Coordinated Signalized Corridor?
The crossing is along a signalized corridor, but is adequately spaced from the adjacent signalized intersections. Go to Step 8 of the evaluation flowchart.

Speed and Pedestrian Use
The speed limit is 35 mph, the population is over 10,000, but the crossing location is at a major transit stop. This transit stop is in a densely populated area and therefore can be considered a major stop.

There were 6 pedestrians during the AM peak hour and 6 pedestrians during the PM peak hour.

Result: Skip to Step 10 of the evaluation flowchart. Consider traffic calming treatments with or without uncontrolled crossing treatments.

School Crossing
This is not a school crossing, go to Step 9.

FHWA Safety Guidance
Multi-lane with raised median, speed limit = 35 mph, ADT = 15,000. Results in P designation. Go to Step 11, Traffic Calming Treatments.

Traffic Calming Treatment Options
Treatment Options should consider the roadway environment.
   a. Urban section (curb)
   b. Four-Lane divided
   c. Speed Limit = 35 mph
   d. Crossing location connects residential areas to bus stop/community center
   e. Clear motorist sight lines (SSD is met)
   f. Pedestrian sight lines impacted (PedSD not met)
   g. Crossing is currently signed and marked
   h. Two pedestrian crashes reported in past 10 years (One fatal).

Review the Traffic Calming Treatment options that are available.
   a. Center Median with Refuge Island – possible, extend median through crossing
   b. Raised Crossing – not recommended due to traffic volume
   c. Lighting – already lit
d. Pavement Striping – possible but difficult to implement without extensive work  
e. Curb Bump-Out/Extensions – possible, but does not fit roadway  
f. Channelized Turn Lanes – not recommended

Based on the existing options, the center median with the refuge island is the most reasonable for this situation because there is already a median installed that doesn’t extend to the crosswalk.

**Repeat Step 4 of the evaluation flowchart.**

**HCM Analysis**  
*Determine inputs:*  

\[ V = 948 \text{ in AM peak hour, 841 in PM peak hour} \]

**Evaluation Inputs:**  

<table>
<thead>
<tr>
<th>Input</th>
<th>defaults:</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L ) = crosswalk length (ft) – east side</td>
<td>( L = 52 )</td>
<td>( L = 25 )</td>
</tr>
<tr>
<td>( L ) = crosswalk length (ft) – west side</td>
<td>( S_p = 3.5 )</td>
<td>( S_p = 4.8 )</td>
</tr>
<tr>
<td>( S_p ) = average pedestrian walking speed (ft/s)</td>
<td>( t_s = 3.0 )</td>
<td>( t_s = 3 )</td>
</tr>
<tr>
<td>( t_s ) = pedestrian start-up and end clearance time (s)</td>
<td>( V = 524 )</td>
<td>( V = 424 )</td>
</tr>
<tr>
<td>( V ) = vehicular hourly volume (veh/hr) – east side</td>
<td>( V = 150 )</td>
<td>( V = 112 )</td>
</tr>
<tr>
<td>( V ) = vehicular hourly volume (veh/hr) – west side</td>
<td>( v_p = 0^* )</td>
<td>( v_p = 0 )</td>
</tr>
<tr>
<td>( v_p ) = pedestrian flow rate (ped/s)</td>
<td>( W_c = 8.0 )</td>
<td>( W_c = 6 )</td>
</tr>
<tr>
<td>( W_c ) = crosswalk width (ft)</td>
<td>( N = \text{INT}(L/11) )</td>
<td>( N = 2 )</td>
</tr>
<tr>
<td>( N ) = number of lanes crossed – east side</td>
<td>( N = 2 )</td>
<td>( N = 2 )</td>
</tr>
<tr>
<td>( N ) = number of lanes crossed – west side</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**AM Peak Hour**  

*Step 1: Identify Two-Staged Crossings*  

This is now a two-stage crossing.

*Step 2: Determine Critical Headway*  

Pedestrian Platooning is **NOT** observed, so the spatial distribution of pedestrians can be assumed to be \( N_p = 1, v_p = 0 \) and the critical headway is determined from the equation below:
Single Pedestrian:

\[ t_c = t_{c,G} = \frac{L}{S_p} + t_s \]

\[ t_{c,G} = \frac{52}{4.8} + 3.0 = 13.8 \text{ sec} \]

\[ t_{c,G} = \frac{25}{4.8} + 3.0 = 8.2 \text{ sec} \]

**Step 3: Estimate Probability of a delayed crossing**

\[ P_b = 1 - e^{-\frac{t_{c,G}v}{N}} \]

\[ P_d = 1 - (1 - P_b)^N \]

\( N = 2 \text{ lanes} \)

\[ v = \frac{V}{PHF} = \frac{524}{524 \frac{4}{4 \cdot 150}} = 600 \text{ veh/hr} = 0.17 \text{ veh/s} \]

\[ v = \frac{V}{PHF} = \frac{424}{424 \frac{4}{4 \cdot 112}} = 448 \text{ veh/hr} = 0.12 \text{ veh/s} \]

\[ P_b = 1 - e^{-13.8(0.17)} = 0.69 \quad P_b = 1 - e^{-8.2(0.12)} = 0.39 \]

\[ P_d = 1 - (1 - 0.69)^2 = 0.90 \quad P_d = 1 - (1 - 0.39)^2 = 0.63 \]

**Step 4: Calculate Average Delay to Wait for Adequate Gap**

\[ d_g = \frac{1}{v}(e^{vt_{c,G}} - vt_{c,G} - 1) \]

\[ d_g = \frac{d_g}{P_d} \]

\[ d_g = \frac{1}{0.17}(e^{0.17(13.8)} - 0.17(13.8) - 1) = 42 \text{ sec} \]

\[ d_g = \frac{1}{0.12}(e^{0.12(8.2)} - 0.12(8.2) - 1) = 6 \text{ sec} \]
\[ d_{gd} = \frac{42}{0.90} = 46 \text{ sec} \quad d_{gd} = \frac{6}{0.63} = 9 \text{ sec} \]

Delay = 55 seconds, LOS F

There is delay reduction. \( M_y = 17\% \) because the crossing has high visibility markings and signs at 35 mph, but is now a staged crossing. As there is already a median along the roadway, it is anticipated that extension of the median would have little to no effect on motorist yielding.

\[ d_p = \sum_{i=1}^{n} h(i - 0.5)P(Y_i) + [P_d - \sum_{i=1}^{n} P(Y_i)] * d_{gd} \]

\[ h = \frac{N}{v} = \frac{2}{0.17} = 11.8 \quad h = \frac{N}{v} = \frac{2}{0.12} = 16.7 \]

\[ n = \text{Int}\left(\frac{d_{gd}}{h}\right) = \text{Int}\left(\frac{46}{11.8}\right) = 3 \quad n = \text{Int}\left(\frac{d_{gd}}{h}\right) = \text{Int}\left(\frac{9}{16.7}\right) = 0, \text{ but must be } > 0, = 1 \]

2-Lane Crossing – east side

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

\[ P(Y_1) = 0.0864 \]
\[ P(Y_2) = 0.0781 \]
\[ P(Y_3) = 0.0707 \]

2-Lane Crossing – west side

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

\[ P(Y_1) = 0.0852 \]

Plug these into equation above to determine average pedestrian delay.

\[ d_p = \sum_{i=1}^{3} 11.8(i - 0.5)P(Y_i) + [0.90 - \sum_{i=1}^{3} P(Y_i)] * 46 = 35.1 \text{ sec} \]
\[d_p = \sum_{i=1}^{1} 16.7(i - 0.5)P(Y_i) + [0.63 - \sum_{i=1}^{1} P(Y_i)] \times 9 = 5.7 \text{ sec}\]

\[40.8 \text{ sec} = LOS E\]

**PM Peak Hour**

Same process as AM Peak Hour:

\[Delay = 23.3 \text{ sec} = LOS D\]

Analysis of the crossing with a median indicates that the pedestrians crossing would experience LOS E during the AM and LOS D during the PM Peak Hour with a median. Pedestrian traffic is essentially equal in the AM and PM.

Result: Unacceptable Service Level in the AM peak hour, but acceptable in the PM peak hour with a median extended through the crossing location. No other changes are recommended.
**Uncontrolled Pedestrian Crossing Level of Service**

**Evaluation Worksheet**

<table>
<thead>
<tr>
<th>Step 1: Identify Two-Stage Crossings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is there a median available for a two-stage crossing?</td>
</tr>
<tr>
<td>If yes, does the median refuge meet ADA requirements (4’ x 4’ landing)?</td>
</tr>
<tr>
<td>If yes, does the median refuge need to meet ADA requirements (4’ x 4’ landing)?</td>
</tr>
</tbody>
</table>

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 sufficient for a safe crossing.

For a single pedestrian:

\[ t_c = \frac{L}{S_p} + t_{s-a} \]

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

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L = 52 )</td>
<td>( L = 25 )</td>
</tr>
<tr>
<td>( S_p = 4.8 )</td>
<td>( S_p = 4.8 )</td>
</tr>
<tr>
<td>( t_s = 3 )</td>
<td>( t_s = 3 )</td>
</tr>
</tbody>
</table>

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

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

\[ N_p = \frac{\nu_p e^{\frac{-t_c}{\nu_p}} + \nu_f e^{\frac{-t_c}{\nu_f}}}{(\nu_p + \nu_f) e^{\frac{-t_c}{\nu_p + \nu_f}}} \]

where:
- \( N_p \) = total number of pedestrians in crossing platoon (ped)
- \( \nu_p \) = pedestrian flow rate (ped/s)
- \( \nu_f \) = vehicular flow rate across crossing (veh/s)
- \( t_c \) = single pedestrian critical headway (s)

2. Compute spatial distribution:

\[ N_p = \text{int} \left[ \frac{8.0(N_p-1)}{W_c} \right] + 1 \]

where:
- \( N_p \) = spatial distributions of pedestrians (ped)
- \( N_p \) = total number of pedestrians in crossing platoon (ped)
- \( W_c \) = crosswalk width (ft)

3. Compute group critical headway:

\[ t_c = t_s + 2(N_p-1) \]

where:
- \( t_c \) = group critical headway (s)
- \( t_s \) = single pedestrian critical headway (s)
- \( N_p \) = spatial distributions of pedestrians (ped)

**Step 2: Determine Critical Headway**

**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.

\[ P = 1 - \frac{t_c}{\nu_a/N} \]

where:
- \( P \) = probability of blocked lane
- \( \nu_a \) = vehicular flow rate across crossing (veh/s)
- \( N \) = number of lanes crossed

\[ P = 1 - (1-P_b)^N \]

where:
- \( P_b \) = probability of delayed crossing

**Calculations Sheet 1**
### 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.

\[ d_o = \frac{1}{u} \left( e^{u t_o} - 1 - \frac{1}{u} t_o \right) \]

where:
- \( d_o \) = average pedestrian gap delay (s)
- \( t_o \) = group critical headway (s)
- \( u \) = vehicular flow rate across crossing (veh/s)

**Crossing 1**

\[ t_o = 13.83 \quad \text{and} \quad d_o = 42.07 \]

**Crossing 2**

\[ t_o = 8.208 \quad \text{and} \quad d_o = 5.7734 \]

**Average Delay for a Pedestrian who is Unable to Cross Immediately upon Reaching the Intersection (e.g., any pedestrian experiencing nonzero delay)**

\[ d_{pd} = \frac{d_o}{P_p} \]

where:
- \( d_{pd} \) = average pedestrian gap delay for pedestrians who incur nonzero delay
- \( P_p \) = probability of a delayed crossing

**Crossing 1**

\[ d_o = 42.07 \quad \text{and} \quad P_p = 0.905 \quad \Rightarrow \quad d_{pd} = 46.494 \]

**Crossing 2**

\[ d_o = 5.7734 \quad \text{and} \quad P_p = 0.627 \quad \Rightarrow \quad d_{pd} = 9.2145 \]

**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 marked crossings and either marked or unmarked crossings at intersections, motorist yield rates actually vary considerably.

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

**Average pedestrian delay**

\[ d_i = \frac{1}{2} h_i (1 - 0.5) P(Y_i) + \left( P_d \sum_{i=1}^{n} P(Y_i) \right) d_{pd} \]

where:
- \( d_i \) = average pedestrian delay (s)
- \( h_i \) = average headway for each through lane = N/i
- \( P(Y_i) \) = probability that motorists yield to pedestrian on crossing event \( i \)

**Crossing 1**

\[ h_1 = 11.8 \quad \Rightarrow \quad d_1 = 35.1 \]

**Crossing 2**

\[ h_2 = 16.67 \quad \Rightarrow \quad d_2 = 5.7 \]

1. **One-Lane Crossing**

   \[ P(Y_i) = P_{i,y} M_j (1-M_j) \]

2. **Two-Lane Crossing**

   \[ P(Y_i) = 2P_{i,y} (1-P_{i,y}) M_j + 1P_{i,y}^2 M_j^2 \]

3. **Three-Lane Crossing**

   \[ P(Y_i) = P_{i,y} - \sum_{j=1}^{n} P(Y_{ij}) + \left( -P_{i,y} M_j^2 + 3P_{i,y} (1-P_{i,y}) M_j^2 + 3P_{i,y} (1-P_{i,y}) Y M_j \right) \]

4. **Four-Lane Crossing**

   \[ P(Y_i) = \left( P_{i,y} - \sum_{j=1}^{n} P(Y_{ij}) + \left( -P_{i,y} M_j^2 + 4P_{i,y} (1-P_{i,y}) M_j^2 + 6P_{i,y} (1-P_{i,y}) Y M_j^2 + 4P_{i,y} (1-P_{i,y}) Y^2 M_j^2 \right) \]

### Summary

<table>
<thead>
<tr>
<th>LOS</th>
<th>Control Delay (sec/ped)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
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<td>30-45</td>
<td>Delay approaches tolerance level, risk-taking likely</td>
</tr>
<tr>
<td>F</td>
<td>&gt;45</td>
<td>Delay exceeds tolerance level, high chance of risk-taking</td>
</tr>
</tbody>
</table>

### Calculations Sheet 2

Page 4 of 5
Uncontrolled Pedestrian Crossing Level of Service
Evaluation Worksheet

Crossing Location: Example 3: Four Lane Divided Street
City, State: Any City, Minnesota
Agency:
Reviewer(s):

<table>
<thead>
<tr>
<th>Scenario: PM Peak Hour, Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data:</td>
</tr>
<tr>
<td>Scenario: PM Peak Hour, Median</td>
</tr>
<tr>
<td>Agency:</td>
</tr>
</tbody>
</table>

**Step 1: Identify Two-Stage Crossings**

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

For a single pedestrian:

\[ t_c = \frac{L}{S_p} + t_e \]

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

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

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

\[ N_x = \frac{u_p - u_j}{(v_p - u_j)e^{-\frac{v_p}{u_j}}} \]

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

2. compute spatial distribution:

\[ N_p = \int \left[ \frac{8.0(N_x - 1)}{W_c} \right] + 1 \]

where:
- \( N_p \) = spatial distributions of pedestrians (ped)
- \( N_x \) = total number of pedestrians in crossing platoon (ped)
- \( W_c \) = crosswalk width (ft)

3. compute group critical headway:

\[ t_{c,g} = t_e + 2(N_x - 1) \]

where:
- \( t_{c,g} \) = group critical headway (s)
- \( t_e \) = single pedestrian critical headway (s)
- \( N_x \) = total number of pedestrians in crossing platoon (ped)

**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.

\[ P_b = 1 - (1 - e^{-t_c/u_j})^N \]

where:
- \( P_b \) = probability of blocked lane
- \( t_c \) = group critical headway (s)
- \( u_j \) = vehicular flow rate across crossing (veh/s)
- \( N \) = number of lanes crossed

\[ P_d = 1 - (1 - P_b)^N \]

where:
- \( P_d \) = probability of delayed crossing
- \( N \) = number of lanes crossed

\[ t_{c,g} = t_e + 2(N_x - 1) \]

where:
- \( t_{c,g} \) = group critical headway (s)
- \( t_e \) = single pedestrian critical headway (s)
- \( N_x \) = total number of pedestrians in crossing platoon (ped)

Developed by Bolton-Merk, Inc. for the Local Road Research Board.
### 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.

\[
d_d = \frac{1}{v} \left( e^{\frac{v}{u_d} - 1} \right) t_{c,g} \cdot 1
\]

where:

- \( d_d \) = average pedestrian gap delay (s)
- \( t_{c,g} \) = group critical headway (s)
- \( v \) = vehicular flow rate across crossing (veh/s)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_{c,g} ) = 13.83</td>
<td>( t_{c,g} ) = 8.208</td>
</tr>
<tr>
<td>( v ) = 0.1</td>
<td>( v ) = 0.16</td>
</tr>
<tr>
<td>( d_d ) = 16.048</td>
<td>( d_d ) = 8.7826</td>
</tr>
</tbody>
</table>

Average delay for a pedestrian who is unable to cross immediately upon reaching the intersection:

\[
d_{d,ad} = \frac{d_d}{P_d}
\]

where:

- \( d_{d,ad} \) = average gap delay for pedestrians who incur nonzero delay
- \( P_d \) = probability of a delayed crossing

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( d_d ) = 16.05</td>
<td>( d_d ) = 8.783</td>
</tr>
<tr>
<td>( P_d ) = 0.749</td>
<td>( P_d ) = 0.731</td>
</tr>
<tr>
<td>( d_{d,ad} ) = 21.419</td>
<td>( d_{d,ad} ) = 12.013</td>
</tr>
</tbody>
</table>

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 marked crossings and either marked or unmarked crossings at intersections, motorist yield rates actually vary considerably.

**Step 5: Estimate Delay Reduction due to Yielding Vehicles**

(If yielding is zero, then skip step 5)

Average pedestrian delay:

\[
d_p = \sum_{i=1}^{n} \left( \frac{1}{i} \times 0.5 \right) P(Y_i) + \left( P_d \times \sum_{i=1}^{n} P(Y_i) \right) d_{d,ad}
\]

where:

- \( d_p \) = average pedestrian delay (s)
- \( P(Y_i) \) = probability that motorists yield to pedestrian on crossing event \( i \)
- \( P(Y_j) \) = probability that motorists yield to pedestrian on crossing event \( j \)
- \( d_{d,ad} \) = average gap delay for pedestrians who incur nonzero delay

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( d_p ) = 20.0</td>
<td>( d_p ) = 15.0</td>
</tr>
<tr>
<td>( P_d ) = 12.5</td>
<td>( P_d ) = 1</td>
</tr>
<tr>
<td>( d_{d,ad} ) = 8.3</td>
<td></td>
</tr>
</tbody>
</table>

**Summary**

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<td>&gt;45</td>
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</tr>
</tbody>
</table>
Example 4: Four-Lane Undivided Urban Street Crossing

Site Review
Conduct a field review and take pedestrian/vehicle counts during the peak hours.

The crossing location is located along a signalized street. The crossing location is unmarked. Roadway is two lanes in each direction, parking along the street.
Complete Field Review Worksheet.

### Uncontrolled Pedestrian Crossing
#### Data Collection Worksheet

| Location: | Example 4: Four Lane Undivided Urban Street | Date: |
| City, State: | | |
| Reviewer(s): | | |
| Agency: | | |
| 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 | Crossing 1 | 60 ft. |
| Crossing Width: Measure the crossing width from curb to curb | Crossing 2 | 8 ft. |
| Median: width of median at crossing location | | |
| 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 | 30 mph |
| Roadway Curvature and Sight Distances: Average walking speed | 5.7 ft/s |

Equations to calculate the following are located on the next page.

#### Traffic and Pedestrian Data

| AM Peak | Hourly | 1,183 | Daily | 13,700 |
| PM Peak | Hourly | 1,111 | Daily | 13,700 |
| Location: | | | | |

#### 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 |

#### Enhancements:

| What enhancements are currently at the crossing location? | | |
| Adjacent Facilities: Distance to nearest marked crosswalk? | 220 ft. |
| What pedestrian control devices are present at the nearest adjacent marked crosswalk? | Traffic Signal |
| Distance to nearest all-way stop, roundabout or signalized intersection | 220 ft. |
| Could another location serve the same pedestrian crossing movement? | Yes | No |
| Could another location serve the movement more effectively? | Yes | No |

*Developed by Boman & Theriault, Inc. in cooperation with the local Road Research Board. Workshheets made without change and under no circumstances shall be sold by third parties for profit.*

Page 1 of 2
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 signing 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 origins and destinations.

Draw or insert map of location being studied

Signalized Intersection
Signalized Intersection
SSD Met, PedSD Not Met
SSD Met, PedSD Not Met

260'

No Curb Ramps
No Curb Ramps

Notes:
- Parking on both sides of street. Signals one block in either direction.
- Direct connections across at crossing location
- On a grade. Street is lower to west, higher to east.

Sight Distance Calculations:

Stopping sight distance (SSD), ft = 1.475t + 1.075S^2/a
Pedestrian sight distance (PedSD), ft = 1.475L / S_p = t

where:
- t = brake reaction time, s
- a = deceleration rate, ft/s^2
- S_p = average pedestrian walking speed, ft/s
- L = length of crossing, ft
- t, a pedestrian start-up and end clearance time, s
- S = design speed, mph

<table>
<thead>
<tr>
<th></th>
<th>defaults:</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>2.5</td>
</tr>
<tr>
<td>a</td>
<td>11.2</td>
</tr>
<tr>
<td>S_p</td>
<td>3.5</td>
</tr>
<tr>
<td>L</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Page 2 of 2
Safety Review
No pedestrian crashes at the location within last ten years. There have been three rear-end
crashes at the location within the last ten years. Rear end crashes could be due to pedestrian
yielding or the adjacent traffic signals. No conclusions are recognized from the crash data.

SSD, PedSD Calculation

\[
SSD = d_{PRT} + d_{MT} = 1.47Vt + 1.075 \frac{V^2}{a}
\]

Where:
- \( d_{PRT} \) = driver perception – reaction distance, (ft)
- \( d_{MT} \) = braking distance (ft)
- \( V \) = design speed (mph)
- \( t \) = brake reaction time (s) \([DEFAULT = 2.5 \text{ sec}]\)
- \( a \) = deceleration rate (\( \frac{\text{ft}}{s^2} \)) \([DEFAULT = 11.2 \frac{\text{ft}}{s^2}]\)

\[
SSD = 1.47 * 30 * 2.5 + 1.075 \frac{30^2}{11.2} = 196.6 \text{ ft} \approx 197 \text{ ft}
\]

Looking at a map of the crossing, there is sufficient stopping sight distance for this crossing.

\[
PedSD = 1.47V \left( \frac{L}{S_p} + t_s \right)
\]

Where:
- \( L \) = length of crossing (ft)
- \( S_p \) = average pedestrian walking speed (\( \frac{\text{ft}}{s} \)) \([DEFAULT = 3.5 \frac{\text{ft}}{s}]\)
- \( t_s \) = pedestrian start – up and clearance time (s) \([DEFAULT = 3.0 \text{ sec}]\)

\[
PedSD = 1.47 * 30 * \left( \frac{60}{5.7} + 3.0 \right) = 597 \text{ ft}
\]

Again, looking at a map of the crossing, there is not a sufficient pedestrian sight distance for one
direction. There is approximately 400 to 500 ft available to the east, and approximately 1,000 ft
available to the west.

HCM Analysis
Determine inputs:

\[ V = 1,183 \text{ in AM peak hour and 1,111 in PM peak hour} \]
Evaluation Inputs:

<table>
<thead>
<tr>
<th>defaults:</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td>L = crosswalk length (ft)</td>
<td>L = 60</td>
</tr>
<tr>
<td>$S_p$ = average pedestrian walking speed (ft/s)</td>
<td>$S_p$ = 3.5</td>
</tr>
<tr>
<td>$t_s$ = pedestrian start-up and end clearance time (s)</td>
<td>$t_s$ = 3</td>
</tr>
<tr>
<td>V = vehicular hourly volume (veh/hr)</td>
<td>V = 1,183</td>
</tr>
<tr>
<td>Peak 15-minute volume (veh)</td>
<td>V = 329</td>
</tr>
<tr>
<td>$v_p$ = pedestrian flow rate (ped/s)</td>
<td>$v_p$ = 0</td>
</tr>
<tr>
<td>$W_c$ = crosswalk width (ft)</td>
<td>$W_c$ = 8</td>
</tr>
<tr>
<td>N = number of through lanes crossed</td>
<td>N = INT(L/11)</td>
</tr>
</tbody>
</table>

AM Peak Hour

Step 1: Identify Two-Staged Crossings

There is no median. There are no curb ramps.

Step 2: Determine Critical Headway

For a single pedestrian:

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

$$t_c = \frac{60}{5.7} + 3 = 13.5 \text{ sec}$$

Pedestrian Platooning is observed, so the spatial distribution of pedestrians should be computed:

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

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

$$v_p = \frac{V_p}{PHF} = \frac{34}{\frac{34}{4 \times 11}} = 44 \text{ ped/hr} = 0.01 \text{ ped/s}$$

$$v = \frac{V}{PHF} = \frac{\frac{1183}{\frac{1183}{4 \times 329}}}{1316 \text{ veh/hr} = 0.37 \text{ veh/s}$$

$$N_c = \left(\frac{0.01 e^{(0.012)(13.5)} + (0.37) e^{-(0.37)(13.5)}}{(0.01 + 0.37) e^{(0.01-0.37)(13.5)}}\right) = 4.77 \text{ ped/s}$$

2. Compute Spatial Distribution:
\[ N_p = \text{Int} \left( \frac{8.0(N_c - 1)}{W_c} \right) + 1 \]

\( N_c = 5.32 \text{ peds (from above)} \)

\( W_c = \text{No crosswalk width} \text{ – so use 8ft} \)

\[ N_p = \text{Int} \left( \frac{8.0(5.32 - 1)}{8} \right) + 1 = 4 \text{ peds} \]

3. Compute Group Critical Headway:

\[ t_{c,G} = t_c + 2(N_p - 1) \]

\( t_c = 18.6 \text{ s} \)

\( N_p = 29 \text{ peds (from above)} \)

\[ t_{c,G} = 13.5 + 2(4 - 1) = 19.5 \text{ sec} \]

Step 3: Estimate Probability of a delayed crossing

\[ P_b = 1 - e^{-\frac{t_{c,G}v}{N}} \]

\[ P_d = 1 - (1 - P_b)^N \]

\( N = 4 \text{ lanes} \)

\[ P_b = 1 - e^{-\frac{19.5(0.37)}{4}} = 0.84 \]

\[ P_d = 1 - (1 - 0.84)^4 = 0.9993 \]

Step 4: Calculate Average Delay to Wait for Adequate Gap

\[ d_g = \frac{1}{v}(e^{vt_{c,G}} - vt_{c,G} - 1) \]

\[ d_{ga} = \frac{d_g}{P_d} \]

\[ d_g = \frac{1}{0.37}\left(e^{0.37(19.5)} - 0.37(19.5) - 1\right) = 3,689 \text{ sec} \]

\[ d_{ga} = \frac{3,689}{0.9993} = 3,691 \text{ sec} \]

In reality, as this is in a signalized corridor, the signals platoon traffic through the area.
Step 5: Estimate Delay Reduction due to Yielding Vehicles

There is no yield rate because the crosswalk is unmarked (My=0). Therefore, there is no reduction in delay due to yielding vehicles, and the average pedestrian delay is the same as in step 4.

\[ d_p = d_{gd} = 3,691 \text{ sec} = \text{LOS F} \]

**PM Peak Hour**

Same process as AM Peak Hour:

\[ Delay = 1,886 \text{ sec} = \text{LOS F} \]

Analysis of the crossing indicates that the crossing is experiencing LOS F during the AM and PM Peak Hours.

Result: Unacceptable Service Level in the AM and PM. Go to Step 6 of the evaluation flowchart.

**Review Origins and Destinations, Alternate Routes**

**Origins and Destinations**

The proposed crossing is located near a commercialized/shopping area. The crossing would connect a densely populated residential area to a shopping area.

**Alternative Route Analysis**

Calculate how much time it would take for a pedestrian to walk to the nearest adjacent marked crossing, cross the roadway, and return to the location where they started.

This total amount of time will be compared to the average pedestrian delay (average measured wait time).

Distance to nearest marked crossing = 220 ft (Signalized intersection)

Walking Time to Signalized Intersection:

\[ \frac{220 \text{ ft}}{5.7 \frac{\text{ft}}{s}} = 39 \text{ sec} \]

Wait Time and Crossing Time at Intersection:

Assume average wait time of 30 sec.
\[
30 + \frac{65 \text{ ft}}{5.7 \text{ ft/s}} = 41 \text{ sec}
\]

Walking Time to Original Location:
\[
\frac{220 \text{ ft}}{5.69 \text{ ft/s}} = 39 \text{ sec}
\]

Total Time:
\[
39 + 41 + 39 = 119 \text{ sec}
\]

*Average Measured Wait Time (Pedestrian Delay) without a crossing*

1,886 to 3,691 sec with current crossing (*from HCM Analysis*)

Because the alternative route time is considerably less than the average wait time, pedestrians should use the crossing at the signalized intersection to cross the roadway.

Result: There are acceptable alternative routes that pedestrians can use at this location. Since there is an acceptable alternative route at either of the adjacent signalized intersections, no changes are recommended at the crossing location studied.

Measures may be taken to prevent pedestrians from crossing, but knowledge of the area indicates that pedestrians will cross at the location no matter what the delay is.

If the signals were further away, a High Level Treatment of a Traffic Signal or Pedestrian Hybrid Beacon may be appropriate.
### Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

**Crossing Location:** Example 4: Four Lane Undivided Urban Street  
**City, State:**  
**Reviewer(s):**  
**Scenario:** AM Peak Hour  
**Agency:**

#### Step 1: Identify Two-Stage Crossings

**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 sufficient 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)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th></th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(L) = 60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(S_p) = 5.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(t_c) = 3.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(t_s) = 3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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

\[
N_p = \frac{\nu_p e^{\frac{t_s}{t_c}} + \nu v e^{-\frac{t_s}{t_c}}}{(\nu_p + \nu) e^{\frac{t_s}{t_c}}}
\]

where:  
- \(N_p\) = total number of pedestrians in crossing platoon (ped)  
- \(\nu_p\) = pedestrian flow rate (ped/s)  
- \(\nu\) = vehicular flow rate across crossing (veh/s)  
- \(t_c\) = single pedestrian critical headway (s)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\nu_p) = 0.01</td>
<td>(\nu_p) = 0.37</td>
</tr>
<tr>
<td>(\nu) = 4.77</td>
<td></td>
</tr>
<tr>
<td>(N_p) = 4.77</td>
<td></td>
</tr>
</tbody>
</table>

2. Compute spatial distribution:

\[N_p = \text{Int}\left[\frac{8.0(N_p-1)}{W_c}\right] + 1\]

where:  
- \(N_p\) = spatial distributions of pedestrians (ped)  
- \(N_p\) = 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)  
- \(t_c\) = single pedestrian critical headway (s)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(N_p) = 4.77</td>
<td></td>
</tr>
<tr>
<td>(W_c) = 8</td>
<td></td>
</tr>
</tbody>
</table>

3. Compute group critical headway:

\[t_{c,G} = t_c + 2(N_p-1)\]

where:  
- \(t_{c,G}\) = group critical headway (s)  
- \(N_p\) = spatial distributions of pedestrians (ped)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(N_p) = 4</td>
<td></td>
</tr>
<tr>
<td>(t_{c,G}) = 19.5</td>
<td></td>
</tr>
</tbody>
</table>

#### Step 2: Determine Critical Headway

**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.

\[P_b = 1 - e^{-t_{c,G}/N}\]

where:  
- \(P_b\) = probability of blocked lane  
- \(t_{c,G}\) = group critical headway (s)  
- \(N\) = number of lanes crossed

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P_b) = 0.84</td>
<td></td>
</tr>
</tbody>
</table>

\[P_d = 1 - (1 - P_b)^N\]

where:  
- \(P_d\) = probability of delayed crossing  
- \(N\) = number of lanes crossed  
- \(t_{c,G}\) = group critical headway (s)  
- \(v\) = vehicular flow rate across crossing (veh/s)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P_d) = 1</td>
<td></td>
</tr>
</tbody>
</table>

**Calculations Sheet 1**
### 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.

\[
d_{4} = \frac{1}{V} \left( e^{\frac{V}{\lambda_{c} \cdot \rho_{c} - 1}} \right)
\]

where:
- \(d_{4}\) = average pedestrian delay gap (s)
- \(\lambda_{c}\) = group critical headway (s)
- \(\rho_{c}\) = vehicular flow rate across crossing (veh/s)

**Crossing 1**
- \(t_{c} = 19.53\)
- \(d_{4} = 3688.5\)

**Crossing 2**
- \(t_{c} = \) __________
- \(d_{4} = \) __________

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

\[
d_{4} = \frac{d_{4}}{P_{d}}
\]

where:
- \(d_{4}\) = average pedestrian delay for pedestrians who incur nonzero delay
- \(P_{d}\) = probability of a delayed crossing

**Crossing 1**
- \(d_{4} = 3689\)
- \(P_{d} = 0.999\)
- \(d_{4} = 3691.2\)

**Crossing 2**
- \(d_{4} = \) __________
- \(P_{d} = \) __________
- \(d_{4} = \) __________

**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 Minnesota at all marked crossings and either marked or unmarked crossings at intersections, motorist yield rates actually vary considerably. Some crossing treatments and yield rates based on research are provided on the next page.

**Average pedestrian delay**

\[
d_{4} = \sum_{i=1}^{n} \left( t_{c} \cdot 0.5 \cdot P(Y_{i}) \right) + \left( P_{d} \cdot \sum_{i=1}^{n} Y_{i} \right) d_{4}
\]

where:
- \(d_{4}\) = average pedestrian delay (s)
- \(t_{c}\) = crossing event (i = 1 to n)
- \(P(Y_{i})\) = probability that motorists yield to pedestrian on crossing event \(i\)
- \(P_{d}\) = Int(d4/t, h), average number of crossing events before an adequate gap is available, >0
- \(Y_{i}\) = crossing event (j = 0 to i-1)

**Crossing 1**
- \(t_{c} = \) __________
- \(P(Y_{i}) = \) __________
- \(P_{d} = \) __________
- \(d_{4} = \) __________

**Crossing 2**
- \(t_{c} = \) __________
- \(P(Y_{i}) = \) __________
- \(P_{d} = \) __________
- \(d_{4} = \) __________

**Summary**

<table>
<thead>
<tr>
<th>Average</th>
<th>3691.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
<td>F</td>
</tr>
</tbody>
</table>

**Step 6: Calculate Average Pedestrian Delay & Determine LOS**

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

Developed by Bolton Monk, Inc. for the Local Road Research Board.

HCM Evaluation Worksheet
### Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

**Crossing Location:** Example 4: Four Lane Undivided Urban Street  
**City, State:**  
**Reviewer(s):**

<table>
<thead>
<tr>
<th>Scenario:</th>
<th>PM Peak Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agency:</td>
<td></td>
</tr>
</tbody>
</table>

**Step 1: Identify Two-Stage Crossings**

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

  For a single pedestrian:

  \[ t_c = \frac{L}{S_p} + t_p \]

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

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L ) = 60</td>
<td>( L ) = 135</td>
</tr>
<tr>
<td>( S_p ) = 5.7</td>
<td>( S_p ) = 13.5</td>
</tr>
</tbody>
</table>

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

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

  \[ N_p = \frac{U_p e^{U_p W} + U v^{n+1} e^{U_p W}}{(U_p + v) e^{U_p W}} \]

  where:
  - \( N_p \) = total number of pedestrians in crossing platoon (ped)
  - \( U_p \) = pedestrian flow rate (ped/s)
  - \( v \) = vehicular flow rate across crossing (veh/s)
  - \( N_p \) = single pedestrian critical headway (s)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( U_p ) = 0.02</td>
<td>( U_p ) = 0.33</td>
</tr>
<tr>
<td>( v ) = 47.8</td>
<td>( v ) = 4.78</td>
</tr>
</tbody>
</table>

  2. Compute spatial distribution:

  \[ N_p = \text{Int} \left( \frac{8.0(N_p-1)}{W_c} \right) + 1 \]

  where:
  - \( N_p \) = total number of pedestrians in crossing platoon (ped)
  - \( N_p \) = 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)
  - \( N_p \) = spatial distributions of pedestrians (ped)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( W_c ) = 4</td>
<td>( W_c ) = 8</td>
</tr>
<tr>
<td>( N_p ) = 4.78</td>
<td>( N_p ) = 4</td>
</tr>
</tbody>
</table>

  3. Compute group critical headway:

  \[ t_{G} = t_c + 2(N_p - 1) \]

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

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N_p ) = 4</td>
<td>( N_p ) = 4</td>
</tr>
<tr>
<td>( t_c ) = 13.5</td>
<td>( t_c ) = 19.5</td>
</tr>
</tbody>
</table>

**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.

\[ P_b = 1 - t_{G} e^{VN} \]

where:
- \( P_b \) = probability of blocked lane
- \( P_d \) = probability of delayed crossing
- \( N \) = number of lanes crossed
- \( t_{G} \) = group critical headway (s)
- \( V \) = vehicular flow rate across crossing (veh/s)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_{G} ) = 19.5</td>
<td>( t_{G} ) = 19.5</td>
</tr>
<tr>
<td>( V ) = 0.33</td>
<td>( V ) = 0.33</td>
</tr>
<tr>
<td>( N ) = 4</td>
<td>( N ) = 4</td>
</tr>
<tr>
<td>( P_b ) = 0.8</td>
<td>( P_b ) = 0.8</td>
</tr>
<tr>
<td>( P_d ) = 1</td>
<td>( P_d ) = 1</td>
</tr>
</tbody>
</table>
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.

\[ d_p = \frac{1}{v} \left( e^{\frac{v}{t_{g,c}} - 1} \right) \]

where:
- \( d_p \) = average pedestrian delay (s)
- \( t_{g,c} \) = group critical headway (s)
- \( v \) = vehicular flow rate across crossing (veh/s)

Crossing 1:
- \( t_{g,c} = 19.53 \) s
- \( v = 1883 \) veh/s

Crossing 2:
- \( t_{g,c} = 0.33 \) s
- \( v = 1885.7 \) veh/s

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

\[ d_{pd} = \frac{d_p}{p_d} \]

where:
- \( d_{pd} \) = average gap delay for pedestrians who incur nonzero delay
- \( p_d \) = probability of a delayed crossing

Crossing 1:
- \( d_p = 1883 \) s
- \( p_d = 0.998 \)
- \( d_{pd} = 1885.7 \) s

Crossing 2:
- \( d_p = 1883 \) s
- \( p_d = 0.998 \)
- \( d_{pd} = 1885.7 \) s

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 MIN at all marked crossings and either marked or unmarked crossings at intersections, motorist yield rates actually vary considerably.

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

Average pedestrian delay

\[ d_p = \sum_{i=1}^{n} h_i \left( \frac{1}{i} \right) \sum_{i=1}^{n} (1-P(Y_i)) + \left( \sum_{i=1}^{n} P(Y_i) \right) d_{pd} \]

where:
- \( d_p \) = average pedestrian delay (s)
- \( h_i \) = average headway for each through lane = N/i
- \( P(Y_i) \) = probability that motorists yield to pedestrian on crossing event \( i \)
- \( n \) = number of crossing events before an adequate gap is available, >0
- \( j \) = crossing event \( j = 0 \) to \( i+1 \)

Crossing 1:
- \( h_1 = 11 \) s
- \( h_2 = 12 \) s
- \( d_1 = \)...

Crossing 2:
- \( h_1 = 11 \) s
- \( h_2 = 12 \) s
- \( d_1 = \)...

Summary

Average: 1885.7 s

LOS: F

Step 6: Calculate Average Pedestrian Delay & Determine LOS

Calculating Sheet 2
Example 5: Four-Lane Divided Urban Highway Crossing

Site Review
Conduct a field review and take pedestrian/vehicle counts during the peak hours.

The crossing location is located on a four lane highway with medians. The median at the crossing doesn’t have a pedestrian platform because the crossing is currently unmarked.
**Uncontrolled Pedestrian Crossing**

**Data Collection Worksheet**

<table>
<thead>
<tr>
<th>Location:</th>
<th>Example 5: Four Lane Undivided Highway</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>City, State:</td>
<td></td>
<td>Noon Weekday Evaluation</td>
</tr>
<tr>
<td>Reviewer(s):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project #:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 | Crossing 1 52 ft. |
| Crossing 2 65 ft. |
| 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. |
| Median: width of median at crossing location | 10 ft. |
| Crossing Width: effective crosswalk width | 8 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 45 mph |
| Roadway Curvature and Sight Distances: | Average walking speed 5.6 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) | 360 ft. provided? Yes No |
| Direction 2: Stopping Sight Distance (SSD) | 360 ft. provided? Yes No |
| Direction 1: Pedestrian Sight Distance (PedSSD) | 813 ft. provided? Yes No |
| Direction 2: Pedestrian Sight Distance (PedSSD) | 966 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: Daily 11,200 pedestrians: Daily 2 |
| AM Peak Hourly | Pk 15-min | Hourly | Pk 15-min |
| PM Peak Hourly | 608 | 237 | Hourly | 2 |

### 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 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? Traffic Signal |
| Adjacent Facilities: | Distance to nearest marked crosswalk? 1,000 ft. |
| What pedestrian control devices are present at the nearest adjacent marked crosswalk? |
| Distance to nearest all-way stop, roundabout or signalized intersection 1,000 ft. |
| Could another location serve the same pedestrian crossing movement? Yes No |
| Could another location serve the movement more effectively? Yes No |

---

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**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 signing 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 origins and destinations.

**Notes:**
- Crossing location currently unsigned and unmarked.
- Median could be extended

**Sight Distance Calculations:**

Stopping sight distance (SSD), ft = $1.475t + 1.015S^2/s$

Pedestrian sight distance (PedSD), ft = $1.475L/S_p^2 + t$

where:
- $L$ = length of crossing, ft
- $S$ = design speed, mph
- $S_p$ = average pedestrian walking speed, ft/s
- $t$ = pedestrian start-up and end clearance time, s

where:
- $t = $brake reaction time, s$
- $a = $deceleration rate, ft/s^2$
- $S_p = $average pedestrian walking speed, ft/s$
- $t = $pedestrian start-up and end clearance time, s$

**Page 2 of 2**
Safety Review
No pedestrian crashes or rear-ends at the location within last ten years. Overall, there have been two crashes at this intersection over the last ten years. No conclusions made regarding crash data.

SSD, PedSD Calculation

\[ SSD = 360 \text{ ft} \]
\[ PedSD_{\text{total}} = 1,700 \text{ ft} \]

The SSD is met for this crossing, but PedSD is not.

HCM Analysis

**Midday Peak Hour**
Yield Rate = 0% (Unmarked Crossing)
\[ Delay = 3,026 \text{ sec} = LOS F \]

Result: Unacceptable Service Level, go to Step 6 of the Evaluation Flowchart.

Review Origins and Destinations, Alternate Routes

*Origins and Destinations*

The crossing connects the business parking lot to shopping/restaurant area. This crossing is a direct origin-destination connection because pedestrians would most likely not walk to the signalized intersection to the north to cross.

*Alternative Route Analysis*

Calculate how much time it would take for a pedestrian to walk to the nearest adjacent marked crossing, cross the roadway, and return to the location where they started.

This total amount of time will be compared to the average pedestrian delay (average measured wait time). The signalized intersection (1000 ft north of the crossing) will be used as the alternative route.

\[ \text{Total Time} = 601 \text{ sec} \]

*Average Measured Wait Time (Pedestrian Delay)*

\[ 3,026 \text{ sec with current crossing (from HCM Analysis)} \]

While the alternate route provides a faster time, it is still unacceptable, resulting in 10 minutes to travel the alternate route.

Result: There is not an acceptable alternative route near the crossing being studied and there is a direct origin-destination connection at the crossing. Go to step 7 of the evaluation flowchart.
Access Spacing and Functional Classification
The crossing is not located in a signalized corridor.

Speed and Pedestrian Use
The speed limit is 45 mph.

There were 2 pedestrians during the peak hour.

Result: Consider appropriate traffic calming treatments in conjunction with or without appropriate uncontrolled crossing treatments. Go to appropriate Step 10 of evaluation flowchart.

School Crossing
This is not a school crossing, go to Step 9.

FHWA Safety Guidance
Multi-lane with raised median, speed limit = 45 mph, ADT = 11,200. Results in N designation. Go to Step 11, Do Nothing or High Level Treatments.

Why do we go to this step if the median could be lengthened to reduce crossing distance?

Say the existing median is extended. As there is already a median along the roadway, it is anticipated that extension of the median would have little to no effect on motorist yielding. Repeat Step 4 of the Evaluation Flowchart.

Check PedSD with shorter crossing distances.

\[
P_{SB} = 813 \text{ ft} \\
P_{NB} = 966 \text{ ft} \\
\text{Delay} = 238 \text{ sec} = LOS F
\]

Result
Still Unacceptable Service Level.

The pedestrian volume is so low, that any additional treatments would likely not be cost effective. Additionally, the safety would likely be decreased, as consistent with FHWA study.

Do Nothing or High Level Treatment Options:
Based on the pedestrian counts, it is unlikely that any High Level Treatments would be justified. The vehicle counts in the area should be reviewed to determine if a signal could be justified based on the intersection turning movement counts. If not, the recommended option would be to do nothing, leave the crossing unmarked and unsigned.
2010 Highway Capacity Manual (HCM)
Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations
Intersection and Mid-Block Crossings

Crossing Location: Example 5  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:**

<table>
<thead>
<tr>
<th>Evaluation Inputs:</th>
<th>defaults:</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L ) = crosswalk length (ft)</td>
<td></td>
<td>( L = ) 127</td>
</tr>
<tr>
<td>( S_p ) = average pedestrian walking speed (ft/s)</td>
<td>( S_p = ) 3.5</td>
<td>( S_p = ) 5.6</td>
</tr>
<tr>
<td>( t_p ) = pedestrian start-up and end clearance time (s)</td>
<td>( t_p = ) 3.0</td>
<td>( t_p = ) 3</td>
</tr>
<tr>
<td>( V ) = vehicular hourly volume (veh/hr)</td>
<td>( V = ) 698</td>
<td>( V = ) 698</td>
</tr>
<tr>
<td>( \nu_p ) = pedestrian flow rate (pcd/s)</td>
<td>( \nu_p = ) 0*</td>
<td>( \nu_p = ) 0.00</td>
</tr>
<tr>
<td>( \nu ) = vehicular flow rate (veh/s) = ( V/3600 )</td>
<td>( \nu = ) V/3600</td>
<td>( \nu = ) ( V/3600 )</td>
</tr>
<tr>
<td>( W_c ) = crosswalk width (ft)</td>
<td>( W_c = ) 8.0</td>
<td>( W_c = ) 8.0</td>
</tr>
<tr>
<td>( N ) = number of lanes crossed (Integer)</td>
<td>( N = \text{INT}(L/11) )</td>
<td>( N = ) 4</td>
</tr>
</tbody>
</table>

*no platooning observed

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

<table>
<thead>
<tr>
<th>Evaluation Inputs:</th>
<th>defaults:</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L ) = crosswalk length (ft)</td>
<td></td>
<td>( L = )</td>
</tr>
<tr>
<td>( S_p ) = average pedestrian walking speed (ft/s)</td>
<td>( S_p = ) 3.5</td>
<td>( S_p = )</td>
</tr>
<tr>
<td>( t_p ) = pedestrian start-up and end clearance time (s)</td>
<td>( t_p = ) 3.0</td>
<td>( t_p = )</td>
</tr>
<tr>
<td>( V ) = vehicular hourly volume (veh/hr)</td>
<td>( V = )</td>
<td>( V = )</td>
</tr>
<tr>
<td>( \nu_p ) = pedestrian flow rate (pcd/s)</td>
<td>( \nu_p = ) 0*</td>
<td>( \nu_p = )</td>
</tr>
<tr>
<td>( \nu ) = vehicular flow rate (veh/s) = ( V/3600 )</td>
<td>( \nu = ) V/3600</td>
<td>( \nu = ) ( V/3600 )</td>
</tr>
<tr>
<td>( W_c ) = crosswalk width (ft)</td>
<td>( W_c = ) 8.0</td>
<td>( W_c = )</td>
</tr>
<tr>
<td>( N ) = number of lanes crossed (Integer)</td>
<td>( N = \text{INT}(L/11) )</td>
<td>( N = )</td>
</tr>
</tbody>
</table>

*no platooning observed

**Crossing Treatment Yield Rate**

\( M_p \) = motorist yield rate (decimal)

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

**Results:**

<table>
<thead>
<tr>
<th>Average Delay</th>
<th>3026.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
<td>F</td>
</tr>
</tbody>
</table>

Inputs and Results  
Page 2 of 5

Developed by Bolton Merk, Inc.  
for the Local Road Research Board.  

HCM Evaluation Worksheet
Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

Crossing Location: Example 5: Four Lane Divided Urban Highway
City, State: 
Reviewer(s): 
Data: Noon Peak Hour, Weekday
Scenario: 
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, does the median refuge need to meet ADA requirements (4' x 4' landing)? ☑ Yes ☐ No

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 sufficient for a safe crossing.

For a single pedestrian:

\[ t_c = \frac{L}{S_p} + t_e \]

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

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

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

\[ N_p = \frac{t_c \cdot \bar{v} \cdot e^{\frac{-\bar{v} \cdot t_c}{\bar{v}_p \cdot \bar{u}}}}{(t_c + \bar{v}) \cdot e^{\frac{-\bar{v} \cdot t_c}{\bar{v}_p \cdot \bar{u}}}} \]

where:
- \( N_p \) = total number of pedestrians in crossing platoon (ped)
- \( \bar{v}_p \) = pedestrian flow rate (ped/s)
- \( t_c = \) single pedestrian critical headway (s)
- \( \bar{u} = \) vehicular flow rate across crossing (veh/s)
- \( \bar{v} = \) single pedestrian critical headway (s)

2. Compute spatial distribution:

\[ N_p = \text{Int} \left( \frac{8.0 (N_1 - 1)}{W_c} \right) + 1 \]

where:
- \( N_p \) = spatial distributions of pedestrians (ped)
- \( N_1 = \) 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.

3. Compute group critical headway:

\[ t_{c,G} = t_c + 2(N_1 - 1) \]

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.

\[ P_b = 1 - e^{-t_{c,G}/N} \]

where:
- \( P_b = \) probability of blocked lane
- \( N = \) number of lanes crossed
- \( t_{c,G} = \) group critical headway (s)

\[ P_d = 1 - (1 - P_b)^N \]

where:
- \( P_d = \) probability of delayed crossing
- \( P_b = \) probability of blocked lane
- \( N = \) number of lanes crossed

Calculated Sheet 1
Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

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

\[ d_p = \frac{1}{\nu} \left( e^{\frac{t_{c,g}}{\nu}} - 1 \right) \]

where:
- \( d_p \) = average pedestrian delay (s)
- \( t_{c,g} \) = group critical headway (s)
- \( \nu \) = vehicular flow rate across crossing (veh/s)

### Step 4: Calculate Average Delay to Wait for Adequate Gap

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_{c,g} = \frac{25.68}{0.26} )</td>
<td>( t_{c,g} = \frac{3022.3}{0.26} )</td>
</tr>
</tbody>
</table>

\[ d_p = \frac{d_i}{p_i} \]

where:
- \( d_i \) = average gap delay for pedestrians who incur nonzero delay
- \( p_i \) = probability of a delayed crossing

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( d_i = 3022 )</td>
<td>( d_i = 3026.1 )</td>
</tr>
<tr>
<td>( p_i = 0.999 )</td>
<td>( p_i = 0.999 )</td>
</tr>
</tbody>
</table>

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 pass. While motorists are legally required to stop for crossing pedestrians in Minnesota at all marked crossings and either marked or unmarked crossings at intersections, motorist yield rates actually vary considerably.

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

Average pedestrian delay

\[ d_p = \sum_{i=1}^{m} \left( \frac{\bar{h} - 0.5}{\nu} P(Y_i) + \left( \frac{1}{\nu} \sum_{j=1}^{n} P(Y_j) \right) d_{gf} \right) \]

where:
- \( d_p \) = average pedestrian delay (s)
- \( \bar{h} \) = average headway for each through lane = \( N/1 \)
- \( P(Y_i) \) = probability that motorists yield to pedestrian on crossing event \( i \)
- \( P(Y_j) \) = probability that motorists yield to pedestrian on crossing event \( j \)

\[ \bar{h} = \text{Int}(d_{gf}/n), \text{average number of crossing events before an adequate gap is available}, >0 \]

1. One-Lane Crossing

\[ P(Y_j) = P_{ij} M_j (1-M_j)^{j-1} \]

2. Two-Lane Crossing

\[ P(Y_i) = 2P_i (1-P_i) M_j + 1P_i^2 M_j^2 \]

3. Three-Lane Crossing

\[ P(Y_i) = \left( P_{ij} - \sum_{j=1}^{m} P(Y_j) \right) + \left( \frac{1}{\nu} \sum_{j=1}^{m} P(Y_j) \right) \left( \frac{\bar{h}}{\nu} + \frac{1}{\nu} \left( \frac{1}{\nu} \sum_{j=1}^{m} P(Y_j) \right) \right) \]

4. Four-Lane Crossing

\[ P(Y_i) = \left( p_{ij} - \sum_{j=1}^{m} P(Y_j) \right) + \left( \frac{1}{\nu} \sum_{j=1}^{m} P(Y_j) \right) \left( \frac{\bar{h}}{\nu} + \frac{1}{\nu} \left( \frac{1}{\nu} \sum_{j=1}^{m} P(Y_j) \right) \right) \]

**Summary**

<table>
<thead>
<tr>
<th>Average</th>
<th>3026.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
<td>F</td>
</tr>
</tbody>
</table>

**Step 6: Calculate Average Pedestrian Delay & Determine LOS**

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

Calculated Sheet 2  
HCM Evaluation Worksheet

Developed by Bolton Merk, Inc.  
for the Local Road Research Board.
2010 Highway Capacity Manual (HCM)
Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations
Intersection and Mid-Block Crossings

Crossing Location: Example 5  Date: 
City, State: 
Reviewer(s): 
Project Number: 
Scenario: Staged Crossing
Agency: 
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: East

<table>
<thead>
<tr>
<th>Evaluation Inputs:</th>
<th>defaults:</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L ) = crosswalk length (ft)</td>
<td></td>
<td>( L = 52 )</td>
</tr>
<tr>
<td>( S_p ) = average pedestrian walking speed (ft/s)</td>
<td>3.5</td>
<td>( S_p = 5.6 )</td>
</tr>
<tr>
<td>( t_e ) = pedestrian start-up and end clearance time (s)</td>
<td>3.0</td>
<td>( t_e = 6 )</td>
</tr>
<tr>
<td>( V ) = vehicular hourly volume (veh/hr)</td>
<td></td>
<td>( V = 349 )</td>
</tr>
<tr>
<td>( v_p ) = pedestrian flow rate (ped/s)</td>
<td>0*</td>
<td>( v_p = 0.00 )</td>
</tr>
<tr>
<td>( v ) = vehicular flow rate (veh/s) = ( V/3600 )</td>
<td>( V/3600 )</td>
<td>( v = 0.26 )</td>
</tr>
<tr>
<td>( W_e ) = crosswalk width (ft)</td>
<td>8.0</td>
<td>( W_e = 8.0 )</td>
</tr>
<tr>
<td>( N ) = number of lanes crossed (Integer)</td>
<td>INT(L/11)</td>
<td>( N = 2 )</td>
</tr>
</tbody>
</table>

### Crossing 2: West

(only used for two-stage crossings)

<table>
<thead>
<tr>
<th>Evaluation Inputs:</th>
<th>defaults:</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L ) = crosswalk length (ft)</td>
<td></td>
<td>( L = 65 )</td>
</tr>
<tr>
<td>( S_p ) = average pedestrian walking speed (ft/s)</td>
<td>3.5</td>
<td>( S_p = 6 )</td>
</tr>
<tr>
<td>( t_e ) = pedestrian start-up and end clearance time (s)</td>
<td>3.0</td>
<td>( t_e = 3 )</td>
</tr>
<tr>
<td>( V ) = vehicular hourly volume (veh/hr)</td>
<td></td>
<td>( V = 349 )</td>
</tr>
<tr>
<td>( v_p ) = pedestrian flow rate (ped/s)</td>
<td>0*</td>
<td>( v_p = 0.00 )</td>
</tr>
<tr>
<td>( v ) = vehicular flow rate (veh/s) = ( V/3600 )</td>
<td>( V/3600 )</td>
<td>( v = 0.26 )</td>
</tr>
<tr>
<td>( W_e ) = crosswalk width (ft)</td>
<td>8.0</td>
<td>( W_e = 8.0 )</td>
</tr>
<tr>
<td>( N ) = number of lanes crossed (Integer)</td>
<td>INT(L/11)</td>
<td>( N = 2 )</td>
</tr>
</tbody>
</table>

### Crossing Treatment Yield Rate

\( M_p \) = motorist yield rate (decimal)

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

### Results:

<table>
<thead>
<tr>
<th>Average Delay</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
</tr>
</tbody>
</table>

Inputs and Results  Page 2 of 5

Developed by Bolton Merk, Inc.
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HCM Evaluation Worksheet

155
## Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

### Step 1: Identify Two-Stage Crossings

**Crossing Location:** Example 5: Four Lane Divided Urban Highway  
**Data:**  
**Scenario:** Staged Crossing  
**Agency:**  

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is there a median available for a two-stage crossing?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If yes, does the median refuge meet ADA requirements (4’ x 4’ landing)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If yes, does the median refuge need to meet ADA requirements (4’ x 4’ landing)?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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 sufficient 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)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L ) = 52</td>
<td>( L ) = 65</td>
</tr>
<tr>
<td>( S_p ) = 5.6</td>
<td>( S_p ) = 5.6</td>
</tr>
<tr>
<td>( t_c ) = 12.3</td>
<td>( t_c ) = 14.6</td>
</tr>
</tbody>
</table>

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

1. **Use field observations or estimate platoon size using equation**

\[ N_p = \frac{\nu_p e^{-\nu_p t_c}}{\nu_p + \nu} \]

Where:
- \( N_p \) = total number of pedestrians in crossing platoon (ped)
- \( \nu_p \) = pedestrian flow rate (ped/s)
- \( \nu \) = vehicular flow rate across crossing (veh/s)
- \( t_c \) = single pedestrian critical headway (s)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \nu_p ) = 0.26</td>
<td>( \nu_p ) = 0.26</td>
</tr>
<tr>
<td>( N_p ) =</td>
<td>( N_p ) =</td>
</tr>
</tbody>
</table>

2. **Compute spatial distribution**

\[ N_p = \int \left[ \frac{8.0(N_p-1)}{W_c} \right] + 1 \]

Where:
- \( N_p \) = spatial distributions of pedestrians (ped)
- \( W_c \) = crosswalk width (ft)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N_p ) =</td>
<td>( N_p ) =</td>
</tr>
</tbody>
</table>

3. **Compute group critical headway**

\[ t_{G} = t_c + 2(N_p-1) \]

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_{c,G} ) = 12.3</td>
<td>( t_{c,G} ) = 14.6</td>
</tr>
</tbody>
</table>

### Step 2: Determine Critical Headway

### 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.**

\[ P_b = 1 - e^{-t_{c,G}/N} \]

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

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \nu ) = 0.26</td>
<td>( \nu ) = 0.26</td>
</tr>
<tr>
<td>( P_b ) = 0.8</td>
<td>( P_b ) = 0.85</td>
</tr>
<tr>
<td>( N ) = 2</td>
<td>( N ) = 2</td>
</tr>
<tr>
<td>( P_d ) = 0.96</td>
<td>( P_d ) = 0.98</td>
</tr>
</tbody>
</table>

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for the Local Road Research Board.

HCM Evaluation Worksheet
Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

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

$$d_p = \frac{1}{v} \left( e^{\frac{u}{v} d_p} - 1 \right)$$

where:
- $$d_p$$ = average pedestrian gap delay (s)
- $$t_{c0}$$ = group critical headway (s)
- $$u$$ = vehicular flow rate across crossing (veh/s)

### Step 4: Calculate Average Delay to Wait for Adequate Gap

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>$$t_{c0}$$ = 12.29</td>
<td>$$t_{c0}$$ = 14.61</td>
<td>$$t_{c0}$$ = 26.90</td>
</tr>
<tr>
<td>$$u$$ = 0.26</td>
<td>$$u$$ = 0.26</td>
<td>$$u$$ = 0.26</td>
</tr>
<tr>
<td>$$d_p$$ = 77.69</td>
<td>$$d_p$$ = 153.11</td>
<td>$$d_p$$ = 230.79</td>
</tr>
<tr>
<td>$$P_p = 0.959$$</td>
<td>$$P_p = 0.978$$</td>
<td>$$P_p = 0.973$$</td>
</tr>
</tbody>
</table>

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

$$d_{ad} = \frac{d_p}{P_p}$$

where:
- $$d_{ad}$$ = average gap delay for pedestrians who incur nonzero delay

### Step 5: Estimate Delay Reduction due to Yielding Vehicles

(If yielding is zero, then skip step 5)

1. One-Lane Crossing

$$P(Y_j) = P_j M_j (1 - M_j)^{j-1}$$

2. Two-Lane Crossing

$$P(Y_j) = 2P_j (1 - P_j) M_j + 2P_j^2 M_j^2 + 2P_j^3 M_j^3$$

3. Three-Lane Crossing

$$P(Y_j) = \frac{1}{P_p} \sum_{i=1}^{j-1} P(Y_i) M_j (1 - P_j)^{i-1}$$

4. Four-Lane Crossing

$$P(Y_j) = \frac{1}{P_p} \sum_{i=1}^{j-1} P(Y_i) M_j (1 - P_j)^{i-1}$$

### Step 6: Calculate Average Pedestrian Delay & Determine LOS

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

Summary

<table>
<thead>
<tr>
<th>Average</th>
<th>237.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
<td>F</td>
</tr>
</tbody>
</table>

Developed by Bolton Monk, Inc. for the Local Road Research Board.

HCM Evaluation Worksheet
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Example 6: Four-Lane Divided Urban High Pedestrian Use Crossing

Site Review
Conduct a field review and take pedestrian/vehicle counts during the peak hours.

The crossing location is located is on a four lane roadway with medians. The median at the crossing doesn’t have a pedestrian platform and is currently not extended to the crosswalk. **There are two flashing beacons at the crossing along with pavement markings and signs.**
Complete Field Review Worksheet.

---

**Uncontrolled Pedestrian Crossing**

**Data Collection Worksheet**

| Location: | Example 6 | Date: | Noon Weekday |
| City, State: | | | |
| Reviewer(s): | | | |
| Project #: | | | |

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. 
  - Crossing 1: 118 ft.
  - Crossing 2: ft.
  - 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.
- **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
  - 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.

### Traffic and Pedestrian Data

<table>
<thead>
<tr>
<th>Direction 1: Stopping Sight Distance (SSD)</th>
<th>Direction 2: Stopping Sight Distance (SSD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>301 ft. provided?</td>
<td>Yes No</td>
</tr>
<tr>
<td>Direction 1: Pedestrian Sight Distance (PedSSD)</td>
<td>Direction 2: Pedestrian Sight Distance (PedSSD)</td>
</tr>
<tr>
<td>1415 ft. provided?</td>
<td>Yes No</td>
</tr>
</tbody>
</table>

### 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?** Continental

### Signs:

- **Currently signed at crosswalk?** Yes No
- **Currently signed in advance of crosswalk?** Yes No

### Distances:

<table>
<thead>
<tr>
<th>Distance</th>
<th>Direction 1</th>
<th>ft.</th>
<th>Direction 2</th>
<th>498 ft.</th>
</tr>
</thead>
</table>

### Enhancements:

- **What enhancements are currently at the crossing location?** Pedestrian Flasher System, Side Mounted

### Adjacent Facilities:

- **Distance to nearest marked crosswalk?** 820 ft.

- **What pedestrian control devices are present at the nearest adjacent marked crosswalk?** Traffic Signal

- **Distance to nearest all-way stop, roundabout or signalized intersection?** 820 ft.

- **Could another location serve the same pedestrian crossing movement?** Yes No

- **Could another location serve the movement more effectively?** Yes No

---

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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 origins and destinations.

draw or insert map of location being studied

Notes: Crossing currently signed and marked. Flashing beacons pedestrian actuated. Crossing updated as compared to aerial with flashers, updated markings, and median cut-through.

Sight Distance Calculations:

- Stopping sight distance (SSD), ft = 1.475t + 1.615S^2/a
- Pedestrian sight distance (PedSD), ft = 1.475L / [S_p - t] + L

where:
- t = brake reaction time, s
- a = deceleration rate, ft/s^2
- S_p = average pedestrian walking speed, ft/s
- L = length of crossing, ft

<table>
<thead>
<tr>
<th>Sight Distance Calculation</th>
<th>where:</th>
<th>defaults:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stopping sight distance (SSD), ft = 1.475t + 1.615S^2/a</td>
<td>t = brake reaction time, s</td>
<td>2.5</td>
</tr>
<tr>
<td>Pedestrian sight distance (PedSD), ft = 1.475L / [S_p - t] + L</td>
<td>a = deceleration rate, ft/s^2</td>
<td>11.2</td>
</tr>
<tr>
<td></td>
<td>S_p = average pedestrian walking speed, ft/s</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>L = length of crossing, ft</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Uncontrolled Pedestrian Crossing Data Collection Worksheet

Location: Example 6  
City, State:  
Reviewer(s):  
Scenario: Noon Weekday, Staged Crossing  
Agency:  
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

<table>
<thead>
<tr>
<th>Crossing Length: Measure the crossing distance from curb to curb.</th>
<th>Crossing 1</th>
<th>50 ft.</th>
<th>Crossing 2</th>
<th>60 ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median: width of median at crossing location</td>
<td>8 ft.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crossing Width: effective crosswalk width</td>
<td>6 ft.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raised Median Available?</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADA Compliant Median Available (minimum 4' x 4' landing)?</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curb Ramps Available?</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADA Compliant Curb Ramp Available (width, grades, truncated domes)?</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed: Post or 85th percentile speed</td>
<td>40 mph</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roadway Curvature and Sight Distances: Average walking speed</td>
<td>5.6 ft/s</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is the crossing location within a horizontal or vertical curve?</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Equations to calculate the following are located on the next page.

| Direction 1: Stopping Sight Distance (SSD) | 301 ft. | provided? | Yes | No |
| Direction 2: Stopping Sight Distance (SSD) | 301 ft. | provided? | Yes | No |
| Direction 1: Pedestrian Sight Distance (PedSD) | 701 ft. | provided? | Yes | No |
| Direction 2: Pedestrian Sight Distance (PedSD) | 806 ft. | provided? | Yes | No |

### Traffic and Pedestrian Data

<table>
<thead>
<tr>
<th>Attach Counts</th>
<th>vehicles: Daily 8,900</th>
<th>pedestrians: Daily 29</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM Peak</td>
<td>Hourly 632</td>
<td>Pk 15-min 252</td>
</tr>
<tr>
<td>PM Peak</td>
<td>Hourly 632</td>
<td>Pk 15-min 252</td>
</tr>
</tbody>
</table>

### 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?

- Continental

### Signing:

| Currently signed at crosswalk? | Yes | No |

Currently signed in advance of crosswalk?

- Yes
- No

### Enhancements:

- What enhancements are currently at the crossing location?
  - Pedestrian Flasher System, Side Mounted

### Adjacent Facilities:

| Distance to nearest marked crosswalk? | 820 ft. |

What pedestrian control devices are present at the nearest adjacent marked crosswalk?

- Traffic Signal

Distance to nearest all-way stop, roundabout or signalized intersection

- 820 ft.

Could another location serve the same pedestrian crossing movement?

- Yes
- No

Could another location serve the movement more effectively?

- Yes
- No

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Safety Review
No pedestrian crashes at the location within last ten years. There were five rear-end crashes and 22 crashes over the last ten years. Motorists may not be seeing the pedestrians until too late. The pedestrian crossing flashers were recently installed so data may indicate need before flashers were installed.

SSD, PedSD Calculation

\[
SSD = 301 \text{ ft} \\
PedSD_{\text{unstaged}} = 1,415 \text{ ft} \\
PedSD_{SB} = 701 \text{ ft} \\
PedSD_{NB} = 806 \text{ ft}
\]

The SSD is met for this crossing. PedSD is not, unless it becomes a staged crossing.

HCM Analysis
No yielding rate available for pedestal mounted flashing beacons on a multi-lane highway, but there is likely some yielding. For purposes of this analysis, it is estimated to be 25%, one half the yield rate of overhead beacons.

\[
\text{Midday Peak Hour} \\
\text{Yield Rate} = 25\% \text{ (Flashing Beacons)} \\
Delay \Rightarrow 10000 \text{ sec} = LOS F
\]

Result: Unacceptable Service Level, go to step 6 of the evaluation flowchart.

Review Origins and Destinations, Alternate Routes
Alternative routing not considered since it is important enough based on the presence of pedestrian flasher system that was just recently installed.

Go to step 7 of the evaluation flowchart.

Access Spacing and Functional Classification
The crossing is not located in a signalized corridor.

Speed and Pedestrian Use
The speed limit is 40 mph.

There were 29 pedestrians during the peak hour.

Go to appropriate Step 9 of evaluation flowchart.

FHWA Safety Guidance
Vehicle ADT < 9,000
Roadway Type: Multilane with raised median
Speed: 40 mph
Result: P, Marked Crosswalks alone are insufficient

Go to Appropriate Step 11 of evaluation flowchart.

Traffic Calming Treatment Options
Based on the FHWA Safety Guidance, the median is likely to produce some improvement by shortening the crossing distance and bring it into the P designation versus N designation as far as safety is concerned. The existing median could be extended. As there is already a median along the roadway, it is anticipated that extension of the median would have little to no effect on motorist yielding. Additionally, due to the multi-lane facility, overhead beacons could provide additional benefit.

Repeat Step 4 of the Evaluation Flowchart.

\[ Delay = 57 \text{ sec} = LOS F \]

Result: Unacceptable Service Level. Still LOS F, but delay reduced substantially.

An option would be to replace the beacons with RRFBs if you are already thinking of installing overhead beacons.

Repeat Step 4 of the Evaluation Flowchart.

\[ Delay = 13 \text{ sec} = LOS C \]
2010 Highway Capacity Manual (HCM)
Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations
Intersection and Mid-Block Crossings

Crossing Location: Example 6  Date: 
City, State: Scenario: Unstaged Crossing
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: South Side
Evaluation Inputs:
L = crosswalk length (ft)
S_p = average pedestrian walking speed (ft/s)
t_s = pedestrian start-up and end clearance time (s)
V = vehicular hourly volume (veh/hr)
\( u_p \) = pedestrian flow rate (ped/s)
\( u \) = vehicular flow rate (veh/s) = V/3600
W_c = crosswalk width (ft)
N = number of lanes crossed (Integer)

defaults:
L = 118
S_p = 3.5
\( t_s \) = 3.0
V = 632
\( u_p \) = 0*
\( u \) = V/3600
W_c = 8.0
N = INT(L/11)

Input Table:
\( L \) = 118
\( S_p \) = 3.5
\( t_s \) = 3.0
V = 632
\( u_p \) = 0*
\( u \) = V/3600
W_c = 8.0
N = INT(L/11)

*no platooning observed

Crossing 2: (only used for two-stage crossings)
Evaluation Inputs:
L = crosswalk length (ft)
S_p = average pedestrian walking speed (ft/s)
t_s = pedestrian start-up and end clearance time (s)
V = vehicular hourly volume (veh/hr)
\( u_p \) = pedestrian flow rate (ped/s)
\( u \) = vehicular flow rate (veh/s) = V/3600
W_c = crosswalk width (ft)
N = number of lanes crossed (Integer)

defaults:
L = 
S_p = 3.5
\( t_s \) = 3.0
V = 
\( u_p \) = 0*
\( u \) = V/3600
W_c = 8.0
N = INT(L/11)

Input Table:
\( L \) = 
\( S_p \) = 3.5
\( t_s \) = 3.0
V = 
\( u_p \) = 0*
\( u \) = V/3600
W_c = 8.0
N = INT(L/11)

*no platooning observed

Crossing Treatment Yield Rate
\( M_y \) = motorist yield rate (decimal)

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

Results:

<table>
<thead>
<tr>
<th>Average Delay</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
</tr>
</tbody>
</table>

HCM Evaluation Worksheet

Developed by Bolton Merli, Inc.
for the Local Road Research Board.

Inputs and Results Page 2 of 5

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## Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

### Step 1: Identify Two-Stage Crossings

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 sufficient for a safe crossing.

For a single pedestrian:

\[ t_c = \frac{L}{S_p} + t_e \]

- L = crosswalk length (ft)
- \( S_p \) = average pedestrian walking speed (ft/s)
- \( t_e \) = pedestrian start-up and end clearance time (s)
- \( t_c \) = critical headway for a single pedestrian (s)

<table>
<thead>
<tr>
<th>Crossing</th>
<th>( L )</th>
<th>( S_p )</th>
<th>( t_e )</th>
<th>( t_c )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing 1</td>
<td>118</td>
<td>5.6</td>
<td>24.1</td>
<td>30.7</td>
</tr>
<tr>
<td>Crossing 2</td>
<td>241</td>
<td>5.6</td>
<td>24.1</td>
<td>30.7</td>
</tr>
</tbody>
</table>

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

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

\[ N_p = \frac{v_p \delta}{(v + \delta) \rho} \]

- \( N_p \) = total number of pedestrians in crossing platoon (ped)
- \( v_p \) = pedestrian flow rate (ped/s)
- \( \delta \) = vehicular flow rate across crossing (veh/s)
- \( \rho \) = single pedestrian critical headway (s)

<table>
<thead>
<tr>
<th>Crossing</th>
<th>( v_p )</th>
<th>( \delta )</th>
<th>( \rho )</th>
<th>( N_p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing 1</td>
<td>0.18</td>
<td>0.28</td>
<td>8.0</td>
<td>400</td>
</tr>
<tr>
<td>Crossing 2</td>
<td>0.18</td>
<td>0.28</td>
<td>8.0</td>
<td>400</td>
</tr>
</tbody>
</table>

2. Compute spatial distribution:

\[ N_p = \text{Int} \left( \frac{8.0(N_p-1)}{W_c} \right) + 1 \]

- \( N_p \) = total number of pedestrians in crossing platoon (ped)
- \( N_p \) = total number of pedestrians in crossing platoon (ped)
- \( W_c \) = crosswalk width (ft)
- \( \delta \) = default clear width used by a single pedestrian to avoid interference with other pedestrians (ft)
- \( N_p \) = spatial distributions of pedestrians (ped)

<table>
<thead>
<tr>
<th>Crossing</th>
<th>( W_c )</th>
<th>( N_p )</th>
<th>( N_p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing 1</td>
<td>331</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>Crossing 2</td>
<td>6</td>
<td>440</td>
<td>400</td>
</tr>
</tbody>
</table>

3. Compute group critical headway:

\[ t_{c,g} = t_c + 2(N_p-1) \]

- \( t_{c,g} \) = group critical headway (s)
- \( N_p \) = spatial distributions of pedestrians (ped)

<table>
<thead>
<tr>
<th>Crossing</th>
<th>( t_c )</th>
<th>( t_{c,g} )</th>
<th>( N_p )</th>
<th>( N_p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing 1</td>
<td>24.1</td>
<td>902</td>
<td>440</td>
<td>440</td>
</tr>
<tr>
<td>Crossing 2</td>
<td>24.1</td>
<td>902</td>
<td>440</td>
<td>440</td>
</tr>
</tbody>
</table>

### Step 2: Determine Critical Headway

### 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.

\[ P_b = 1 - (1-P_d)^N \]

- \( P_b \) = probability of blocked lane
- \( P_d \) = probability of delayed crossing
- \( N \) = number of lanes crossed

<table>
<thead>
<tr>
<th>Crossing</th>
<th>( t_{c,g} )</th>
<th>( P_b )</th>
<th>( P_d )</th>
<th>( N )</th>
<th>( P_b )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing 1</td>
<td>902</td>
<td>1</td>
<td>0.28</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>
### 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.

\[
d_d = \frac{1}{v} \left( e^{\frac{v \cdot t_{c,0}}{u}} - 1 \right)
\]

where:
- \( d_d \) = average pedestrian delay (s)
- \( t_{c,0} \) = group critical headway (s)
- \( u \) = vehicular flow rate across crossing (veh/s)

**Crossing 1**

\[
t_{c,0} = 9.02 \quad d_d = 16E+10
\]

**Crossing 2**

\[
t_{c,0} = 2E+110 \quad d_d =
\]

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

\[
d_{pd} = \frac{d_d}{P_d}
\]

where:
- \( d_{pd} \) = average gap delay for pedestrians who incur nonzero delay

**Crossing 1**

\[
P_d = 1 \quad d_{pd} = 16E+10
\]

**Crossing 2**

\[
P_d = d_{pd} =
\]

**Step 5: Estimate Delay Reduction due to Yielding Vehicles**

(If yielding is zero, then skip step 5)

Average pedestrian delay

\[
d_p = \sum_{i=1}^{n} \left[ (1 - 0.5) P(Y_{ij}) + P_p \sum_{j=1}^{n} P(Y_{ij}) \right] d_{pd}
\]

where:
- \( d_p \) = average pedestrian delay (s)
- \( n \) = crossing event (1 to \( n \))
- \( \bar{h} \) = average headway for each through lane = \( N / v \)
- \( P(Y_{ij}) \) = probability that motorists yield to pedestrian on crossing event \( i \)
- \( r_i = \ln(d_{pd}) / h_i \), average number of crossing events before an adequate gap is available, \( > 0 \)
- \( j \) = crossing event (0 to \( i - 1 \))
- \( P(Y_{ij}) \) = probability that motorists yield to pedestrian on crossing event \( j \)

1. One-Lane Crossing

\[
P(Y_{i}) = P_p M_p (1 - M_p)^{i-1}
\]

2. Two-Lane Crossing

\[
P(Y_{i}) = 2P_p (1 - P_p) M_p + P_p^2 M_p^2
\]

3. Three-Lane Crossing

\[
P(Y_{i}) = \left( P_p - \sum_{j=1}^{i-1} P(Y_{ij}) \right) + P_p^2 M_p^2 + P_p (1 - P_p) M_p^2 + P_p^2 (1 - P_p) M_p^2
\]

4. Four-Lane Crossing

\[
P(Y_{i}) = \left( P_p - \sum_{j=1}^{i-1} P(Y_{ij}) \right) + P_p^4 M_p^2 + 4P_p^2 (1 - P_p) M_p^2 + 6P_p^2 (1 - P_p) M_p^2 + 4P_p (1 - P_p^2) M_p^2
\]

**Summary**

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

Calculations Sheet 2 | HCM Evaluation Worksheet | Page 4 of 5
### 2010 Highway Capacity Manual (HCM)

**Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations**

**Intersection and Mid-Block Crossings**

<table>
<thead>
<tr>
<th>Crossing Location:</th>
<th>Example 6</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>City, State:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reviewer(s):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Number:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ID #:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario:</td>
<td>Staged Crossing, Overhead Beacons</td>
<td></td>
</tr>
</tbody>
</table>

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: West

<table>
<thead>
<tr>
<th>Evaluation Inputs:</th>
<th>defaults:</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L ) = crosswalk length (ft)</td>
<td>( S_p = 3.5 )</td>
<td>( L = 50 )</td>
</tr>
<tr>
<td>( S_p ) = average pedestrian walking speed (ft/s)</td>
<td>( t_e = 3.0 )</td>
<td>( S_p = 5.6 )</td>
</tr>
<tr>
<td>( t_e ) = pedestrian start-up and end clearance time (s)</td>
<td>( V = 316 )</td>
<td>( t_e = 3 )</td>
</tr>
<tr>
<td>( V ) = vehicular hourly volume (veh/hr)</td>
<td>( \nu_p ) = 0*</td>
<td>( V = 316 )</td>
</tr>
<tr>
<td>( \nu_p ) = pedestrian flow rate (ped/s)</td>
<td>( \nu = V/3600 )</td>
<td>( \nu_p = 0.18 )</td>
</tr>
<tr>
<td>( \nu ) = vehicular flow rate (veh/s) = ( V/3600 )</td>
<td>( W_e ) = 8.0</td>
<td>( \nu = 0.280 )</td>
</tr>
<tr>
<td>( W_e ) = crosswalk width (ft)</td>
<td>( N = \text{INT}(L/11) )</td>
<td>( W_e = 6.0 )</td>
</tr>
<tr>
<td>( N ) = number of through lanes crossed (integer)</td>
<td>( N = 2 )</td>
<td>*no plateothing observed</td>
</tr>
</tbody>
</table>

#### Crossing 2: East

(only used for two-stage crossings)

<table>
<thead>
<tr>
<th>Evaluation Inputs:</th>
<th>defaults:</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L ) = crosswalk length (ft)</td>
<td>( S_p = 3.5 )</td>
<td>( L = 50 )</td>
</tr>
<tr>
<td>( S_p ) = average pedestrian walking speed (ft/s)</td>
<td>( t_e = 3.0 )</td>
<td>( S_p = 6 )</td>
</tr>
<tr>
<td>( t_e ) = pedestrian start-up and end clearance time (s)</td>
<td>( V = 316 )</td>
<td>( t_e = 3 )</td>
</tr>
<tr>
<td>( V ) = vehicular hourly volume (veh/hr)</td>
<td>( \nu_p ) = 0*</td>
<td>( V = 316 )</td>
</tr>
<tr>
<td>( \nu_p ) = pedestrian flow rate (ped/s)</td>
<td>( \nu = V/3600 )</td>
<td>( \nu_p = 0.18 )</td>
</tr>
<tr>
<td>( \nu ) = vehicular flow rate (veh/s) = ( V/3600 )</td>
<td>( W_e ) = 8.0</td>
<td>( \nu = 0.28 )</td>
</tr>
<tr>
<td>( W_e ) = crosswalk width (ft)</td>
<td>( N = \text{INT}(L/11) )</td>
<td>( W_e = 6.0 )</td>
</tr>
<tr>
<td>( N ) = number of through lanes crossed (integer)</td>
<td>( N = 2 )</td>
<td>*no plateothing observed</td>
</tr>
</tbody>
</table>

#### Crossing Treatment Yield Rate

\( M_y \) = motorist yield rate (decimal)

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

### Results:

<table>
<thead>
<tr>
<th>Average Delay</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>57.2</td>
<td>F</td>
</tr>
</tbody>
</table>

**Inputs and Results**

Page 2 of 5
### Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

**Crossing Location:** Example 6  
**City, State:**  
**Reviewer(s):**  
**Data:**  
**Scenario:** Staged Crossing with Overhead Beacons  
**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, does the median refuge need to meet ADA requirements (4’ x 4’ landing)?**  
  - Yes  
  - No

**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 sufficient for a safe crossing.**

For a single pedestrian:

\[ t_c = \frac{L}{S_p} + t_e \]

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>L = 50 ft</td>
<td>L = 60 ft</td>
</tr>
<tr>
<td>S_p = 5.6 ft/s</td>
<td>S_p = 5.6 ft/s</td>
</tr>
<tr>
<td>t_c = 3.3 sec</td>
<td>t_c = 3.7 sec</td>
</tr>
</tbody>
</table>

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

1. **Use field observations or estimate platoon size using equation:**

\[ N_p = \frac{\nu_p}{\nu + \nu_c} \times \frac{t_c}{t} \]

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \nu_p = 0.18 )</td>
<td>( \nu_p = 0.18 )</td>
</tr>
<tr>
<td>( t_c = 11.9 ) sec</td>
<td>( t_c = 13.7 ) sec</td>
</tr>
<tr>
<td>( N_p = 11.1 )</td>
<td>( N_p = 13.7 )</td>
</tr>
</tbody>
</table>

2. Compute spatial distribution:

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

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N_p = 11.1 )</td>
<td>( N_p = 18.3 )</td>
</tr>
<tr>
<td>( W_c = 6 ) ft</td>
<td>( W_c = 6 ) ft</td>
</tr>
</tbody>
</table>

3. Compute group critical headway:

\[ t_{g,c} = t_c + 2(N_p - 1) \]

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N_p = 14 )</td>
<td>( N_p = 24 )</td>
</tr>
<tr>
<td>( t_c = 11.9 ) sec</td>
<td>( t_c = 13.7 ) sec</td>
</tr>
<tr>
<td>( t_{g,c} = 37.9 ) sec</td>
<td>( t_{g,c} = 59.7 ) sec</td>
</tr>
</tbody>
</table>

#### Step 2: Determine Critical Headway

**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.**

\[ P_b = 1 - e^{-t_{g,c}/N} \]

\[ P_d = 1 - (1-P_b)^N \]

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_{g,c} = 37.9 ) sec</td>
<td>( t_{g,c} = 59.7 ) sec</td>
</tr>
<tr>
<td>( \nu = 0.28 ) veh/lane</td>
<td>( \nu = 0.28 ) veh/lane</td>
</tr>
<tr>
<td>( N = 2 ) lanes</td>
<td>( N = 2 ) lanes</td>
</tr>
<tr>
<td>( P_b = 1 )</td>
<td>( P_b = 1 )</td>
</tr>
<tr>
<td>( P_d = 1 )</td>
<td>( P_d = 1 )</td>
</tr>
</tbody>
</table>

**Calculations Sheet 1**
### 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.

\[
d_d = \frac{1}{U} \left( e^{\frac{U}{V}} - 1 \right)
\]

where:
- \( d_d \) = average pedestrian gap delay (s)
- \( v \) = vehicular flow rate across crossing (veh/s)
- \( U \) = group critical headway (s)
- \( t_{c,0} \) = crossing 1
- \( t_{c,1} \) = crossing 2

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_{c,0} ) = 37.93</td>
<td>( t_{c,1} ) = 37.93</td>
</tr>
<tr>
<td>( U ) = 0.28</td>
<td>( U ) = 0.28</td>
</tr>
</tbody>
</table>

\[
d_d = \frac{d_d}{P_d}
\]

where:
- \( d_d \) = average gap delay for pedestrians who incur nonzero delay
- \( P_d \) = probability of a delayed crossing

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( d_d ) = 1E+05</td>
<td>( d_d ) = 7E+07</td>
</tr>
<tr>
<td>( P_d ) = 1</td>
<td>( P_d ) = 1</td>
</tr>
</tbody>
</table>

**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 MD at all marked crossings and either marked or unmarked crossings at intersections, motorist yield rates actually vary considerably.

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

Average pedestrian delay

\[
d_d = \sum_{i=1}^{n} \left( 1 - 0.5P(Y_i) + \left( P_d \sum_{i=1}^{n} P(Y_i) \right) \right)\Delta t
\]

where:
- \( d_d \) = average pedestrian delay (s)
- \( \Delta t \) = crossing event \( i \) \(= 1 \) to \( n \)
- \( h_i \) = average headway for each through lane \( = N_i/h_i \)
- \( P(Y_i) \) = probability that motorists yield to pedestrian on crossing event \( i \)
- \( n_i \) = Int(\( d_d/h_i \)), average number of crossing events before an adequate gap is available, \( > 0 \)
- \( j \) = crossing event \( j = 0 \) to \( i-1 \)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( h_i ) = 7.1</td>
<td>( h_i ) = 7.1</td>
</tr>
<tr>
<td>( \tau_i ) = 20467</td>
<td>( \tau_i ) = 9E+06</td>
</tr>
<tr>
<td>( d_d ) = 28.4</td>
<td>( d_d ) = 28.7</td>
</tr>
</tbody>
</table>

1. One-Lane Crossing

\[ P(Y_i) = P_d M_y(1-M_y)^{i-1} \]

2. Two-Lane Crossing

\[ P(Y_i) = 2P_d(1-P_d)M_y + 1P_d^2M_y^2 \]

3. Three-Lane Crossing

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

4. Four-Lane Crossing

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

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

**Summary**

- Average: 57.2 sec/ped
- LOS: F

Developed by Bolton Monk, Inc. for the Local Road Research Board.

HCM Evaluation Worksheet
## 2010 Highway Capacity Manual (HCM)

### Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations

#### Intersection and Mid-Block Crossings

<table>
<thead>
<tr>
<th>Crossing Location:</th>
<th>Example 6</th>
<th>Date:</th>
</tr>
</thead>
</table>

| City, State: | | Scenario: Staged Crossing, Overhead RRFBs |
| 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: West

#### Evaluation Inputs:

<table>
<thead>
<tr>
<th>Default Value</th>
<th>Input Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>316</td>
<td></td>
</tr>
<tr>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>INT(L/11)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

### Crossing 2: East

#### Evaluation Inputs:

<table>
<thead>
<tr>
<th>Default Value</th>
<th>Input Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>316</td>
<td></td>
</tr>
<tr>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>INT(L/11)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

*no platooning observed*

### Crossing Treatment Yield Rate

\[ M_y = \text{motorist yield rate (decimal)} \]

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

### Results:

| Average Delay | 13.1 |
| LOS | C |

Inputs and Results Page 2 of 5

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for the Local Road Research Board.

HCM Evaluation Worksheet
### Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

**Crossing Location:** Example 6  
**Data:** Staged Crossing with Overhead RRFBs  
**City, State:**  
**Reviewers:**  
**Agency:**  
**Scenario:**  

#### Step 1: Identify Two-Stage Crossings

**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 sufficient for a safe crossing.

For a single pedestrian:

\[
\text{headway} = \frac{L}{S_p} + t_e
\]

- \(L\) = crosswalk length (ft)
- \(S_p\) = average pedestrian walking speed (ft/s)
- \(t_e\) = pedestrian start-up and end clearance time (s)

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

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

\[
N_p = \frac{v_p e^{\frac{t_c - L}{v + u}}}{(v_p + u)e^{\frac{t_c - L}{v + u}}} \]

where:
- \(N_p\) = 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)

#### Step 2: Determine Critical Headway

2. Compute spatial distribution:

\[
N_p = \text{Int}\left(\frac{8.0(N_p - 1)}{W_G}\right) + 1
\]

where:
- \(N_p\) = spatial distributions of pedestrians (ped)
- \(W_G\) = total number of pedestrians in crossing platoon (ped)

3. Compute group critical headway:

\[
t_{cG} = t_e + 2(N_p - 1)
\]

#### 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.**

\[
P_b = 1 - \frac{1}{t_c g(N)}
\]

where:
- \(P_b\) = probability of blocked lane

\[
P_d = 1 - (1 - P_b)^N
\]

where:
- \(P_d\) = probability of delayed crossing
- \(N\) = number of lanes crossed
- \(t_{cG}\) = group critical headway (s) if no platooning
- \(v\) = vehicular flow rate across crossing (veh/s)

### Calculations Sheet 1

<table>
<thead>
<tr>
<th>Crossing</th>
<th>(L)</th>
<th>(S_p)</th>
<th>(t_e)</th>
<th>(N_p)</th>
<th>(W_G)</th>
<th>(t_{cG})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing 1</td>
<td>50</td>
<td>5.6</td>
<td>3</td>
<td>14</td>
<td>6</td>
<td>39.7</td>
</tr>
<tr>
<td>Crossing 2</td>
<td>60</td>
<td>5.6</td>
<td>3</td>
<td>24</td>
<td>6</td>
<td>59.7</td>
</tr>
</tbody>
</table>

### HCM Evaluation Worksheet

Developed by Bolton-McKibb, Inc. for the Local Road Research Board.
### Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

**Step 4: Calculate Average Delay to Wait for Adequate Gap**

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{cr} = 37.93$</td>
<td>$t_{cr} = 59.71$</td>
</tr>
<tr>
<td>$v = 146193$</td>
<td>$v = 0.28$</td>
</tr>
</tbody>
</table>

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

$$d_{ped} = \frac{d_{p}}{P_{d}}$$

- $d_{p}$: average pedestrian gap delay (s)
- $P_{d}$: probability of a delayed crossing

### Step 5: Estimate Delay Reduction due to Yielding Vehicles

(If yielding is zero, then skip step 5)

#### Average pedestrian delay

$$d_{p} = \sum_{\tau=1}^{h_1}(1 - \tau \cdot 0.5)P(Y_{\tau}) + (P_{d} - \sum_{\tau=1}^{h_1}P(Y_{\tau}))d_{ped}$$

- $h_1$: average headway for each through lane = N/l;
- $P(Y_{\tau})$: probability that motorists yield to pedestrian on crossing event $\tau$;
- $P_{d}$: probability of a delayed crossing event $\tau$.

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$h_1 = 7.1$</td>
<td>$h_1 = 7.143$</td>
</tr>
<tr>
<td>$\tau_1 = 20467$</td>
<td>$\tau_2 = 9e+06$</td>
</tr>
<tr>
<td>$d_{p} = 6.5$</td>
<td>$d_{p} = 6.6$</td>
</tr>
</tbody>
</table>

1. One-Lane Crossing

$$P(Y_{\tau}) = P_{d}M_{yj}(1-M_{yj})^{\tau-1}$$

2. Two-Lane Crossing

$$P(Y_{\tau}) = 2P_{d}(1-P_{d})M_{yj} = 1P_{d}M_{yj}^{2}$$

3. Three-Lane Crossing

$$P(Y_{\tau}) = P_{d}M_{yj} [1 - \sum_{\tau=1}^{\tau}P(Y_{\tau}) + \frac{P_{d}M_{yj}}{M_{yj}} [1 - P_{d}(1 - P_{d})M_{yj}^{2} + 3P_{d}(1 - P_{d})M_{yj}^{3}] + \frac{P_{d}(1 - P_{d})M_{yj}^{3}}{P_{d}}]$$

4. Four-Lane Crossing

$$P(Y_{\tau}) = P_{d}M_{yj} [1 - \sum_{\tau=1}^{\tau}P(Y_{\tau}) + \frac{P_{d}M_{yj}}{M_{yj}} [1 - P_{d}(1 - P_{d})M_{yj}^{2} + 3P_{d}(1 - P_{d})M_{yj}^{3}] + \frac{P_{d}(1 - P_{d})M_{yj}^{3}}{P_{d}}]$$

<table>
<thead>
<tr>
<th>LOS</th>
<th>Control Delay (sec/ped)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.5</td>
<td>Usually no conflicting traffic</td>
</tr>
<tr>
<td>B</td>
<td>5-10</td>
<td>Occasionally some delay due to conflicting traffic</td>
</tr>
<tr>
<td>C</td>
<td>10-20</td>
<td>Delay noticeable to pedestrians, but not inconvenient</td>
</tr>
<tr>
<td>D</td>
<td>20-30</td>
<td>Delay noticeable/irritating, increased chance of risk-taking</td>
</tr>
<tr>
<td>E</td>
<td>30-45</td>
<td>Delay approaches tolerance level, risk-taking likely</td>
</tr>
<tr>
<td>F</td>
<td>&gt;45</td>
<td>Delay exceeds tolerance level, high chance of risk-taking</td>
</tr>
</tbody>
</table>

#### Summary

- Average: 13.1
- LOS: C

Calculations Sheet 2
**Example 7: School Crossing**

**Site Review**
Conduct a field review and take pedestrian/vehicle counts during the peak hours.

The crossing location is marked and signed as a school crossing with an in-road crossing sign. There are crossing guards during the times children travel to and from school.
Complete Field Review Worksheet.

Uncontrolled Pedestrian Crossing Data Collection Worksheet

Location: Example 7  Date: Scenario: School Crossing
City, State:  Agency: 
Reviewer(s):  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

<table>
<thead>
<tr>
<th>Crossing Length: Measure the crossing distance from curb to curb. Crossing 1 40 ft. Crossing 2  ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
</tr>
<tr>
<td>Median: width of median at crossing location ft. ft.</td>
</tr>
<tr>
<td>Crossing Width: effective crosswalk width ft.</td>
</tr>
<tr>
<td>Raised Median Available? Yes ☐ No ☐</td>
</tr>
<tr>
<td>ADA Compliant Median Available (minimum 4' x 4' landing)? Yes ☐ No ☐</td>
</tr>
<tr>
<td>Curb Ramps Available? Yes ☐ No ☐</td>
</tr>
<tr>
<td>ADA Compliant Curb Ramp Available (width, grades, truncated domes)? Yes ☐ No ☐</td>
</tr>
<tr>
<td>Speed: Posted or 85th percentile speed 30 mph</td>
</tr>
<tr>
<td>Roadway Curvature and Sight Distances: Average walking speed 4.3 ft/s</td>
</tr>
<tr>
<td>Is the crossing location within a horizontal or vertical curve? Yes ☐ No ☐</td>
</tr>
</tbody>
</table>

Equations to calculate the following are located on the next page.

Direction 1: Stopping Sight Distance (SSD) 197 ft. provided? Yes ☐ No ☐
Direction 2: Stopping Sight Distance (SSD) ft. provided? Yes ☐ No ☐
Direction 1: Pedestrian Sight Distance (PedSD) 543 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: Daily 5,600 pedestrians: Daily |
|---|---|---|
| AM Peak Hourly 456 Pk 15-min 181 Hourly 9 Pk 15-min 5 |
| PM Peak Hourly 521 Pk 15-min 166 Hourly 6 Pk 15-min 4 |

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? Continental |

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? high visibility markings, in-street signs school crossing guards |

Adjacent Facilities:

<table>
<thead>
<tr>
<th>Distance to nearest marked crosswalk? ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>What pedestrian control devices are present at the nearest adjacent marked crosswalk?</td>
</tr>
<tr>
<td>Distance to nearest all-way stop, roundabout or signalized intersection 2000 ft.</td>
</tr>
<tr>
<td>Could another location serve the same pedestrian crossing movement? Yes ☐ No ☐</td>
</tr>
<tr>
<td>Could another location serve the the movement more effectively? Yes ☐ No ☐</td>
</tr>
</tbody>
</table>

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Page 1 of 2
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 signing 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 origins and destinations.

draw or insert map of location being studied

Notes:
No Ped Ramps
In-Street School Crossing signs and crossing guards.

Sight Distance Calculations:

| Stopping sight distance (SSD), ft = 1.475t + 1.0755(s - t) |
| Pedestrian sight distance (PedSD), ft = 1.475L / S_p |

where:  
S = design speed, mph  
L = length of crossing, ft  
t = brake reaction time, s  
a = deceleration rate, ft/s^2  
S_p = average pedestrian walking speed, ft/s  
t, s = pedestrian start-up and end clearance time, s

<table>
<thead>
<tr>
<th>where</th>
<th></th>
<th>defaults:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t = brake reaction time, s</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>a = deceleration rate, ft/s^2</td>
<td>11.2</td>
</tr>
<tr>
<td></td>
<td>S_p = average pedestrian walking speed, ft/s</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>t, s = pedestrian start-up and end clearance time, s</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Safety Review
No pedestrian crashes at the location within last ten years. There were a total of 3 crashes at this location over the last ten years, all being rear-end. Likely the result of yielding to pedestrians.

SSD, PedSD Calculation

\[
SSD = 197 \text{ ft} \\
PedSD = 543 \text{ ft}
\]

The SSD and PedSD is met for this crossing.

HCM Analysis
Since the crossing is primarily used by school children, walking speed changed to 3.5 ft/s in calculations of LOS.

**AM Peak Hour**
Yield Rate = 86% (Crossing Guards)
\[Delay = 7.3 \text{ sec} = LOS B\]

**PM Peak Hour**
Yield Rate = 86% (Crossing Guards)
\[Delay = 7.9 \text{ sec} = LOS B\]

Result
Acceptable Level of Service

Consider no changes to the existing crossing as far as treatments. Because there are crossing guards at the school crossings before and after school, the yield rates and safety are greatly improved.

One consideration is the addition of pedestrian curb ramps and truncated domes to make the crossing usable by all.
2010 Highway Capacity Manual (HCM)
Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations
Intersection and Mid-Block Crossings

Crossing Location: Example 7  
City, State:  
Reviewer(s):  
Project Number:  
Date: Scenario: School Crossing, AM  
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:**
- $L$: crosswalk length (ft)
- $S_p$: average pedestrian walking speed (ft/s)
- $t_c$: pedestrian start-up and end clearance time (s)
- $V$: vehicular hourly volume (veh/hr)
- $u_p$: pedestrian flow rate (ped/s)
- $u$: vehicular flow rate (veh/s) = $V/3600$
- $W_i$: crosswalk width (ft)
- $N$: number of lanes crossed (Integer)

**Input Table:**

<table>
<thead>
<tr>
<th>defaults</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L = 40$</td>
<td>$S_p = 3.5$</td>
</tr>
<tr>
<td>$S_p = 3.5$</td>
<td>$L = 40$</td>
</tr>
<tr>
<td>$t_c = 3$</td>
<td>$V = 496$</td>
</tr>
<tr>
<td>$V = 496$</td>
<td>$u_p = 0.01$</td>
</tr>
<tr>
<td>$u_p = 0.01$</td>
<td>$u = 0.200$</td>
</tr>
<tr>
<td>$u = 0.200$</td>
<td>$W_i = 6.0$</td>
</tr>
<tr>
<td>$W_i = 6.0$</td>
<td>$N = 2$</td>
</tr>
</tbody>
</table>
| $N = 2$ | *no platooning observed*

### Crossing 2:

**Evaluation Inputs:**
- $L$: crosswalk length (ft)
- $S_p$: average pedestrian walking speed (ft/s)
- $t_c$: pedestrian start-up and end clearance time (s)
- $V$: vehicular hourly volume (veh/hr)
- $u_p$: pedestrian flow rate (ped/s)
- $u$: vehicular flow rate (veh/s) = $V/3600$
- $W_i$: crosswalk width (ft)
- $N$: number of lanes crossed (Integer)

**Input Table:**

<table>
<thead>
<tr>
<th>defaults</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L = $</td>
<td>$S_p = 3.5$</td>
</tr>
<tr>
<td>$S_p = 3.5$</td>
<td>$L = $</td>
</tr>
<tr>
<td>$t_c = 3$</td>
<td>$V = $</td>
</tr>
<tr>
<td>$V = $</td>
<td>$u_p = 0$</td>
</tr>
<tr>
<td>$u_p = 0$</td>
<td>$u = $</td>
</tr>
<tr>
<td>$u = $</td>
<td>$W_i = $</td>
</tr>
<tr>
<td>$W_i = $</td>
<td>$N = $</td>
</tr>
</tbody>
</table>
| $N = $ | *no platooning observed*

**Crossing Treatment Yield Rate**
- $M_y$: motorist yield rate (decimal)

<table>
<thead>
<tr>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_y = 86%$</td>
</tr>
</tbody>
</table>

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

### Results:

| Average Delay | 7.3 |
| LOS | B |

**Inputs and Results**
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 sufficient for a safe crossing.

For a single pedestrian:

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

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

$$t_c = 3.5 \text{ ft/s}$$

$$t_r = 3 \text{ sec}$$

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

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

$$N_p = \frac{v_p - v_f}{v_p - v_f} e^{v_p - v_f}$$

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

$$\frac{v_p}{v_f} = 0.01$$

$$\frac{v_f}{v_p} = 0.2$$

$$N_p = 14.4$$

$$N_p = 14.4$$

2. Compute spatial distribution:

$$N_p = \text{Int} \left( \frac{8.0(N_p-1)}{W_c} \right) + 1$$

where:
- $N_p$ = spatial distributions of pedestrians (ped)
- $N_p$ = 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)

$$W_c = 6$$

$$N_p = 1$$

$$N_p = 1$$

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)

$$t_{c,G} = 14.4$$

$$t_{c,G} = 14.4$$

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.

$$P_b = 1 - (1-P_d)/N$$

where:
- $P_b$ = probability of blocked lane
- $P_d$ = probability of delayed crossing
- $N$ = number of lanes crossed

$$P_b = 0.76$$

$$P_d = 0.94$$

Calculations Sheet 1
## Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

### Step 4: Calculate Average Delay to Wait for Adequate Gap

**Crossing 1**

- \( t_{c,0} = 14.43 \) seconds
- \( u = 70.15 \) veh/s
- \( d_c = 70.15 \) seconds

**Crossing 2**

- \( t_{c,0} = 0.2 \) seconds
- \( u = 70.15 \) veh/s
- \( d_c = 74.3 \) seconds

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

\[
d_{ped} = \frac{d_c}{P_d}
\]

### Step 5: Estimate Delay Reduction due to Yielding Vehicles

(If yielding is zero, then skip step 5)

- Crossing 1: \( \tau_1 = 10.0 \) seconds
- Crossing 2: \( \tau_2 = 7.3 \) seconds

Some crossing treatments and yield rates based on research are provided on the next page. Average pedestrian delay:

\[
d_p = \sum_{i=1}^{N} t_i (1 - 0.5) P(Y_i) + (P_d - \sum_{j=1}^{N} P(Y_j)) d_{ped}
\]

- \( P(Y_i) = P_d M_p (1 - M_p)^{i-1} \) for One-Lane Crossing
- \( i = 1 \) to \( \tau_i \)
- \( P(Y_i) = 2P_d (1 - P_d) M_p + 1P_d^2 M_p^2 \) for Two-Lane Crossing
- \( P(Y_i) = \sum_{j=1}^{N} P(Y_j) \) for Three-Lane Crossing
- \( P(Y_i) = \sum_{j=1}^{N} P(Y_j) \) for Four-Lane Crossing

### Summary

<table>
<thead>
<tr>
<th>LOS</th>
<th>Average Delay (sec/ped)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.5</td>
<td>Usually no conflicting traffic</td>
</tr>
<tr>
<td>B</td>
<td>5-10</td>
<td>Occasionally some delay due to conflicting traffic</td>
</tr>
<tr>
<td>C</td>
<td>10-20</td>
<td>Delay noticeable to pedestrians, but not inconveniencing</td>
</tr>
<tr>
<td>D</td>
<td>20-30</td>
<td>Delay noticeable/irritating, increased chance of risk-taking</td>
</tr>
<tr>
<td>E</td>
<td>30-45</td>
<td>Delay approaches tolerance level, risk-taking likely</td>
</tr>
<tr>
<td>F</td>
<td>&gt;45</td>
<td>Delay exceeds tolerance level, high chance of risk-taking</td>
</tr>
</tbody>
</table>

Developed by Bollon Monk, Inc. for the Local Road Research Board.
## 2010 Highway Capacity Manual (HCM)

### Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations

**Intersection and Mid-Block Crossings**

### Crossing 1:

**Evaluation Inputs:**

- \( L = \) crosswalk length (ft)
- \( S_p = \) average pedestrian walking speed (ft/s)
- \( t_c = \) pedestrian start-up and end clearance time (s)
- \( V = \) vehicular hourly volume (veh/hr)
- \( \nu_p = \) pedestrian flow rate (ped/s)
- \( \nu_v = \) vehicular flow rate (veh/s) = \( V/3600 \)
- \( W_c = \) crosswalk width (ft)
- \( N = \) number of lanes crossed (Integer)

**Defaults:**

- \( S_p = 3.5 \)
- \( t_c = 3.0 \)
- \( \nu_v = V/3600 \)
- \( W_c = 8.0 \)
- \( N = \text{INT}(L/11) \)

**Input Table:**

<table>
<thead>
<tr>
<th>L (ft)</th>
<th>S_p (ft/s)</th>
<th>t_c (s)</th>
<th>V (veh/hr)</th>
<th>( \nu_p ) (ped/s)</th>
<th>( \nu_v ) (veh/hr)</th>
<th>W_c (ft)</th>
<th>N (Integer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>3.5</td>
<td>3.0</td>
<td>521</td>
<td>0</td>
<td>0.00</td>
<td>8.0</td>
<td>2</td>
</tr>
</tbody>
</table>

*No platooning observed

### Crossing 2:

**Evaluation Inputs:**

- \( L = \) crosswalk length (ft)
- \( S_p = \) average pedestrian walking speed (ft/s)
- \( t_c = \) pedestrian start-up and end clearance time (s)
- \( V = \) vehicular hourly volume (veh/hr)
- \( \nu_p = \) pedestrian flow rate (ped/s)
- \( \nu_v = \) vehicular flow rate (veh/s) = \( V/3600 \)
- \( W_c = \) crosswalk width (ft)
- \( N = \) number of lanes crossed (Integer)

**Defaults:**

- \( S_p = 3.5 \)
- \( t_c = 3.0 \)
- \( \nu_v = V/3600 \)
- \( W_c = 8.0 \)
- \( N = \text{INT}(L/11) \)

**Input Table:**

<table>
<thead>
<tr>
<th>L (ft)</th>
<th>S_p (ft/s)</th>
<th>t_c (s)</th>
<th>V (veh/hr)</th>
<th>( \nu_p ) (ped/s)</th>
<th>( \nu_v ) (veh/hr)</th>
<th>W_c (ft)</th>
<th>N (Integer)</th>
</tr>
</thead>
</table>

*No platooning observed

### Crossing Treatment Yield Rate

- \( M_y = \) motorist yield rate (decimal)

**Input Table:**

- \( M_y = 86\% \)

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

### Results:

<table>
<thead>
<tr>
<th>Average Delay</th>
<th>7.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
<td>B</td>
</tr>
</tbody>
</table>

**Inputs and Results**

Page 2 of 5

---

Developed by Bolton Merk, Inc.

for the Local Road Research Board.

HCM Evaluation Worksheet
# Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

**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, does the median refuge need to meet ADA requirements (4' x 4' landing)? [ ] Yes [ ] No

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 sufficient for a safe crossing.

For a single pedestrian:

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

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

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L = 40$ ft</td>
<td>$L = 14.4$ ft</td>
</tr>
<tr>
<td>$S_p = 3.5$ ft/s</td>
<td>$S_p = 3.5$ ft/s</td>
</tr>
<tr>
<td>$t_e = 3$ sec</td>
<td>$t_e = 3$ sec</td>
</tr>
</tbody>
</table>

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

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

$$ N_p = \frac{\nu_p e^{-\nu_p W_i} + \nu v^{\nu - 1}}{(\nu_p + \nu) e^{\nu - 1} W_i} $$

where:
- $N_p$ = total number of pedestrians in crossing platoon (ped)
- $\nu_p$ = pedestrian flow rate (ped/s)
- $\nu$ = vehicular flow rate across crossing (veh/s)
- $W_i$ = single pedestrian critical headway (s)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\nu_p = 0$ ped/s</td>
<td>$\nu = 0.18$ veh/s</td>
</tr>
<tr>
<td>$N_p = 1.22$ ped</td>
<td>$N_p = 1.22$ ped</td>
</tr>
</tbody>
</table>

2. Compute spatial distribution:

$$ N_p = \left\lfloor \frac{8.0(N_p-1)}{W_i} \right\rfloor + 1 $$

where:
- $N_p$ = spatial distributions of pedestrians (ped)
- $W_i$ = crosswalk width (ft)
- $8.0 = \text{default clear width used by a single pedestrian to avoid interference with other pedestrians (ft)}$

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_i = 6$ ft</td>
<td>$W_i = 6$ ft</td>
</tr>
<tr>
<td>$N_p = 1$ ped</td>
<td>$N_p = 1$ ped</td>
</tr>
</tbody>
</table>

3. Compute group critical headway:

$$ t_{GC} = t_c + 2(N_p-1) $$

where:
- $t_{GC}$ = group critical headway (s)
- $N_p$ = spatial distributions of pedestrians (ped)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_p = 1$ ped</td>
<td>$N_p = 1$ ped</td>
</tr>
<tr>
<td>$t_c = 14.4$ sec</td>
<td>$t_c = 14.4$ sec</td>
</tr>
</tbody>
</table>

**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.

$$ P_b = 1 - e^{-t_{GC}/\nu} $$

where:
- $P_b$ = probability of blocked lane
- $t_{GC}$ = group critical headway (s)

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

where:
- $P_d$ = probability of delayed crossing
- $N$ = number of lanes crossed

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{GC} = 14.4$ sec</td>
<td>$t_{GC} = 14.4$ sec</td>
</tr>
<tr>
<td>$\nu = 0.18$ veh/s</td>
<td>$\nu = 0.18$ veh/s</td>
</tr>
<tr>
<td>$N = 2$</td>
<td>$N = 2$</td>
</tr>
<tr>
<td>$P_b = 0.73$</td>
<td>$P_b = 0.73$</td>
</tr>
<tr>
<td>$P_d = 0.93$</td>
<td>$P_d = 0.93$</td>
</tr>
</tbody>
</table>
## Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

### Step 4: Calculate Average Delay to Wait for Adequate Gap

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{c,0}$ = 14.43</td>
<td>$t_{c,0}$ = 14.43</td>
</tr>
<tr>
<td>$v$ = 54.60</td>
<td>$v$ = 54.60</td>
</tr>
<tr>
<td>$d_{c}$ = 0.18</td>
<td>$d_{c}$ = 0.18</td>
</tr>
</tbody>
</table>

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

$$d_{pf} = \frac{d_{c}}{P_d}$$

where:
- $d_{pf}$ = average pedestrian delay for pedestrians who incur nonzero delay
- $d_{c}$ = average pedestrian delay (s)
- $P_d$ = probability of a delayed crossing

### Step 5: Estimate Delay Reduction due to Yielding Vehicles

(If yielding is zero, then skip step 5)

#### Average pedestrian delay

$$d_{p} = \sum_{t=1}^{T}(t-0.5)P(Y_{t}) + (P_{d} - \sum_{t=1}^{T}P(Y_{t}))d_{pf}$$

where:
- $d_{p}$ = average pedestrian delay (s)
- $P_{d}$ = probability of a delayed crossing
- $Y_{t}$ = crossing event
- $N$ = number of crossing events
- $P(Y_{t})$ = probability that motorists yield to pedestrian on crossing event $t$

#### Delay reduction

$$\Delta d = \sum_{t=1}^{T}(t-0.5)P(Y_{t})$$

#### Summary

<table>
<thead>
<tr>
<th>LOS</th>
<th>Average</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.5</td>
<td>Usually no conflicting traffic</td>
</tr>
<tr>
<td>B</td>
<td>5-10</td>
<td>Occasionally some delay due to conflicting traffic</td>
</tr>
<tr>
<td>C</td>
<td>10-20</td>
<td>Delay noticeable to pedestrians, but not inconveniences</td>
</tr>
<tr>
<td>D</td>
<td>20-30</td>
<td>Delay noticeable/irritating, increased chance of risk-taking</td>
</tr>
<tr>
<td>E</td>
<td>30-45</td>
<td>Delay approaches tolerance level, risk-taking likely</td>
</tr>
<tr>
<td>F</td>
<td>&gt;45</td>
<td>Delay exceeds tolerance level, high chance of risk-taking</td>
</tr>
</tbody>
</table>
Example 8: Recreational Fields Crossing

Site Review
Conduct a field review and take pedestrian/vehicle counts during the peak hours.

The crossing location is on a four lane roadway with no medians. The studies crossing connects two schools and recreational facilities to a residential area.
Complete Field Review Worksheet.

Uncontrolled Pedestrian Crossing
Data Collection Worksheet

Location: ___________________________ Date: ___________________________
City, State: ___________________________ Scenario: ___________________________
Reviewer(s): ___________________________ Agency: ___________________________
Project #: ___________________________

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

Geometrics

<table>
<thead>
<tr>
<th>Crossing Length: Measure the crossing distance from curb to curb</th>
<th>Crossing 1</th>
<th>ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fill in Crossing 1 if there is no median. If there is a median at the crossing location, fill in Crossing 1 and 2 distances.</td>
<td>Crossing 2</td>
<td>ft.</td>
</tr>
<tr>
<td>Median: width of median at crossing location</td>
<td>0 ft.</td>
<td></td>
</tr>
<tr>
<td>Crossing Width: effective crosswalk width</td>
<td>8 ft.</td>
<td></td>
</tr>
<tr>
<td>Raised Median Available?</td>
<td>Yes ☐ No ☐</td>
<td></td>
</tr>
<tr>
<td>ADA Compliant Median Available (minimum 4’ x 4’ landing)?</td>
<td>Yes ☐ No ☐</td>
<td></td>
</tr>
<tr>
<td>Curb Ramps Available?</td>
<td>Yes ☐ No ☐</td>
<td></td>
</tr>
<tr>
<td>ADA Compliant Curb Ramp Available (width, grades, truncated domes)?</td>
<td>Yes ☐ No ☐</td>
<td></td>
</tr>
<tr>
<td>Speed:</td>
<td>Posted or 85th percentile speed 35 mph</td>
<td></td>
</tr>
<tr>
<td>Roadway Curvature and Sight Distances:</td>
<td>Average walking speed 4.7 ft/s</td>
<td></td>
</tr>
<tr>
<td>Is the crossing location within a horizontal or vertical curve?</td>
<td>Yes ☐ No ☐</td>
<td></td>
</tr>
</tbody>
</table>

Equations to calculate the following are located on the next page.

Traffic and Pedestrian Data

<table>
<thead>
<tr>
<th>Measure traffic and pedestrian volume in 15-minute increments on the roadway to be crossed.</th>
<th>Attach Counts</th>
<th>vehicles:</th>
<th>pedestrian:</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM Peak</td>
<td>Hourly</td>
<td>402</td>
<td>Daily 8,400</td>
</tr>
<tr>
<td>PM Peak</td>
<td>Hourly</td>
<td>565</td>
<td>Daily 8,400</td>
</tr>
<tr>
<td>Hourly Pk 15-min</td>
<td>140</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hourly Pk 15-min</td>
<td>180</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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? | 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? | Traffic Signal |

Adjacent Facilities:

| Distance to nearest marked crosswalk? | 3,250 ft. |
| What pedestrian control devices are present at the nearest adjacent marked crosswalk? | | |
| Distance to nearest all-way stop, roundabout or signalized intersection | 3,250 ft. |
| Could another location serve the same pedestrian crossing movement? | Yes ☐ No ☐ |
| Could another location serve the movement more effectively? | Yes ☐ No ☐ |

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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 origins and destinations.

Draw or insert map of location being studied

Notes: Crossing location currently unmarked and unsigned.
No ped

Sight Distance Calculations:

Stopping sight distance (SSD), ft = 1.475t + 1.075S^2/a
Pedestrian sight distance (PedSD), ft = 1.475(L/S_p + t)

where: S = design speed, mph
L = length of crossing, ft

where: t = brake reaction time, s
a = deceleration rate, ft/s^2
S_p = average pedestrian walking speed, ft/s

defaults:
t = 2.5
a = 11.2
S_p = 3.5

Page 2 of 2

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Safety Review
No pedestrian crashes at the location within last ten years. There was one rear-end crash and 5 crashes over the last ten years. No concerns as related to the pedestrian crossing.

SSD, PedSD Calculation

\[ SSD = 246 \text{ ft} \]
\[ PedSD = 975 \text{ ft} \]

The SSD and PedSD are met for this crossing.

HCM Analysis

**AM Peak Hour**
Yield Rate = 0%
\[ Delay = 110 \text{ sec} = LOS F \]

**PM Peak Hour**
Yield Rate = 0%
\[ Delay = 202 \text{ sec} = LOS F \]

Review Origins and Destinations, Alternative Routes

*Origins and Destinations*

The crossing connects a residential area to a school and trails (direct origin-destination). There is no marked crossing near the studied crossing, so pedestrians must choose the best place to cross.

*Alternative Route Analysis*

Calculate how much time it would take for a pedestrian to walk to the nearest adjacent marked crossing, cross the roadway, and return to the location where they started.

This total amount of time will be compared to the average pedestrian delay (average measured wait time). The nearest marked crossing is located 3,200 ft west of the unmarked crossing.

Because this crossing is so far away, it can be assumed that pedestrians will opt to wait at the unmarked crossing to cross the roadway.

*Access Spacing and Functional Classification*

The crossing is not located in a coordinated signalized corridor.

*Speed and Pedestrian Use*

The speed limit is 35 mph and the population is greater than 10,000.

There were 3 pedestrians during the AM peak hour and 4 pedestrians in the PM peak hour.
Result: Go to Step 10.

School Crossing
This is a crossing adjacent to two school and could be considered a school crossing if there are students that use the crossing, go to Step 11, Traffic Calming Treatment Options. Students were not observed using the crossing during the data collection period.

If it is not a school crossing, go to FHWA Safety Guidance. ADT = 8,200, Multilane without raised median, 35 mph. Results in P designation, go to Step 11, Traffic Calming Treatment Options.

Traffic Calming Treatment Options
Based on the existing options, a median with a refuge island or RRFB system with a median could be considered, but the cost to implement may be unreasonable based on the current pedestrian use. Overall, the crossing should likely be left alone.

School crossing guards could also be considered if there are children crossing the street before and after school hours. In which case, the crossing would be signed and marked as a school crossing, but a median with or without RRFB would also be recommended.

A median with a refuge island could decrease delay to 19.7 sec (LOS C) in the AM peak hour and 23.9 sec (LOS D) in the PM peak hour.

A median with a refuge island and an RRFB system could decrease delay to 14.8 sec (LOS C) in the AM peak hour and 14.5 sec (LOS C) in the PM peak hour.
2010 Highway Capacity Manual (HCM)
Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations
Intersection and Mid-Block Crossings

Crossing Location: Example 8  Date:  
City, State:  
Reviewer(s):  
Project Number:  
ID #:  
Scenario: AM Peak Hour

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:
- \( L = \) crosswalk length (ft)
- \( S_p = \) average pedestrian walking speed (ft/s)
- \( t_s = \) pedestrian start-up and end clearance time (s)
- \( V = \) vehicular hourly volume (veh/hr)
- \( U_p = \) pedestrian flow rate (ped/s)
- \( U = \) vehicular flow rate (veh/s) = \( V/3600 \)
- \( W_c = \) crosswalk width (ft)
- \( N = \) number of through lanes crossed (integer)

**Crossing Treatment Yield Rate**
- \( M_y = \) motorist yield rate (decimal)

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

**Results:**

<table>
<thead>
<tr>
<th>Average Delay</th>
<th>109.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
<td>F</td>
</tr>
</tbody>
</table>

Developed by Bolton Merk, Inc. for the Local Road Research Board.
### Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

**Crossing Location:**  
**City, State:**  
**Reviewer(s):**  
**Agency:**  
**Data:**  
**Scenario:**

#### Step 1: Identify Two-Stage Crossings

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

For a single pedestrian:

\[ t_c = \frac{L}{S_p} + t_e \]

- **For crossing 1:**  
  - \( L = 75 \) ft  
  - \( S_p = 4.7 \) ft/s  
  - \( t_e = 19 \) sec

- **For crossing 2:**  
  - \( L = 75 \) ft  
  - \( S_p = 4.7 \) ft/s  
  - \( t_e = 19 \) sec

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

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

\[ N_p = \frac{\nu_p \cdot \nu + N_e - 1}{\nu_p + \nu} \]

- **For crossing 1:**  
  - \( \nu_p = 0.16 \)  
  - \( N_e = 19 \)

- **For crossing 2:**  
  - \( \nu_p = 0.9 \)  
  - \( N_e = 19 \)

2. Compute spatial distribution:

\[ N_p = \text{Int} \left( \frac{8.0(N_e - 1)}{W_c} \right) + 1 \]

- **For crossing 1:**  
  - \( N_e = 19 \)  
  - \( W_c = 8 \) ft

- **For crossing 2:**  
  - \( N_e = 19 \)  
  - \( W_c = 8 \) ft

3. Compute group critical headway:

\[ t_{c,G} = t_c + 2(N_e - 1) \]

- **For crossing 1:**  
  - \( t_c = 19 \) sec  
  - \( N_e = 19 \)

- **For crossing 2:**  
  - \( t_c = 19 \) sec  
  - \( N_e = 19 \)

#### Step 2: Determine Critical Headway

#### 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.**

\[ P_b = 1 - (\frac{t_{c,G}}{N}) \]

- **For crossing 1:**  
  - \( t_{c,G} = 19 \) sec  
  - \( N = 4 \)  
  - \( P_b = 0.53 \)

- **For crossing 2:**  
  - \( t_{c,G} = 19 \) sec  
  - \( N = 4 \)  
  - \( P_b = 0.53 \)

---

Developed by Bolton, Inc. for the Local Road Research Board.
Uncontrolled Pedestrian Crossing Level of Service
Evaluation Worksheet

Step 4: Calculate Average Delay to Wait for Adequate Gap

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{c,5}$ = 18.96</td>
<td>$t_{c,5}$ = 104.56</td>
</tr>
<tr>
<td>$u$ = 0.16</td>
<td>$u$ =</td>
</tr>
<tr>
<td>$d_c$ = 104.6</td>
<td>$d_c$ =</td>
</tr>
</tbody>
</table>

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

$$d_{ef} = \frac{d_c}{P_d}$$

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

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 MnDOT at all marked crossings and either marked or unmarked crossings at intersections, motorist yield rates actually vary considerably.

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

Average pedestrian delay

$$d_p = \sum_{i=1}^{n} \left[ \lambda_i (1 - 0.5) P(Y_i) + (P_s \sum_{i=1}^{n} P(Y_i)) d_{ef} \right]$$

where:
- $d_p$ = average pedestrian delay (s)
- $\lambda_i$ = crossing event [1 to $n$]
- $h_i$ = average headway for each lane = N_i
- $P(Y_i)$ = probability that motorists yield to pedestrian on crossing event $i$
- $P(Y_i)$ = probability that motorists yield to pedestrian on crossing event $j$
- $\lambda_i = \text{Int}(d_{ct}/h_i)$, average number of crossing events before an adequate gap is available, >0

1. One-Lane Crossing
   $$P(Y_i) = P_s M_y (1 - M_y)^{i-1}$$

2. Two-Lane Crossing
   $$P(Y_i) = 2P_s (1 - P_s) M_y + 1P_s M_y^2$$

3. Three-Lane Crossing
   $$P(Y_i) = P_s \left( M_y - \sum_{i=1}^{n} P(Y_i) \right) + \frac{P_s (1 - P_s) M_y^2}{P_s}$$

4. Four-Lane Crossing
   $$P(Y_i) = P_s \left( M_y - \sum_{i=1}^{n} P(Y_i) \right) + \frac{P_s (1 - P_s) M_y^2}{P_s}$$

Step 6: Calculate Average Pedestrian Delay & Determine LOS

<table>
<thead>
<tr>
<th>LOS</th>
<th>Control Delay (sec/ped)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.5</td>
<td>Usually no conflicting traffic</td>
</tr>
<tr>
<td>B</td>
<td>5-10</td>
<td>Occasionally some delay due to conflicting traffic</td>
</tr>
<tr>
<td>C</td>
<td>10-20</td>
<td>Delay noticeable to pedestrians, but not inconveniencing</td>
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<td>D</td>
<td>20-30</td>
<td>Delay noticeable/irritating, increased chance of risk-taking</td>
</tr>
<tr>
<td>E</td>
<td>30-45</td>
<td>Delay approaches tolerance level, risk-taking likely</td>
</tr>
<tr>
<td>F</td>
<td>&gt;45</td>
<td>Delay exceeds tolerance level, high chance of risk-taking</td>
</tr>
</tbody>
</table>

Summary

<table>
<thead>
<tr>
<th>Average</th>
<th>109.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
<td>F</td>
</tr>
</tbody>
</table>

Calculations Sheet 2
2010 Highway Capacity Manual (HCM)
Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations
Intersection and Mid-Block Crossings

Crossing Location: Example 8  Date: 
City, State:  Scenario: PM Peak Hour 
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:

<table>
<thead>
<tr>
<th>L = crosswalk length (ft)</th>
<th>( S_p = ) average pedestrian walking speed (ft/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_c = ) pedestrian start-up and end clearance time (s)</td>
<td></td>
</tr>
<tr>
<td>( V = ) vehicular hourly volume (veh/hr)</td>
<td></td>
</tr>
<tr>
<td>( \nu_p = ) pedestrian flow rate (ped/s)</td>
<td></td>
</tr>
<tr>
<td>( \nu = ) vehicular flow rate (veh/s) = ( V/3600 )</td>
<td></td>
</tr>
<tr>
<td>( W_c = ) crosswalk width (ft)</td>
<td></td>
</tr>
<tr>
<td>( N = ) number of through lanes crossed (integer)</td>
<td></td>
</tr>
</tbody>
</table>

defaults: 

| \( L = \) 75 |
| \( S_p = \) 3.5 |
| \( t_c = \) 3.0 |
| \( V = \) 585 |
| \( \nu_p = \) 0* |
| \( \nu = \) \( V/3600 \) |
| \( W_c = \) 8.0 |
| \( N = \) \( \text{INT}(L/11) \) |

Input Table:

| \( L = \) 75 |
| \( S_p = \) 3.5 |
| \( t_c = \) 3.0 |
| \( V = \) 585 |
| \( \nu_p = \) 0* |
| \( \nu = \) \( V/3600 \) |
| \( W_c = \) 8.0 |
| \( N = \) \( \text{INT}(L/11) \) |

*no platooning observed

Crossing 2:

(only used for two-stage crossings)

Evaluation Inputs:

<table>
<thead>
<tr>
<th>L = crosswalk length (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( S_p = ) average pedestrian walking speed (ft/s)</td>
</tr>
<tr>
<td>( t_c = ) pedestrian start-up and end clearance time (s)</td>
</tr>
<tr>
<td>( V = ) vehicular hourly volume (veh/hr)</td>
</tr>
<tr>
<td>( \nu_p = ) pedestrian flow rate (ped/s)</td>
</tr>
<tr>
<td>( \nu = ) vehicular flow rate (veh/s) = ( V/3600 )</td>
</tr>
<tr>
<td>( W_c = ) crosswalk width (ft)</td>
</tr>
<tr>
<td>( N = ) number of through lanes crossed (integer)</td>
</tr>
</tbody>
</table>

defaults: 

Input Table:

| \( L = \) |
| \( S_p = \) |
| \( t_c = \) |
| \( V = \) |
| \( \nu_p = \) |
| \( \nu = \) |
| \( W_c = \) |
| \( N = \) |

*no platooning observed

Crossing Treatment Yield Rate

\( M_y = \) motorist yield rate (decimal)

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

Results:

<table>
<thead>
<tr>
<th>Average Delay</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>202.2</td>
<td>F</td>
</tr>
</tbody>
</table>

Inputs and Results

Page 2 of 5

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for the Local Road Research Board.

HCM Evaluation Worksheet
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, does the median refuge need to meet ADA requirements (4' x 4' landing)? Yes ☐ No ☐

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 sufficient for a safe crossing.

For a single pedestrian:
\[ t_c = \frac{L}{S_p} + t_e \]
where: \( t_c \) = critical headway for a single pedestrian (s)
\( L \) = crosswalk length (ft)
\( S_p \) = average pedestrian walking speed (ft/s)
\( t_e \) = pedestrian start-up and end clearance time (s)
\( S_p = 3.5 \) ft/s
\( t_e = 3 \) sec

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L = 75 )</td>
<td>( L = )</td>
</tr>
<tr>
<td>( S_p = 4.7 )</td>
<td>( S_p = )</td>
</tr>
<tr>
<td>( t_e = 3 )</td>
<td>( t_e = )</td>
</tr>
</tbody>
</table>

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

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

\[ N_p = \frac{v_p e^{v_p t_c}}{(v_p + v) e^{(v_p + v) t_c}} \]

where: \( N_p \) = 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)

2. Compute spatial distribution:

\[ N_p = \left\lfloor \frac{8.0(N_p-1)}{W_c} \right\rfloor + 1 \]

where: \( N_p \) = spatial distributions of pedestrians (ped)
\( N_p \) = total number of pedestrians in crossing platoon (ped)
\( W_c \) = crosswalk width (ft)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N_p = )</td>
<td>( N_p = )</td>
</tr>
<tr>
<td>( W_c = 8 )</td>
<td>( W_c = )</td>
</tr>
</tbody>
</table>

3. Compute group critical headway:

\[ t_{cg} = t_c + 2(N_p-1) \]

where: \( t_{cg} \) = group critical headway (s)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_{cg} = )</td>
<td>( t_{cg} = )</td>
</tr>
</tbody>
</table>

**Step 2: Determine Critical Headway**

**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.

\[ P_b = 1 - e^{-N t_c/N} \]

where: \( P_b \) = probability of blocked lane
\( N \) = number of lanes crossed
\( t_c \) = group critical headway (s) = \( t_c \) if no platooning
\( v \) = vehicular flow rate across crossing (veh/s)

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( v = 0.2 )</td>
<td>( v = )</td>
</tr>
<tr>
<td>( P_b = 0.61 )</td>
<td>( P_b = )</td>
</tr>
<tr>
<td>( N = 4 )</td>
<td>( N = )</td>
</tr>
<tr>
<td>( P_b = 0.98 )</td>
<td>( P_b = )</td>
</tr>
</tbody>
</table>

Calculations Sheet 1
### 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.

\[ d_g = \frac{1}{v} \left( e^{v t_{o.d}} - 1 \right) \]

- **\( d_g \)** = average pedestrian delay (s)
- **\( t_{o.d} \)** = group critical headway (s)
- **\( v \)** = vehicular flow rate across crossing (veh/s)

**Crossing 1**
- **\( t_{o.d} \)** = 18.96
- **\( d_g = 202.22 \)**

**Crossing 2**
- **\( t_{o.d} \)** = 0.2
- **\( d_g = 202.22 \)**

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

\[ d_{ed} = d_g / P_d \]

- **\( d_{ed} \)** = average pedestrian delay for pedestrians who incur nonzero delay
- **\( P_d \)** = probability of a delayed crossing

**Crossing 1**
- **\( d_{ed} = 197.7 \)**
- **\( P_d = 0.977 \)**

**Crossing 2**
- **\( d_{ed} = 202.22 \)**
- **\( P_d = \) unreported**

**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 MVN at all marked crossings and either marked or unmarked crossings at intersections, motorist yield rates actually vary considerably.

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

**Average pedestrian delay**

\[ d_g = \sum_{i=1}^{n} \left( t_i \cdot 0.5 \right) \bar{P}(v) + (\bar{P} - \sum_{i=1}^{n} \bar{P}(v)) d_{ed} \]

- **\( t_i \)** = crossing event \( i = 1 \) to \( n \)
- **\( \bar{P}(v) \)** = average headway for each through lane = \( N_i / v \)
- **\( \bar{P} \)** = probability that motorists yield to pedestrian on crossing event \( i \)
- **\( \bar{P}(v) \)** = average number of crossing events before an adequate gap is available, \( > 0 \)

**Crossing 1**
- **\( t_1 = \) unreported**
- **\( t_2 = \) unreported**
- **\( d_g = \) unreported**

**Crossing 2**
- **\( t_1 = \) unreported**
- **\( t_2 = \) unreported**
- **\( d_g = \) unreported**

**Summary**

<table>
<thead>
<tr>
<th>LOS</th>
<th>Average</th>
<th>202.2</th>
<th>F</th>
</tr>
</thead>
</table>

**Step 6: Calculate Average Pedestrian Delay & Determine LOS**

**Table of LOS, Control Delay, & Comments**

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

---

Developed by Bolton Monk, Inc. for the Local Road Research Board.

HCM Evaluation Worksheet

195
2010 Highway Capacity Manual (HCM)
Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations
Intersection and Mid-Block Crossings

Crossing Location: Example 8
City, State: 
Reviewer(s): 
Project Number: 
ID #: 
Scenario: AM Peak Hour, Staged, RRFB
Agency: 

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:** south

**Evaluation Inputs:**
- \( L = \) crosswalk length (ft)
- \( S_p = \) average pedestrian walking speed (ft/s)
- \( t_c = \) pedestrian start-up and end clearance time (s)
- \( V = \) vehicular hourly volume (veh/hr)
- \( \nu_p = \) pedestrian flow rate (ped/s)
- \( \nu = \) vehicular flow rate (veh/s) = \( V/3600 \)
- \( W_c = \) crosswalk width (ft)
- \( N = \) number of lanes crossed (integer)

<table>
<thead>
<tr>
<th>defaults</th>
<th>Input Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L = 50 )</td>
<td>( L = 50 )</td>
</tr>
<tr>
<td>( S_p = 3.5 )</td>
<td>( S_p = 4.7 )</td>
</tr>
<tr>
<td>( t_c = 3.0 )</td>
<td>( t_c = 3 )</td>
</tr>
<tr>
<td>( V = 201 )</td>
<td>( V = 201 )</td>
</tr>
<tr>
<td>( \nu_p = 0^* )</td>
<td>( \nu_p = 0.00 )</td>
</tr>
<tr>
<td>( \nu = V/3600 )</td>
<td>( \nu = 0.060 )</td>
</tr>
<tr>
<td>( W_c = 8.0 )</td>
<td>( W_c = 8.0 )</td>
</tr>
<tr>
<td>( N = \text{INT}(L/11) )</td>
<td>( N = 2 )</td>
</tr>
</tbody>
</table>

*no platooning observed

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

**Evaluation Inputs:**
- \( L = \) crosswalk length (ft)
- \( S_p = \) average pedestrian walking speed (ft/s)
- \( t_c = \) pedestrian start-up and end clearance time (s)
- \( V = \) vehicular hourly volume (veh/hr)
- \( \nu_p = \) pedestrian flow rate (ped/s)
- \( \nu = \) vehicular flow rate (veh/s) = \( V/3600 \)
- \( W_c = \) crosswalk width (ft)
- \( N = \) number of lanes crossed (integer)

<table>
<thead>
<tr>
<th>defaults</th>
<th>Input Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L = 25 )</td>
<td>( L = 25 )</td>
</tr>
<tr>
<td>( S_p = 5 )</td>
<td>( S_p = 5 )</td>
</tr>
<tr>
<td>( t_c = 3 )</td>
<td>( t_c = 3 )</td>
</tr>
<tr>
<td>( V = 201 )</td>
<td>( V = 201 )</td>
</tr>
<tr>
<td>( \nu_p = 0^* )</td>
<td>( \nu_p = 0.00 )</td>
</tr>
<tr>
<td>( \nu = V/3600 )</td>
<td>( \nu = 0.060 )</td>
</tr>
<tr>
<td>( W_c = 8.0 )</td>
<td>( W_c = 8.0 )</td>
</tr>
<tr>
<td>( N = \text{INT}(L/11) )</td>
<td>( N = 2 )</td>
</tr>
</tbody>
</table>

*no platooning observed

**Crossing Treatment Yield Rate**

\( M_y = \) motorist yield rate (decimal)

<table>
<thead>
<tr>
<th>Input Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>( M_y = 84% )</td>
</tr>
</tbody>
</table>

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

**Results:**

<table>
<thead>
<tr>
<th>Average Delay</th>
<th>14.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
<td>C</td>
</tr>
</tbody>
</table>

Inputs and Results  
Page 2 of 5

Developed by Bolton Merik, Inc.  
for the Local Road Research Board.  
HCM Evaluation Worksheet
## Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

### Step 1: Identify Two-Stage Crossings

**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 sufficient for a safe crossing.**

For a single pedestrian:

\[ t_c = \frac{L}{S_p} + t_i \]

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>L = 60 ft</td>
<td>L = 25 ft</td>
</tr>
<tr>
<td>( S_p = 4.7 )</td>
<td>( S_p = 4.7 )</td>
</tr>
<tr>
<td>( t_i = 3 ) sec</td>
<td>( t_i = 3 ) sec</td>
</tr>
</tbody>
</table>

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

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

\[ N_p = \frac{\nu_p (t + \frac{L}{v_p})}{(t + \frac{L}{v_p}) e^{\frac{L}{v_p}} + \epsilon} \]

   where:
   - \( N_p \) = total number of pedestrians in crossing platoon (ped)
   - \( \nu_p \) = pedestrian flow rate (ped/s)
   - \( t \) = pedestrian start-up and end clearance time (s)
   - \( L \) = crosswalk length (ft)
   - \( S_p \) = average pedestrian walking speed (ft/s)
   - \( v_p \) = vehicular flow rate across crossing (veh/s)

2. Compute spatial distribution:

\[ N_p = \left\lfloor \frac{8.0(N_p - 1)}{W_c} \right\rfloor + 1 \]

   where:
   - \( W_c \) = crosswalk width (ft)
   - 8.0 = default clear width used by a single pedestrian to avoid interference with other pedestrians (ft)

3. Compute group critical headway:

\[ t_{c,g} = t_c + 2(N_p - 1) \]

### Step 2: Determine Critical Headway

#### Crossing 1

- \( \nu_p = 0.06 \) veh/s
- \( N_p = 8 \)

#### Crossing 2

- \( \nu_p = 0.06 \) veh/s
- \( N_p = 8 \)

### 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.

\[ P_b = 1 - e^{-t_{c,b}/N} \]

\[ P_d = 1 - (1 - P_b)^n \]

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

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \nu_c = 0.06 )</td>
<td>( \nu_c = 0.06 )</td>
</tr>
<tr>
<td>( N = 2 )</td>
<td>( N = 2 )</td>
</tr>
<tr>
<td>( P_b = 0.34 )</td>
<td>( P_b = 0.34 )</td>
</tr>
<tr>
<td>( P_d = 0.22 )</td>
<td>( P_d = 0.39 )</td>
</tr>
</tbody>
</table>
Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

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

\[ d_a = \frac{1}{v} (\frac{1}{t_{G,1}} + \frac{1}{t_{G,2}} + 1) \]

where:
- \( d_a \) = average pedestrian gap delay (s)
- \( t_{G,1} \) = group critical headway (s)
- \( t_{G,2} \) = pedestrian group critical headway (s)
- \( v \) = vehicular flow rate across crossing (veh/s)

**Step 4: Calculate Average Delay to Wait for Adequate Gap**

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_{G,1} ) = 13.64</td>
<td>( t_{G,2} ) = 8.319</td>
</tr>
<tr>
<td>( v ) = 0.06</td>
<td>( v ) = 0.06</td>
</tr>
<tr>
<td>( d_a ) = 7.4723</td>
<td>( d_a ) = 2.4695</td>
</tr>
</tbody>
</table>

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

\[ d_{a,d} = \frac{d_a}{P_d} \]

where:
- \( d_{a,d} \) = average gap delay for pedestrians who incur nonzero delay
- \( P_d \) = probability of a delayed crossing

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( d_{a,d} ) = 7.4723</td>
<td>( d_{a,d} ) = 2.4695</td>
</tr>
<tr>
<td>( P_d ) = 0.559</td>
<td>( P_d ) = 0.393</td>
</tr>
</tbody>
</table>

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 MIN at all marked crossings and either marked or unmarked crossings at intersections, motorist yield rates actually vary considerably.

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

**Step 5: Estimate Delay Reduction due to Yielding Vehicles**

(If yielding is zero, then skip step 5)

Average pedestrian delay

\[ d_p = \sum_{i=1}^{n} h_i (1 - 0.5) P(Y_i) + \sum_{i=1}^{n} P(Y_i) d_{a,1} \]

where:
- \( d_p \) = average pedestrian delay (s)
- \( h_i \) = average headway for each through lane = N/12
- \( P(Y_i) \) = probability that motorists yield to pedestrian on crossing event \( i \)

1. One-Lane Crossing

\[ P(Y) = P_d M_p (1 - M_p) \]

2. Two-Lane Crossing

\[ P(Y) = 2P_d (1 - P_d) M_p + 3P_d^2 M_p^2 \]

3. Three-Lane Crossing

\[ P(Y) = \sum_{i=1}^{3} P(Y_i) = \frac{3P_d^2 M_p^2 + 3P_d (1 - P_d) M_p^2 + 3P_d (1 - P_d) M_p}{P_d} \]

4. Four-Lane Crossing

\[ P(Y) = \sum_{i=1}^{4} P(Y_i) = \frac{4P_d^4 M_p^4 + 4P_d^3 (1 - P_d) M_p^2 + 6P_d^2 (1 - P_d)^2 M_p^2 + 4P_d (1 - P_d)^3 M_p}{P_d} \]

**Step 6: Calculate Average Pedestrian Delay & Determine LOS**

<table>
<thead>
<tr>
<th>LOS</th>
<th>Control Delay (sec/ped)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0-5</td>
<td>Usually no conflicting traffic</td>
</tr>
<tr>
<td>B</td>
<td>5-10</td>
<td>Occasionally some delay due to conflicting traffic</td>
</tr>
<tr>
<td>C</td>
<td>10-20</td>
<td>Delay noticeable to pedestrians, but not inconvenient</td>
</tr>
<tr>
<td>D</td>
<td>20-30</td>
<td>Delay noticeable/irritating, increased chance of risk-taking</td>
</tr>
<tr>
<td>E</td>
<td>30-40</td>
<td>Delay approaches tolerance level, risk-taking likely</td>
</tr>
<tr>
<td>F</td>
<td>&gt;45</td>
<td>Delay exceeds tolerance level, high chance of risk-taking</td>
</tr>
</tbody>
</table>

Summary

<table>
<thead>
<tr>
<th>Average Delay Reduction</th>
<th>14.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
<td>C</td>
</tr>
</tbody>
</table>

Developed by Bolton Monk, Inc. for the Local Road Research Board.
2010 Highway Capacity Manual (HCM)
Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations
Intersection and Mid-Block Crossings

Crossing Location: Example 8
Date: PM, Staged, RRFB
City, State: 
Reviewer(s): 
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: south
Evaluation Inputs: 
- \( L \): crosswalk length (ft)
- \( S_p \): average pedestrian walking speed (ft/s)
- \( t_s \): pedestrian start-up and end clearance time (s)
- \( V \): vehicular hourly volume (veh/hr)
- \( u_p \): pedestrian flow rate (ped/s)
- \( u \): vehicular flow rate (veh/s) = \( V/3600 \)
- \( W_c \): crosswalk width (ft)
- \( N \): number of lanes crossed (Integer)

.defaults:
- \( L \):
- \( S_p \):
- \( t_s \):
- \( V \):
- \( u_p \):
- \( u \):
- \( W_c \):
- \( N \):

*no platooning observed

Crossing 2: north
(only used for two-stage crossings)
Evaluation Inputs: 
- \( L \): crosswalk length (ft)
- \( S_p \): average pedestrian walking speed (ft/s)
- \( t_s \): pedestrian start-up and end clearance time (s)
- \( V \): vehicular hourly volume (veh/hr)
- \( u_p \): pedestrian flow rate (ped/s)
- \( u \): vehicular flow rate (veh/s) = \( V/3600 \)
- \( W_c \): crosswalk width (ft)
- \( N \): number of lanes crossed (Integer)

.defaults:
- \( L \):
- \( S_p \):
- \( t_s \):
- \( V \):
- \( u_p \):
- \( u \):
- \( W_c \):
- \( N \):

*no platooning observed

Crossing Treatment Yield Rate
\( M_y \): motorist yield rate (decimal)

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

Results:

<table>
<thead>
<tr>
<th>LOS</th>
<th>Average Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>14.5</td>
</tr>
</tbody>
</table>

Inputs and Results Page 2 of 5

Developed by Bolton Merik, Inc.
for the Local Road Research Board.

HCM Evaluation Worksheet
### Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

**Step 1: Identify Two-Stage Crossings**

Is there a median available for a two-stage crossing?  
If yes, does the median refuge meet ADA requirements (4' x 4' landing)?  
If no, does the median refuge need to meet ADA requirements (4' x 4' landing)?

<table>
<thead>
<tr>
<th>Crossing</th>
<th>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 sufficient for a safe crossing.</th>
</tr>
</thead>
</table>
| Crossing 1 | $t_c = \frac{L}{S_p} + t_{p}$  
$L = \text{crosswalk length (ft)}$  
$S_p = \text{average pedestrian walking speed (ft/s)}$  
$t_{p} = \text{pedestrian start-up and end clearance time (s)}$  
$t_{p} = 3 \text{ sec}$  

| Crossing 2 | $t_c = \frac{L}{S_p} + t_{p}$  
$L = \text{25}$  
$S_p = \text{4.7}$  
$t_{p} = \text{8.32}$  

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

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

   $N_p = \frac{v_p}{v_p + v} e^{(v_p + v) t_{c}}$

   where:
   - $N_p = \text{total number of pedestrians in crossing platoon (ped)}$
   - $v_p = \text{pedestrian flow rate (ped/s)}$
   - $v = \text{vehicular flow rate across crossing (veh/s)}$
   - $t_{c} = \text{single pedestrian critical headway (s)}$

2. Compute spatial distribution:

   $N_p = \text{Int} \left( \frac{8.0(N_p-1)}{W_c} \right) + 1$

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

3. Compute group critical headway:

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

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

### Step 2: Determine Critical Headway

| Crossing 1 | $v_p = 0.08$  
$t_c = 13.6$  
$N_p = \_\_\_\_$  
$W_c = 8$  
| Crossing 2 | $v_p = 0.08$  
$t_c = 8.32$  
$N_p = \_\_\_\_$  
$W_c = 8$  

### 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.

$P_b = 1 - e^{-\frac{v_p}{v_p+k}}$

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

### Calculations Sheet 1

| Crossing 1 | $t_{c,G} = 13.6$  
$\frac{v}{P_b} = 0.42$  
$N = 2$  
| Crossing 2 | $t_{c,G} = 8.32$  
$\frac{v}{P_b} = 0.28$  
$N = 2$  
$P_b = 0.49$
Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

**Step 4: Calculate Average Delay to Wait for Adequate Gap**

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d_{c1}$ = 13.64</td>
<td>$d_{c2}$ = 9.319</td>
</tr>
<tr>
<td>$P_{c1}$ = 0.08</td>
<td>$P_{c2}$ = 0.08</td>
</tr>
</tbody>
</table>

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

$\bar{d}_{pe} = \frac{d_{c}}{P_{c}}$

where:
- $d_{c}$ = average pedestrian delay gap (s)
- $P_{c}$ = probability of a delayed crossing

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{d}_{pe1}$ = 11.08</td>
<td>$\bar{d}_{pe2}$ = 3.5</td>
</tr>
<tr>
<td>$P_{c1}$ = 0.664</td>
<td>$P_{c2}$ = 0.486</td>
</tr>
</tbody>
</table>

**Step 5: Estimate Delay Reduction due to Yielding Vehicles**

(If yielding is zero, then skip step 5)

- **One-Lane Crossing**
  - $P(Y_j) = P_0 \cdot M_j \cdot (1-M_j)^{j-1}$
- **Two-Lane Crossing**
  - $P(Y_j) = 2P_0 \cdot (1-P_0) \cdot M_j \cdot (1-M_j)^{j-1}$
- **Three-Lane Crossing**
  - $P(Y_j) = \frac{P_0}{M_j} \sum_{i=1}^{j-1} P(Y_i) \cdot \left[ 3P_0 M_j + 3(1-P_0) M_j^2 + 3(1-P_0) M_j^3 \right]$
- **Four-Lane Crossing**
  - $P(Y_j) = \frac{P_0}{M_j} \sum_{i=1}^{j-1} P(Y_i) \cdot \left[ 3P_0 M_j + 3(1-P_0) M_j^2 + 3(1-P_0) M_j^3 + 3(1-P_0) M_j^4 \right]$

**Summary**

<table>
<thead>
<tr>
<th>LOS</th>
<th>Average Delay (s)</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0-5</td>
<td>C</td>
</tr>
<tr>
<td>B</td>
<td>5-10</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>10-20</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>20-30</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>30-45</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>&gt;45</td>
<td></td>
</tr>
</tbody>
</table>

**Calculations Sheet 2**

Page 4 of 5

Developed by Bolton Monk, Inc. for the Local Road Traffic Board.

HCM Evaluation Worksheet

201
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Chapter 9

Conclusion

Pedestrian crossings are an important aspect of the multi-modal transportation system that are essential to get pedestrians across highways and streets. While motorists are required to stop for pedestrians in most situations, additional measures may be appropriate at a specific crossing location.

The evaluation of uncontrolled pedestrian crossings depends on multiple factors including safety and delay, similar to the procedure for evaluation of roadways and intersections for motorists. There has been significant research into the safety of pedestrian crossings that is being applied by agencies, but the missing component has been the delay. The Highway Capacity Manual (HCM) presents a procedure for evaluating pedestrian crossing delay. As of this research study, the HCM procedure has not been widely applied to the evaluation of pedestrian crossings but can help to provide an equivalent process to vehicle intersection operational analysis and be applied to the engineering study requirement as mentioned in the MUTCD.

This report presents a procedure for the evaluation of uncontrolled pedestrian crossing locations that takes into account both safety and delay, in addition to other factors. The evaluation procedure runs through a multi-step process from field data review through the consideration of appropriate treatment options. The specific steps include

- Field Data Review
- Safety Review
- Stopping Sight Distance Analysis
- HCM Level of Service (LOS) Analysis
- Pedestrian Sight Distance Analysis
- Review of Origins and Destinations and Alternate Routes
- Review of Access Spacing and Functional Classification
- Review of Speed and Pedestrian Use
- Review of FHWA Safety Guidance
- School Crossing Considerations
- Consideration of Appropriate Treatment Options
  - Signing and Marking Treatments
  - Traffic Calming Treatments
  - Uncontrolled Crossing Treatments
  - High-Level Treatments

The background, understanding and analysis methodology of each step in the process is important to understand. The methodology presented for the evaluation of uncontrolled pedestrian crossings is available to the public and should be tailored for individual use as needed. In support of this study, a Guidebook has been developed to provide a summary of the methodology and is included in Appendix F. This Guidebook is intended to be a working document to be updated as additional research is conducted.
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References


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UNCONTROLLED PEDESTRIAN CROSSING EVALUATION FLOWCHART

Field Data Review

Safety Review

Yes

Yes

Yes Yes

Yes

No

No

No

Yes

HCM LOS Analysis

Acceptable LOS?

Yes

Location has Treatments?

Yes

No

Pedestrian Sight Distance Provided?

Yes

No

Review:
- Origins and Destinations
- Alternate Routes

Alternative Route Available that Serves Same O-D Pair, has a Shorter Travel Time and can be Seen from the Crossing Location?

No

Yes

Consider Evaluation of Alternative Crossing Location

Consider No Changes at Existing Crossing or Removal, if Location Does Not Need Treatments

Step 3

Step 4

Step 5

Step 6

Step 7

Step 8

Step 9

Step 10

Step 11

REPEAT

REPEAT

REPEAT

Move Crossing Location and/or Modify Roadway to Meet SSD

Stopping Sight Distance Provided?

Yes

No

Access Spacing and Functional Classification

Location on a Coordinated Signalized Corridor with Pedestrian Crossings Consistent with Primary Intersection Access Spacing or on a Grade Separated Facility?

* The Application of a Crosswalk and any Treatments Shall Consider Engineering Judgment and shall be approved by the Jurisdictional Authority.
Appendix B
Field Review Worksheet
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**Uncontrolled Pedestrian Crossing Data Collection Worksheet**

<table>
<thead>
<tr>
<th>Location:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>City, State:</td>
<td>Scenario:</td>
</tr>
<tr>
<td>Reviewer(s):</td>
<td>Agency:</td>
</tr>
<tr>
<td>Project #:</td>
<td>ID #:</td>
</tr>
</tbody>
</table>

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 Width: effective crosswalk width | Crossing 2 | ft. |
| Median: width of median at crossing location | 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: | Daily | pedestrians: | Daily |
| AM Peak Hourly | Pk 15-min | Hourly | Pk 15-min |
| PM Peak Hourly | Pk 15-min | Hourly | Pk 15-min |

**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 |

**Signing:**

| Currently signed at crosswalk? | Yes | No |
| Currently signed in advance of crosswalk? | Yes | No |

**Enhancements:**

| What enhancements are currently at the crossing location? |

**Adjacent Facilities:**

| Distance to nearest marked crosswalk? | ft. |

**Additional Site Characteristics**

| 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 |

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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
- t = brake reaction time, s
- a = deceleration rate, ft/s^2
- S_p = average pedestrian walking speed, ft/s
- t_s = pedestrian start-up and end clearance time, s

defaults:
- t = 2.5
- a = 11.2
- S_p = 3.5
- t_s = 3.0
Appendix C
HCM Evaluation Worksheets
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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 practitioners. 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
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:**
- \( L \) = crosswalk length (ft)
- \( S_p \) = average pedestrian walking speed (ft/s)
- \( t_s \) = pedestrian start-up and end clearance time (s)
- \( V \) = vehicular hourly volume (veh/hr)
- \( v_p \) = pedestrian flow rate (ped/s)
- \( V \) = vehicular flow rate (veh/s) = \( V/3600 \)
- \( W_c \) = crosswalk width (ft)
- \( N \) = number of through lanes crossed (Integer)

**Input Table:**

<table>
<thead>
<tr>
<th>defaults:</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L = )</td>
<td>( S_p = 3.5 )</td>
</tr>
<tr>
<td>( S_p = 3.5 )</td>
<td>( t_s = 3.0 )</td>
</tr>
<tr>
<td>( t_s = 3.0 )</td>
<td>( V = )</td>
</tr>
<tr>
<td>( V = )</td>
<td>( v_p = 0^* )</td>
</tr>
<tr>
<td>( v_p = 0^* )</td>
<td>( V/3600 )</td>
</tr>
<tr>
<td>( V/3600 )</td>
<td>( W_c = 8.0 )</td>
</tr>
<tr>
<td>( W_c = 8.0 )</td>
<td>( N = )</td>
</tr>
<tr>
<td>( N = )</td>
<td>( \text{INT}(L/11) )</td>
</tr>
</tbody>
</table>

*no platooning observed

### Crossing 2:

(only used for two-stage crossings)

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

**Input Table:**

<table>
<thead>
<tr>
<th>defaults:</th>
<th>Input Table:</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L = )</td>
<td>( S_p = 3.5 )</td>
</tr>
<tr>
<td>( S_p = 3.5 )</td>
<td>( t_s = 3.0 )</td>
</tr>
<tr>
<td>( t_s = 3.0 )</td>
<td>( V = )</td>
</tr>
<tr>
<td>( V = )</td>
<td>( v_p = 0^* )</td>
</tr>
<tr>
<td>( v_p = 0^* )</td>
<td>( V/3600 )</td>
</tr>
<tr>
<td>( V/3600 )</td>
<td>( W_c = 8.0 )</td>
</tr>
<tr>
<td>( W_c = 8.0 )</td>
<td>( N = )</td>
</tr>
<tr>
<td>( N = )</td>
<td>( \text{INT}(L/11) )</td>
</tr>
</tbody>
</table>

*no platooning observed

### Crossing Treatment Yield Rate

\( M_{y} \) = motorist yield rate (decimal)

### Results:

<table>
<thead>
<tr>
<th>Average Delay</th>
<th>LOS</th>
<th>sec/ped</th>
</tr>
</thead>
</table>

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for the Local Road Research Board

Inputs and Results Page 2 of 5

HCM Evaluation Worksheet C-3
### Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

<table>
<thead>
<tr>
<th>Crosswalk Location:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>City, State:</td>
<td>Scenario:</td>
</tr>
<tr>
<td>Reviewer(s):</td>
<td>Agency:</td>
</tr>
</tbody>
</table>

#### Step 1: Identify Two-Stage Crossings

<table>
<thead>
<tr>
<th>Crossing 1</th>
<th>Crossing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>L =</td>
<td>L =</td>
</tr>
<tr>
<td>S&lt;sub&gt;p&lt;/sub&gt; =</td>
<td>S&lt;sub&gt;p&lt;/sub&gt; =</td>
</tr>
<tr>
<td>t&lt;sub&gt;s&lt;/sub&gt; =</td>
<td>t&lt;sub&gt;s&lt;/sub&gt; =</td>
</tr>
</tbody>
</table>

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

#### 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 sufficient 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)

\( S_p = 3.5 \text{ ft/s} \)
\( t_s = 3 \text{ sec} \)

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

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

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

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)

2. Compute spatial distribution:

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

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)

3. Compute group critical headway:

\[ t_{c,G} = t_c + 2(N_p - 1) \]

#### 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.

\[ P_b = 1 - e^{-t_{c,G}v} \]
\[ P_d = 1 - (1 - P_b)^L \]

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

Developed by Bolton & Menk, Inc. for the LRRB.
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.

\[ d_g = \frac{1}{\nu} \left( e^{\nu t_{c,G}} - \nu t_{c,G} - 1 \right) \]

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

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
- \( P_d \): probability of a delayed crossing

### Step 5: Estimate Delay Reduction due to Yielding Vehicles

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)
- \( h \): crossing event \( i \) to \( n \)
- \( P(Y_i) \): probability that motorists yield to pedestrian on crossing event \( i \)
- \( P_d \): average gap delay for pedestrians who incur nonzero delay
- \( n \): \( \text{Int}(d_{gd}/h) \), average number of crossing events before an adequate gap is available, \( >0 \)

1. One-Lane Crossing

\[ P(Y_i) = P_d M_y \left( 1 - M_y \right)^{i-1} \]

2. Two-Lane Crossing

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

3. Three-Lane Crossing

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

4. Four-Lane Crossing

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

### Step 6: Calculate Average Pedestrian Delay & Determine LOS

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

Summary

<table>
<thead>
<tr>
<th>LOS</th>
<th>Average</th>
<th>LOS</th>
</tr>
</thead>
</table>

Developed by Bolton & Menk, Inc. for the LRRB.
Determine if there is a crossing treatment used that could provide vehicle yielding. This then provides a possible reduction in delay.

<table>
<thead>
<tr>
<th>Crossing Treatment</th>
<th>Staged Pedestrian Yield Rate</th>
<th>Unstaged Pedestrian Yield Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crosswalk Markings and Signs Only (1)</td>
<td>7%</td>
<td>7%</td>
</tr>
<tr>
<td>Median Refuge Islands (1)</td>
<td>34%</td>
<td>29%</td>
</tr>
<tr>
<td>Pedestal Mounted Flashing Beacon (2-Lane, 35 mph) (3)</td>
<td>N/A</td>
<td>57%</td>
</tr>
<tr>
<td>Overhead Flashing Beacon (push-button activation) (1)</td>
<td>47%</td>
<td>49%</td>
</tr>
<tr>
<td>Overhead Flashing Beacon (passive activation) (1)</td>
<td>31%</td>
<td>67%</td>
</tr>
<tr>
<td>Pedestrian Crossing Flags (1)</td>
<td>65%</td>
<td>74%</td>
</tr>
<tr>
<td>School Crossing Guards (5)</td>
<td>N/A</td>
<td>86%</td>
</tr>
<tr>
<td>In-street Crossing Signs (25-30 mph) (1)</td>
<td>87%</td>
<td>90%</td>
</tr>
<tr>
<td>Warning Sign with Edge Mounted LEDs (6)</td>
<td>N/A</td>
<td>28%</td>
</tr>
<tr>
<td>In-road warning lights (1)</td>
<td>N/A</td>
<td>66%</td>
</tr>
<tr>
<td>High-visibility Signs and Markings (35 mph) (1)</td>
<td>17%</td>
<td>20%</td>
</tr>
<tr>
<td>High-visibility Signs and Markings (25 mph) (1)</td>
<td>61%</td>
<td>91%</td>
</tr>
<tr>
<td>Rectangular Rapid-Flash Beacon (RRFB) (2)(4)</td>
<td>84%</td>
<td>81%</td>
</tr>
<tr>
<td>School Crossing Guards with RRFB (5)</td>
<td>N/A</td>
<td>91%</td>
</tr>
<tr>
<td>Pedestrian Hybrid Beacon (HAWK) (1)</td>
<td>97%</td>
<td>99%</td>
</tr>
</tbody>
</table>

N/A: No Research Found on Effect to Yielding Rate

(3) Bolton & Menk Field Data Collection
(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.
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Appendix D
FHWA Safety Guidance Table
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Table 11. Recommendations for installing marked crosswalks and other needed pedestrian improvements at uncontrolled locations.*

<table>
<thead>
<tr>
<th>Roadway Type (Number of Travel Lanes and Median Type)</th>
<th>Vehicle ADT</th>
<th>Speed Limit**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 9,000</td>
<td>≤ 48.3 km/h (30 mi/h)</td>
</tr>
<tr>
<td></td>
<td>&gt;9,000 to 12,000</td>
<td>≤ 48.3 km/h (30 mi/h)</td>
</tr>
<tr>
<td></td>
<td>&gt;12,000–15,000</td>
<td>≤ 48.3 km/h (30 mi/h)</td>
</tr>
<tr>
<td></td>
<td>&gt; 15,000</td>
<td>≤ 48.3 km/h (30 mi/h)</td>
</tr>
<tr>
<td>Two lanes</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Three lanes</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Multilane (four or more lanes) with raised median***</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Multilane (four or more lanes) without raised median</td>
<td>C</td>
<td>P</td>
</tr>
</tbody>
</table>

* 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.
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Appendix E
Treatment Tables
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## Signing and Marking Treatments
(Treatments Should be Justified Through an Engineering Study)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Recommended Locations</th>
<th>Motorist Yield Rate</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crosswalk Markings Only</td>
<td>Inexpensive</td>
<td>Very little effect at night</td>
<td>Not usually recommended alone</td>
<td>NR</td>
<td>$500 to $2,000</td>
</tr>
<tr>
<td></td>
<td>Helps define a crossing location</td>
<td>Speeds increase over time</td>
<td>Low volume and low speed roadways</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indicates to drivers that a crossing location is present</td>
<td>Not been shown to reduce crashes</td>
<td>Where justified</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warning Signs</td>
<td>Inexpensive</td>
<td>Tend to be ignored unless pedestrians use the crossing consistently</td>
<td>Where unexpected entries into the roadway by pedestrians may occur</td>
<td></td>
<td>$300 to $1,200</td>
</tr>
<tr>
<td></td>
<td>Helps define a crossing location</td>
<td>Proven to be ineffective at reducing crashes at uncontrolled intersections</td>
<td>Either at or before the crossing location</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Warning to drivers that a crossing location is present</td>
<td>Either with or without a marked crosswalk</td>
<td></td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Overhead Warning Signs</td>
<td>Visual distance increased</td>
<td>Requires overhead structure</td>
<td>Multi-lane roadways</td>
<td>NR</td>
<td>$10,000 to $75,000</td>
</tr>
<tr>
<td></td>
<td>Warning to drivers that a crossing location is present</td>
<td>Tend to be ignored unless pedestrians use the crossing consistently</td>
<td>Midblock crossing locations</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Signs easier to see when have multiple lanes of approach</td>
<td>Requires overhead structure</td>
<td>Usually coupled with other measures such as RRFBs or beacons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colored Concrete/Brick Pavers</td>
<td>May decrease vehicle speed</td>
<td>Can be expensive</td>
<td>Downtown/Urban conditions</td>
<td>NR</td>
<td>$800 to $3,200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not been shown to reduce crashes</td>
<td>Traffic signal locations</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Speeds increase over time</td>
<td>In conjunction with pavement markings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crosswalk Markings and Signs</td>
<td>Inexpensive</td>
<td>Very little effect at night</td>
<td>Where justified</td>
<td>7%</td>
<td>$5,000 to $50,000</td>
</tr>
<tr>
<td></td>
<td>Warning to drivers that a crossing location is present</td>
<td>Not been shown to reduce crashes</td>
<td></td>
<td>7%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>May decrease vehicle speed</td>
<td>Speeds increase over time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-Street Crossing Signs (25 to 30 mph)</td>
<td>Inexpensive</td>
<td>May make snow removal more difficult</td>
<td>Downtown/Urban conditions</td>
<td>87%</td>
<td>$500 to $1,000</td>
</tr>
<tr>
<td></td>
<td>Additional Warning to drivers that a crossing location is present</td>
<td>Need consistent maintenance and replacement due to vehicle hits</td>
<td>Supplement warning signs at high pedestrian volume locations</td>
<td>90%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>In conjunction with pavement markings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Visibility Crosswalk Markings</td>
<td>May decrease vehicle speed</td>
<td>Not been shown to reduce crashes</td>
<td>Where justified</td>
<td>61% (25 mph)</td>
<td>$5,000 to $50,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Speeds increase over time</td>
<td>Urban conditions</td>
<td>17% (35 mph)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>91% (25 mph)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20% (35 mph)</td>
<td></td>
</tr>
</tbody>
</table>

NR = No Research Found on Effect to Yielding Rate
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Recommended Locations</th>
<th>Motorist Yield Rate</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Median with Refuge Island</td>
<td>Decreases pedestrian crossing distance, Provides higher pedestrian visibility, Reduces vehicle speeds approaching the island, Reduces conflicts, Increases usable gaps, Reduces pedestrian exposure time</td>
<td>May make snow removal more difficult, May be a hazard for motorists, Small islands not recommended on high speed (&gt;40 mph) roadways</td>
<td>Wide two-lane roads and multi-lane roads with sufficient right-of-way</td>
<td>34% 29%</td>
<td>Variable depending on length</td>
</tr>
<tr>
<td>School Crossing Guards</td>
<td>Inexpensive, Provides higher pedestrian visibility to drivers, Highlights when a pedestrian crossing is being used</td>
<td>May require trained staff or local law enforcement, especially on high speed and high volume roadways</td>
<td>At school locations</td>
<td>NR 86%</td>
<td>Variable</td>
</tr>
<tr>
<td>Pedestrian Crossing Flag</td>
<td>Inexpensive, Provides higher pedestrian visibility to drivers assuming the flag is held in a noticeable location</td>
<td>No effect at night, Requires pedestrian to actively use a flag, Can be easily removed/stolen, Shorter crossings are preferred</td>
<td>Downtown/Urban locations, High pedestrian volume locations, Across low speed (&lt;45 mph) roadways</td>
<td>65% 74%</td>
<td>&lt;$500</td>
</tr>
<tr>
<td>Warning Sign with Edge Mounted LEDs</td>
<td>Highlights a crossing both at night and during the day</td>
<td>Requires pedestrian activation, Minimal to no effect on speed, Snow plows can cause maintenance issues</td>
<td>In conjunction with In-Road Warning Lights, Downtown/Urban conditions</td>
<td>NR 28%</td>
<td>$3,000 to $8,000</td>
</tr>
<tr>
<td>In-Road Warning Lights</td>
<td>Highlights a crossing both at night and during the day, Provides higher driver awareness when a pedestrian is present</td>
<td>No effect when road surface is covered in snow</td>
<td>Downtown/Urban conditions</td>
<td>NR 66%</td>
<td>$20,000 to $40,000</td>
</tr>
<tr>
<td>Pedestal Mounted Pedestrian Flashing Signal Beacons</td>
<td>Provides higher driver awareness when a pedestrian is present</td>
<td>Requires pedestrian activation, Not advisable on multi-lane streets</td>
<td>Low speed school crossings, Two lane roadways, Midblock crossing locations</td>
<td>NR 57% (2-Lane, 35 mph)</td>
<td>$12,000 to $18,000</td>
</tr>
<tr>
<td>Pedestrian Overhead Flashing Signal Beacons</td>
<td>Provides higher driver awareness when a pedestrian is present</td>
<td>Requires pedestrian activation, Not been shown to reduce crashes</td>
<td>Multi-lane roadways, Midblock crossing locations, Lower speed roadways</td>
<td>active 47% passive 31% active 49% passive 67%</td>
<td>$75,000 to $150,000</td>
</tr>
<tr>
<td>Rectangular Rapid Flash Beacons (RRFBs)</td>
<td>Provides higher driver awareness when a pedestrian is present, Increases yielding percentage, Increase in usable gaps, Reduces the probability of pedestrian risk taking, Can be configured to be seen from 360 degrees</td>
<td>Requires pedestrian activation</td>
<td>Supplement existing pedestrian crossing warning signs, School Crossings, Midblock crossing locations, Low and high speed roadways</td>
<td>84% 81%</td>
<td>$12,000 to $18,000</td>
</tr>
</tbody>
</table>

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

NR = No Research Found on Effect to Yielding Rate
### High Level Treatments

*Treatments Should be Justified Through an Engineering Study*

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Recommended Locations</th>
<th>Motorist Yield Rate</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian Hybrid Beacon</td>
<td>Provides higher driver awareness when a pedestrian is present</td>
<td>Potential increase in vehicle crashes, Can have spotty compliance rates due to a lack of driver understanding</td>
<td>Justified locations</td>
<td>97%</td>
<td>$150,000 to $300,000</td>
</tr>
<tr>
<td>Traffic Signal</td>
<td>Provides higher driver awareness when a pedestrian is present</td>
<td>May increase crashes due to the driver expectation of a green signal indication</td>
<td>High pedestrian volume crossings, Justified locations, meets signal warrants</td>
<td>NA</td>
<td>$100,000 to $300,000</td>
</tr>
<tr>
<td>Underpass Grade Separation</td>
<td>Removes pedestrian/vehicle conflicts</td>
<td>Potential of the crossing not being used, Very expensive, Drainage within an underpass can be problematic, Underpass would require lighting</td>
<td>Location with compatible grades</td>
<td>NA</td>
<td>$800,000+</td>
</tr>
<tr>
<td>Overpass Grade Separation</td>
<td>Removes pedestrian/vehicle conflicts</td>
<td>Potential of the crossing not being used, Very location specific, Very expensive, Snow removal on overpass may be difficult</td>
<td>Location with compatible grades</td>
<td>NA</td>
<td>$1,200,000+</td>
</tr>
</tbody>
</table>

NA = Not Applicable or No Research Found on Effect to Yielding Rates

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**Bolton & Menk, Inc.**

Uncontrolled Pedestrian Crossing Evaluation
Appendix F
Guidebook
Pedestrian Crossings: Uncontrolled Locations

June 2014

Published By
Minnesota Local Road Research Board (LRRB)
Web: www.lrrb.org

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Acknowledgements

The financial and logistical support provided by the Minnesota Local Road Research Board, the Minnesota Department of Transportation (MnDOT), and the Minnesota Local Technical Assistance Program (LTAP) at the Center for Transportation Studies (CTS), University of Minnesota for this work is greatly acknowledged.

The procedures presented in this report were developed based on information from previously published research studies and reports and newly collected field data.

The authors would also like to thank the following individuals and organizations for their contributions to this document.

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This material was developed by Bolton & Menk, Inc., in coordination with the Minnesota Local Road Research Board for use by practitioners. Under no circumstances shall this guidebook be sold by third parties for profit.

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.
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:
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.
Consider Pedestrian Barriers and Pedestrian Re-Routing

Consider Appropriate Traffic Calming Treatments

Consider Do Nothing, Pedestrian Re-Routing and/or Appropriate High Level Treatments (Traffic Signal, Pedestrian Overpass/Bridge or Pedestrian Underpass/Tunnel)*

FHWA Safety Guidance

Consider Appropriate Traffic Calming Treatments With or Without Uncontrolled Crossing Treatments

Consider Appropriate Uncontrolled Crossing Treatments May Need Traffic Calming Treatments Also for School Locations Consider Crossing Guards as a Treatment

HCM LOS Analysis Acceptable LOS?

Consider Appropriate Signing and Marking Treatments May Need Additional Treatment Options

Use Option(s)*


* 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.

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 (Wc) 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).

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

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:


**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 85\textsuperscript{th} percentile speed of the roadway being crossed. In the absence of collected speed data, it is assumed that the 85\textsuperscript{th} 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).

![Impact speeds, pedestrian fatality and injury](chart.png)

**Sources:**

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.

\[
SSD = 1.47S^2 \pm \frac{3.075}{30} \left(\frac{a}{32.2}\right) \pm G
\]

Where:
SSD = stopping sight distance
S = speed (mph)
t = brake reaction distance, 2.5 s
a = deceleration rate, ft/s², default = 11.2 ft/s²
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.

\[
PedSD = 1.47S^2 \left(\frac{L}{S_p} + t_s\right)
\]

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

Signing

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

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

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.

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 (Wc) 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:
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.

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 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.

Sources:
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:
<table>
<thead>
<tr>
<th>Roadway Type (Number of Travel Lanes and Median Type)</th>
<th>Vehicle ADT ≤ 9,000</th>
<th>Vehicle ADT &gt; 9,000–12,000</th>
<th>Vehicle ADT &gt; 12,000–15,000</th>
<th>Vehicle ADT &gt; 15,000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Speed Limit*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>≤ 48.3 km/h (30 mph)</td>
<td>56.4 km/h (35 mph)</td>
<td>64.4 km/h (40 mph)</td>
<td>≤ 48.3 km/h (30 mph)</td>
</tr>
<tr>
<td>Two lanes</td>
<td>C</td>
<td>C</td>
<td>P</td>
<td>C</td>
</tr>
<tr>
<td>Three lanes</td>
<td>C</td>
<td>C</td>
<td>P</td>
<td>C</td>
</tr>
<tr>
<td>Multilane (four or more lanes) with raised median**</td>
<td>C</td>
<td>C</td>
<td>P</td>
<td>C</td>
</tr>
<tr>
<td>Multilane (four or more lanes) without raised median</td>
<td>C</td>
<td>P</td>
<td>N</td>
<td>P</td>
</tr>
</tbody>
</table>

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

**The raised median or crossing island must be at least 1.2 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 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 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.
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.
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:
Bolton & Menk, Inc.
Before-and-After Study of the Effectiveness of Rectangular Rapid-Flashi ng Beacons Used with School Sign in Garland, Texas. Texas Transportation Institute, College Station, TX, April 2012.
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Recommended Locations</th>
<th>Staged Pedestrian Yield Rate</th>
<th>Unstaged Pedestrian Yield Rate</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crosswalk Markings Only</td>
<td>• Inexpensive • Helps define a crossing location • Indicates to drivers that crossing location is present</td>
<td>• Very little effect at night • Speeds increase over time • Not shown to reduce crashes</td>
<td>• Not usually recommended alone • Low-volume and low-speed roadways • Where justified</td>
<td>NR</td>
<td>NR</td>
<td>$500–$2,000</td>
</tr>
<tr>
<td>Warning Signs</td>
<td>• Inexpensive • Helps define a crossing location • Warning to drivers that crossing location is present</td>
<td>• Tend to be ignored unless pedestrians use the crossing consistently • Proven to be ineffective at reducing crashes at uncontrolled intersections</td>
<td>• Where unexpected entries into the road by pedestrians may occur • At or before the crossing location • With or without a marked crosswalk</td>
<td>NR</td>
<td>NR</td>
<td>$300–$1,200</td>
</tr>
<tr>
<td>Overhead Warning Signs</td>
<td>• May decrease vehicle speed</td>
<td>• Requires overhead structure • Tend to be ignored unless pedestrians use the crossing consistently</td>
<td>• Multilane roadways • Mid-block crossing locations • Usually coupled with other measures such as RFRBs or beacons</td>
<td>NR</td>
<td>NR</td>
<td>$60,000–$75,000</td>
</tr>
<tr>
<td>Colored Concrete/Brick Pavers</td>
<td>• Inexpensive • Warning to drivers that crossing location is present • May decrease vehicle speed</td>
<td>• Can be expensive • Not shown to reduce crashes</td>
<td>• Downtown/urban conditions • Traffic signal locations • In conjunction with pavement markings</td>
<td>NR</td>
<td>NR</td>
<td>$10,000–$75,000</td>
</tr>
<tr>
<td>Crosswalk Markings and Signs</td>
<td>• Inexpensive • Warning to drivers that crossing location is present • May decrease vehicle speed</td>
<td>• Make snow removal more difficult • Need consistent maintenance and replacement due to vehicle hits</td>
<td>• Where justified</td>
<td>7%</td>
<td>7%</td>
<td>$800–$3,200</td>
</tr>
<tr>
<td>In-Street Crossing Signs (25–30 mph)</td>
<td>• Inexpensive • Additional warning to drivers that crossing location is present</td>
<td>• Not shown to reduce crashes • Speeds increase over time</td>
<td>• Downtown/urban conditions • Supplement warning signs at high pedestrian volume locations • In conjunction with pavement markings</td>
<td>87%</td>
<td>90%</td>
<td>$500–$1,000</td>
</tr>
<tr>
<td>High-Visibility Crosswalk Markings</td>
<td>• May decrease vehicle speed</td>
<td>• Not shown to reduce crashes • Speeds increase over time</td>
<td>• Where justified • Urban conditions</td>
<td>61% (25mph)</td>
<td>17% (35mph)</td>
<td>$5,000–$50,000</td>
</tr>
</tbody>
</table>

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 treatment options are outlined in Table 3 on page 23 (treatments should be justified through an engineering study). Selected treatment examples are also shown below.
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Recommended Locations</th>
<th>Staged Pedestrian Yield Rate</th>
<th>Unstaged Pedestrian Yield Rate</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Median with Refuge Island</td>
<td>• Decreases pedestrian crossing distance • Provides higher pedestrian visibility • Reduces vehicle speeds approaching the island • Reduces conflicts • Increases usable gaps • Reduces pedestrian exposure time</td>
<td>• May make snow removal more difficult • May be a hazard for motorists • Small islands not recommended on high-speed roadways (&gt;40 mph)</td>
<td>Wide, two-lane roads and multilane roads with sufficient right-of-way</td>
<td>34%</td>
<td>29%</td>
<td>Variable depending on length</td>
</tr>
<tr>
<td>School Crossing Guards</td>
<td>• Inexpensive • Provides higher pedestrian visibility • Highlights when a pedestrian crossing is being used</td>
<td>• May require trained staff or local law enforcement, especially on high-speed and high-volume roadways</td>
<td>At school locations</td>
<td>NR</td>
<td>86%</td>
<td>Variable</td>
</tr>
<tr>
<td>Pedestrian Crossing Flags</td>
<td>• Inexpensive • Provides higher pedestrian visibility to drivers assuming the flag is held in a noticeable location</td>
<td>• No effect at night • Requires pedestrians to actively use a flag • Can be easily removed/stolen • Shorter crossings are preferred</td>
<td>Downtown/urban locations • High pedestrian volume locations • Across low-speed (&lt;45 mph) roadways</td>
<td>65%</td>
<td>74%</td>
<td>&lt;$500</td>
</tr>
<tr>
<td>Warning Sign with Edge Mounted LEDs</td>
<td>• Highlights a crossing both at night and during the day</td>
<td>• Requires pedestrian activation • Minimal to no effect on speed</td>
<td>In conjunction with in-road warning lights • Downtown/urban conditions</td>
<td>NR</td>
<td>28%</td>
<td>$3,000–$8,000</td>
</tr>
<tr>
<td>In-Road Warning Lights</td>
<td>• Highlights a crossing both at night and during the day • Provides higher driver awareness when a pedestrian is present</td>
<td>• Snowplows can cause maintenance issues • No effect when road surface is snow covered • Requires pedestrian activation</td>
<td>Downtown/urban conditions</td>
<td>NR</td>
<td>66%</td>
<td>$20,000–$40,000</td>
</tr>
<tr>
<td>Pedestal Mounted Pedestrian Flashing Signal Beacons</td>
<td>• Provides higher driver awareness when a pedestrian is present</td>
<td>• Requires pedestrian activation • Not advisable on multilane streets • Not shown to reduce crashes</td>
<td>Low-speed school crossings • Two-lane roads • Midblock crossing locations</td>
<td>NR</td>
<td>57% (two-lane, 35mph)</td>
<td>$12,000–$18,000</td>
</tr>
<tr>
<td>Pedestrian Overhead Flashing Signal Beacons</td>
<td>• Provides higher driver awareness when a pedestrian is present</td>
<td>• Requires pedestrian activation</td>
<td>Multilane roadways • Mid-block crossing locations • Lower speed roadways</td>
<td>active 47% passive 31%</td>
<td>active 49% passive 67%</td>
<td>$75,000–$150,000</td>
</tr>
<tr>
<td>Rectangular Rapid Flash Beacons (RRFBs)</td>
<td>• 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</td>
<td>• Requires pedestrian activation</td>
<td>Supplement existing pedestrian crossing warning signs • School crossings • Midblock crossing locations • Low- and high-speed roadways</td>
<td>84%</td>
<td>81%</td>
<td>$12,000–$18,000</td>
</tr>
</tbody>
</table>

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

Sources:
Bolton & Menk, Inc.
Before-and-After Study of the Effectiveness of Rectangular Rapid-Flash Beacons Used with School Sign in Garland, Texas. Texas Transportation Institute, College Station, TX, April 2012.
### Table 4: Traffic Calming Treatments

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

*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.

**Sources:**
- Bolton & Menk, Inc.
- 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

<table>
<thead>
<tr>
<th>Treatment Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Yield Rate</th>
<th>Location Characteristics</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian Pedestrian Beacon</td>
<td>• Provides higher driver awareness when a pedestrian is present • Has been shown to decrease pedestrian crashes</td>
<td>• Potential increase in vehicle crashes • Can have spotty compliance rates due to a lack of driver understanding</td>
<td>97%</td>
<td>Justified locations • Mid-block crossing locations</td>
<td>$150,000–$300,000</td>
</tr>
<tr>
<td>Pedestrian Traffic Signal</td>
<td>• Provides higher driver awareness when a pedestrian is present • Easily understandable</td>
<td>• May increase crashes due to the driver expectation of a green signal indication</td>
<td>NA</td>
<td>NA</td>
<td>$150,000–$300,000</td>
</tr>
<tr>
<td>Underpass Grade</td>
<td>• 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</td>
<td>• Location with compatible grades • High pedestrian volume crossings • High-volume roadways • High-speed roadways</td>
<td>NA</td>
<td>NA</td>
<td>$800,000+</td>
</tr>
<tr>
<td>Overpass Grade</td>
<td>• Removes pedestrian/vehicle conflicts • Potential of the crossing not being used • Very location specific • Very expensive • Snow removal on overpass may be difficult</td>
<td>• Location with compatible grades • High pedestrian volume crossings • High-volume roadways • High-speed roadways</td>
<td>NA</td>
<td>NA</td>
<td>$1,200,000+</td>
</tr>
</tbody>
</table>

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. Crossing 1 ft. |
| 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 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: Daily |
| pedestrians: Daily |
| AM Peak Hourly Pk 15-min |
| PM Peak Hourly Pk 15-min |

### 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

### Enhancements:

What enhancements are currently at the crossing location?

### Adjacent Facilities:

Distance to nearest marked crosswalk? ft.

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

---

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F-30
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 origins and destinations.

draw or insert map of location being studied

Notes:

Sight Distance Calculations:

Stopping sight distance (SSD), \( d_t = 1.475t + 1.075S^2/a \)
Pedestrian sight distance (PedSD), \( d_p = 1.475(L/S_p + t_p) \)

where:
- \( d_t \): brake reaction time, s
- \( d_p \): deceleration rate, \( ft/s^2 \)
- \( S_p \): average pedestrian walking speed, \( ft/s \)
- \( t_p \): pedestrian start-up and end clearance time, s

\( t \) defaults: 2.5
\( a \) defaults: 11.2
\( S_p \) defaults: 3.5
\( t_p \) defaults: 3.0
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 practitioners. 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:**

<table>
<thead>
<tr>
<th>City, State:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reviewer(s):</td>
</tr>
<tr>
<td>Project Number:</td>
</tr>
</tbody>
</table>

**Date:**

| Scenario: |
| Agency: |

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:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L )</td>
<td>crosswalk length (ft)</td>
</tr>
<tr>
<td>( S_p )</td>
<td>average pedestrian walking speed (ft/s)</td>
</tr>
<tr>
<td>( t_e )</td>
<td>pedestrian start-up and end clearance time (s)</td>
</tr>
<tr>
<td>( V )</td>
<td>vehicular hourly volume (veh/hr)</td>
</tr>
<tr>
<td>( v )</td>
<td>vehicular flow rate (veh/s) = ( V/3600 )</td>
</tr>
<tr>
<td>( W_c )</td>
<td>crosswalk width (ft)</td>
</tr>
<tr>
<td>( N )</td>
<td>number of through lanes crossed (Integer)</td>
</tr>
</tbody>
</table>

### Input Table:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L )</td>
<td></td>
</tr>
<tr>
<td>( S_p )</td>
<td></td>
</tr>
<tr>
<td>( t_e )</td>
<td></td>
</tr>
<tr>
<td>( V )</td>
<td></td>
</tr>
<tr>
<td>( v )</td>
<td></td>
</tr>
<tr>
<td>( W_c )</td>
<td></td>
</tr>
<tr>
<td>( N )</td>
<td></td>
</tr>
</tbody>
</table>

*No platooning observed*

### Crossing 2:

**Evaluation Inputs:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L )</td>
<td>crosswalk length (ft)</td>
</tr>
<tr>
<td>( S_p )</td>
<td>average pedestrian walking speed (ft/s)</td>
</tr>
<tr>
<td>( t_e )</td>
<td>pedestrian start-up and end clearance time (s)</td>
</tr>
<tr>
<td>( V )</td>
<td>vehicular hourly volume (veh/hr)</td>
</tr>
<tr>
<td>( v )</td>
<td>vehicular flow rate (veh/s) = ( V/3600 )</td>
</tr>
<tr>
<td>( W_c )</td>
<td>crosswalk width (ft)</td>
</tr>
<tr>
<td>( N )</td>
<td>number of through lanes crossed (Integer)</td>
</tr>
</tbody>
</table>

**Input Table:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L )</td>
<td></td>
</tr>
<tr>
<td>( S_p )</td>
<td></td>
</tr>
<tr>
<td>( t_e )</td>
<td></td>
</tr>
<tr>
<td>( V )</td>
<td></td>
</tr>
<tr>
<td>( v )</td>
<td></td>
</tr>
<tr>
<td>( W_c )</td>
<td></td>
</tr>
<tr>
<td>( N )</td>
<td></td>
</tr>
</tbody>
</table>

*No platooning observed*

### Crossing Treatment Yield Rate

**\( M_v \) =** motorist yield rate (decimal)

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

### Results:

<table>
<thead>
<tr>
<th>Average Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
</tr>
</tbody>
</table>

**Developed by Bolton & Menk, Inc. for the Local Road Research Board**

**Inputs and Results**

Page 2 of 5

**HCM Evaluation Worksheet**
Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

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

**Step 1: Identify Two-Stage Crossings**

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 sufficient 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)

\[ S_p = 3.5 \text{ ft/s} \]
\[ t_s = 3 \text{ sec} \]

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

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

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

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)

2. compute spatial distribution:

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

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)

3. compute group critical headway:

\[ t_{c,G} = t_c + 2(N_p - 1) \]

**Step 2: Determine Critical Headway**

**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.

\[ P_b = 1 - e^{-t_{c,G} v} \]
\[ P_d = 1 - (1 - P_b)^N \]

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)
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.

\[
d_g = \frac{1}{v} \left( e^{\nu t_{c,g}} - \nu t_{c,g} - 1 \right)
\]

where:
- \(d_g\) = average pedestrian gap delay (s)
- \(t_{c,g}\) = group critical headway (s)
- \(\nu\) = vehicular flow rate across crossing (veh/s)

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
- \(P_d\) = probability of a delayed crossing

### Step 5: Estimate Delay Reduction due to Yielding Vehicles

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

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

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

1. One-Lane Crossing

\[
P(Y_i) = P_d M_y (1 - M_y)^{i-1}
\]

2. Two-Lane Crossing

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

3. Three-Lane Crossing

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

4. Four-Lane Crossing

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

### Summary

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

Developed by Bolton & Menk, Inc. for the LRRB.
**Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet**

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

<table>
<thead>
<tr>
<th>Crossing Treatment</th>
<th>Staged Pedestrian Yield Rate</th>
<th>Unstaged Pedestrian Yield Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crosswalk Markings and Signs Only (1)</td>
<td>7%</td>
<td>7%</td>
</tr>
<tr>
<td>Median Refuge Islands (1)</td>
<td>34%</td>
<td>29%</td>
</tr>
<tr>
<td>Pedestal Mounted Flashing Beacon (2-Lane, 35 mph) (3)</td>
<td>N/A</td>
<td>57%</td>
</tr>
<tr>
<td>Overhead Flashing Beacon (push-button activation) (4)</td>
<td>47%</td>
<td>49%</td>
</tr>
<tr>
<td>Overhead Flashing Beacon (passive activation) (1)</td>
<td>31%</td>
<td>67%</td>
</tr>
<tr>
<td>Pedestrian Crossing Flags (1)</td>
<td>65%</td>
<td>74%</td>
</tr>
<tr>
<td>School Crossing Guards (5)</td>
<td>N/A</td>
<td>86%</td>
</tr>
<tr>
<td>In-street Crossing Signs (25-30 mph) (1)</td>
<td>87%</td>
<td>90%</td>
</tr>
<tr>
<td>Warning Sign with Edge Mounted LEDs (6)</td>
<td>N/A</td>
<td>28%</td>
</tr>
<tr>
<td>In-road warning lights (1)</td>
<td>N/A</td>
<td>66%</td>
</tr>
<tr>
<td>High-visibility Signs and Markings (35 mph) (4)</td>
<td>17%</td>
<td>20%</td>
</tr>
<tr>
<td>High-visibility Signs and Markings (25 mph) (1)</td>
<td>61%</td>
<td>91%</td>
</tr>
<tr>
<td>Rectangular Rapid-Flash Beacon (RRFB) (2)(4)</td>
<td>84%</td>
<td>81%</td>
</tr>
<tr>
<td>School Crossing Guards with RRFB (5)</td>
<td>N/A</td>
<td>91%</td>
</tr>
<tr>
<td>Pedestrian Hybrid Beacon (HAWK) (3)</td>
<td>97%</td>
<td>99%</td>
</tr>
</tbody>
</table>

N/A: No Research Found on Effect to Yielding Rate

Sources:
(3) Bolton & Menk Field Data Collection
(5) Brewer, Marcus A., Kay Fitzpatrick. Before-and-After Study of the Effectiveness of Rectangular Rapid-Flash Beacons Used with School Sign in Garland, Texas. Texas Transportation Institute, College Station, TX, April 2012.