

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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This report provides a procedure	for the evaluation of uncontro	lled pedestrian crossir	g locations that takes into
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delay that can be included in the a			
research procedures and adds i	n delay considerations to de	evelop a methodology	y appropriate for use by
jurisdictional agencies in the evalu	nation of what is needed for trea	tments at uncontrolled	pedestrian crossings.
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destinations/alternate routes; acce			
FHWA guidance for placement			
options. Treatment options inclu			eatments; Traffic Calming
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2014-21 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 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
 - o 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.

A guidebook was also developed to help Minnesota transportation agencies evaluate their uncontrolled pedestrian crossings and determine appropriate treatment options. The guidebook recommends when to install marked crosswalks and other enhancements at uncontrolled locations based on a number of factors, including the average daily vehicle count, number of pedestrians, number of lanes, and average vehicle speed. It helps agencies rate a crossing for pedestrian service, and it includes a flow chart and several worksheets to assist in data collection and decision making.

The data collection worksheets featured in the guidebook are also available for download as Excel spreadsheets, which automatically complete the evaluation calculations based on entered data.

Board.

- Pedestrian Crossings: Uncontrolled Locations guidebook (3.68 MB PDF)
- Data collection worksheets (2.03 MB XLS)

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 rightof-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[2]

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.

<u>Signs</u>

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.

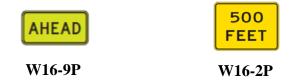
"Non-vehicular signs should be used only at locations where the crossing activity is unexpected or at locations not readily apparent."

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

The S1-1 sign can be used is 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]



R1-5b



R1-5c

"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]

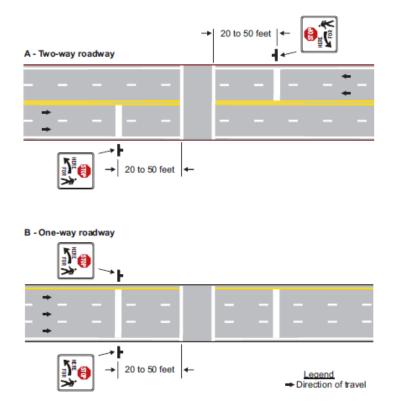
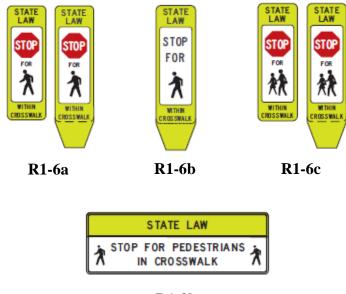


Figure 3.3 Example of Stop Lines at Unsignalized Midblock Crosswalks [2] The advance stop bars with the pedestrian signs have been shown to improve motorist yielding on multi-lane facilities. [4]

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]



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]



W16-13P

Important Points

- 1. Pedestrian crossing signs may be used to alert road users to locations <u>where unexpected</u> <u>entries onto the roadway by pedestrians may occur</u>.
- 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 3I.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]

Traffic Engineering Manual, State of Minnesota Department of Transportation[5]

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,
- vii. Increased law enforcement, and/or
- viii. 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.

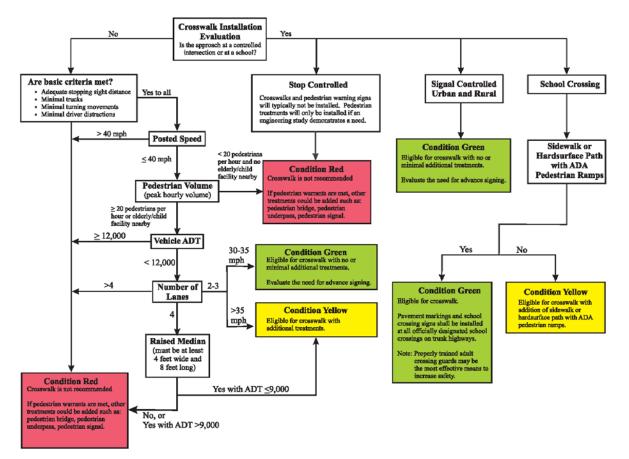


Figure 3.4 MnDOT Crosswalk Installation Flowchart

A Policy on Geometric Design of Highways and Streets (Green Book) [6]

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 [6]

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. [6]

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. [6]

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

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.

Guide for the Planning, Design, and Operation of Pedestrian Facilities [7]

"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 3.1 Percent of Pedestrians Using the a Bridge or Tunnel Route

Travel Times	Bridge	Tunnel
Equal	15 to 60%	95%
30% Longer on Safe Route	0%	25 to 70%
50% Longer on Safe Route	0%	0%

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-H	HOUR, 35 MPH (55 KM/H) OR	LESS	
Analyst and Site Information			
Analyst: Analysis Date: Data Collection Date:	Major Street: Minor Street or Location: Peak Hour:		
a) Worksheet 1 – 35 mph (55 km/h) or less	ed or statutory speed limit or 85 th percentile speed on t		
Step 2: Does the crossing meet minimum ped	estrian volumes to be considered for a TCD type of tre	atment?	
Peak-hour pedestrian volume (ped/h), V_{p}		2a	
If $2a \ge 20$ ped/h, then go to Step 3.		•	
If 2a < 20 ped/h, then consider median refug	ge islands, curb extensions, traffic calming, etc. as fea	sible.	
Step 3: Does the crossing meet the pedestriar	n volume warrant for a traffic signal?		
Major road volume, total of both approaches	s during peak hour (veh/h), V _{maj-s}	За	
Minimum signal warrant volume for peak ho SC = $(0.00021 \text{ V}_{\text{maj-s}}^2 - 0.74072 \text{ V}_{\text{maj-s}}^2)$ OR [$(0.00021 3a^2 - 0.74072)$	+ 734.125)/0.75	3b	
If $3b < 133$, then enter 133. If $3b \ge 133$, then	n enter <i>3b</i> .	3c	
If 15 th percentile crossing speed of pedestria up to 50 percent; otherwise enter <i>3c.</i>	ans is less than 3.5 ft/s (1.1 m/s), then reduce <i>3c</i> by	3d	
If $2a \ge 3d$, then the warrant has been met al another traffic signal. Otherwise, the warrant	nd a traffic signal should be considered if not within 30 ant has not been met. Go to Step 4.	0 ft (91 m) of	
Step 4: Estimate pedestrian delay.			
Pedestrian crossing distance, curb to curb (ft), L	4a	
Pedestrian walking speed (ft/s), S _p		4b	
Pedestrian start-up time and end clearance	time (s), t _s	4c	
Critical gap required for crossing pedestrian	$(s), t_c = (L/S_p) + t_s \text{ OR } [(4a/4b) + 4c)]$	4d	
Major road volume, total both approaches o island is present during peak hour (veh/h		4e	
Major road flow rate (veh/s), $v = V_{maj-d}/3600$		4f	
Average pedestrian delay (s/person), $d_{\rho} = (d_{\rho})$	$e^{vtc} - vt_c - 1) / v OR [(e^{4f \times 4d} - 4f x 4d - 1) / 4f]$	4g	
Total pedestrian delay (h), $D_p = (d_p \times V_p)/3$,6 (this is estimated delay for all pedestrians treatment – assumes 0% compliance). Thi total pedestrian delay measured at the site	crossing the major roadway without a crossing is calculated value can be replaced with the actual	4h	
Step 5: Select treatment based upon total ped	lestrian delay and expected motorist compliance.		
Expected motorist compliance at pedestrian	crossings in region, Comp = high or low	<i>5</i> a	
Total Pedestrian Delay, D _p (from <i>4h</i>) and Motorist Compliance, Comp (from <i>5a</i>)	See Descriptions of Sample Treatments for example	oles)	
$D_p \ge 21.3 \text{ h}$ (Comp = high or low) OR 5.3 h $\le D_p < 21.3 \text{ h}$ and Comp = low	RED		
$1.3 \text{ h} \le D_p < 5.3 \text{ h} (\text{Comp} = \text{high or low})$	ACTIVE		
5.3 h \leq D _p $<$ 21.3 h and Comp = high	ENHANCED		
$D_p < 1.3 h$ (Comp = high or low)	CROSSWALK		

Figure 3.5 Pedestrian Safety Crossing Treatments Worksheet 1: 35 MPH or Less

Analyst and Site Information		
Analyst: Analysis Date: Data Collection Date:	Major Street: Minor Street or Location: Peak Hour:	
a) Worksheet 1 – 35 mph (55 km/h) or less	ed or statutory speed limit or 85 th percentile speed on t), communities with less than 10,000, or where major t	
Step 2: Does the crossing meet minimum ped	estrian volumes to be considered for a TCD type of tre	eatment?
Peak-hour pedestrian volume (ped/h), $V_{ m p}$		2a
If $2a \ge 14$ ped/h, then go to Step 3.		
If 2a < 14 ped/h, then consider median refug	ge islands, curb extensions, traffic calming, etc. as fea	sible.
Step 3: Does the crossing meet the pedestria	n volume warrant for a traffic signal?	
Major road volume, total of both approaches	s during peak hour (veh/h), V _{mai-s}	За
Minimum signal warrant volume for peak ho SC = $(0.00035 V_{maj-s}^2 - 0.80083 V_{maj-s})$ OR [$(0.00035 3a^2 - 0.8008)$	+ 529.197)/0.75	Зb
If $3b < 93$, then enter 93. If $3b \ge 93$, then en	ter <i>3b</i> .	3c
If 15 th percentile crossing speed of pedestrians is less than 3.5 ft/s (1.1 m/s), then reduce <i>3c</i> by up to 50 percent; otherwise enter <i>3c</i> .		Зd
If $2a \ge 3d$, then the warrant has been met a another traffic signal. Otherwise, the warr	nd a traffic signal should be considered if not within 30 ant has not been met. Go to Step 4.	0 ft (91 m) of
Step 4: Estimate pedestrian delay.		
Pedestrian crossing distance, curb to curb (ft), L	4a
Pedestrian walking speed (ft/s), S _p		4b
Pedestrian start-up time and end clearance time (s), t_s		4c
Critical gap required for crossing pedestrian	$(s), t_{o} = (L/S_{p}) + t_{s} \text{ OR } [(4a/4b) + 4c)]$	4d
Major road volume, total both approaches or approach being crossed if median refuge island is present during peak hour (veh/h), V _{mai-d}		4e
Major road flow rate (veh/s), $v = (V_{maj-d}/0.7)/$		4f
Average pedestrian delay (s/person), $d_{\rho} = ($	$e^{vtc} - vt_c - 1) / v \text{ OR } [(e^{4f \times 4d} - 4fx 4d - 1) / 4f]$	4g
	crossing the major roadway without a crossing scalculated value can be replaced with the actual	4h
Step 5: Select treatment based upon total peo	lestrian delay and expected motorist compliance.	•
Expected motorist compliance at pedestrian	crossings in region, Comp = high or low	<i>5</i> a
Total Pedestrian Delay, D _p (from 4h) and Motorist Compliance, Comp (from 5a)	Treatment Category (see Descriptions of Sample Treatments for example	oles)
$D_p \ge 21.3 \text{ h}$ (Comp = high or low) OR 5.3 h $\le D_p < 21.3 \text{ h}$ and Comp = low	RED	
$D_p < 5.3 h$ (Comp = high or low)	ACTIVE	
OR	OR	
5.3 h \leq D _p $<$ 21.3 h and Comp = high	ENHANCED	

Figure 3.6 Pedestrian Safety Crossing Treatments Worksheet 2: Greater than 35 MPH

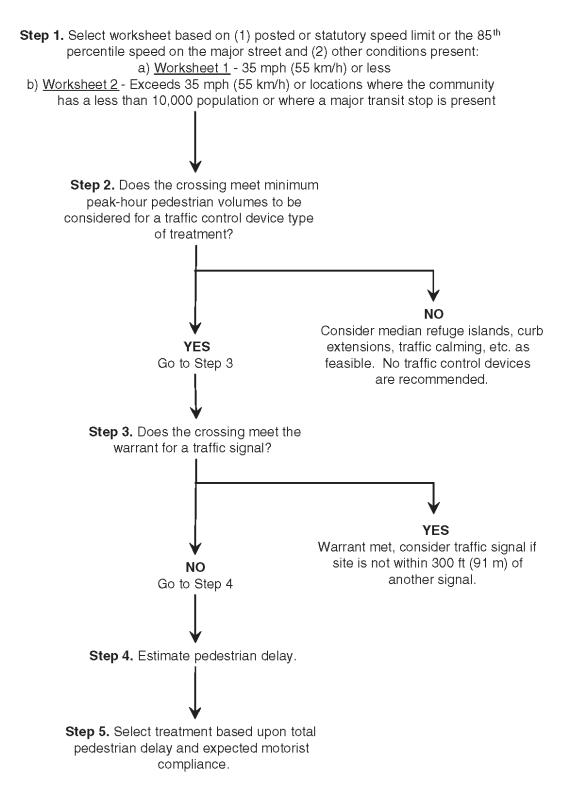


Figure 3.7 Pedestrian Safety Crossing Treatments Flowchart

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 crossings 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.

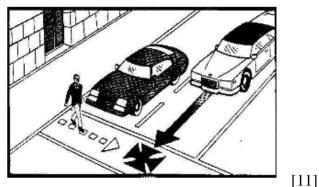


Figure 3.8 Multiple-Threat Pedestrian Crash Illustration

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]

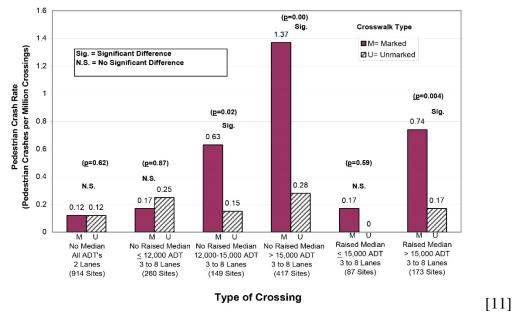


Figure 3.9 Pedestrian Crash Rate versus Type of Crossing

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

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.

HCM 2010, Highway Capacity Manual_[12]

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 4.3 Pedestrian Crossing Length (2 of 2)



Figure 4.2 Two-Stage Pedestrian Crossing Length

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.



Figure 4.4 Median Width (1 of 2) ADA Compliant



Figure 4.5 Median Width (2 of 2) Not ADA Compliant

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_c) 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.

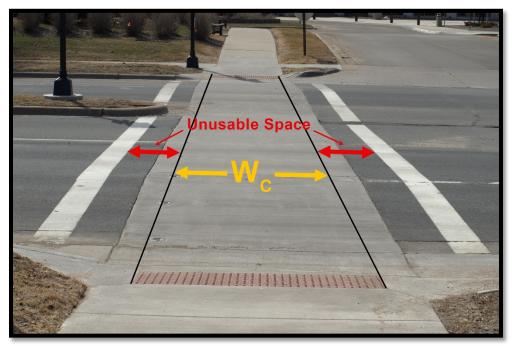


Figure 4.6 Effective Crosswalk Width (1 of 2)



Figure 4.7 Effective Crosswalk Width (2 of 2)

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]



Figure 4.8 Curb Ramp Elements



Figure 4.9 Detectable Warning Surfaces (Truncated Domes)

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. [13] 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. [13]

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.



Figure 4.10 Curb Ramps with Landing and No Truncated Domes [14]



Figure 4.11 Curb Ramp with Landing and Truncated Domes [14] Eagan

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.



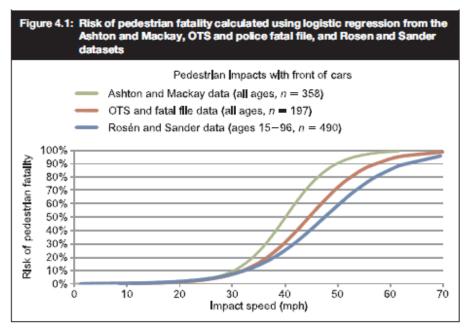
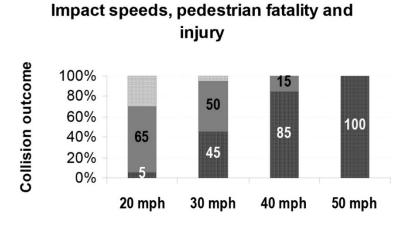


Figure 4.12 Risk of Pedestrian Fatality Based on Vehicle Impact Speed [15]



■ Fatality ■ Injury ■ No injury

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 15^{th} 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.

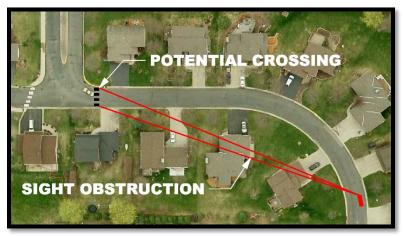


Figure 4.14 Horizontal Curvature Obstruction

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]

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

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:

 $S_p = 3.5$ ft/s from MN MUTCD $t_s = 1.5$ s 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.

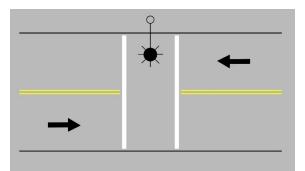


Figure 4.15 Lighting Placement (1 of 5) Two Lane Mid-Block Crossing

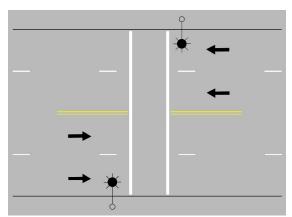


Figure 4.16 Lighting Placement (2 of 5) Multi-Lane or Long Mid-Block Crossing

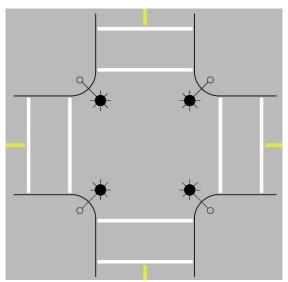


Figure 4.17 Lighting Placement (3 of 5) Intersection: Traditional

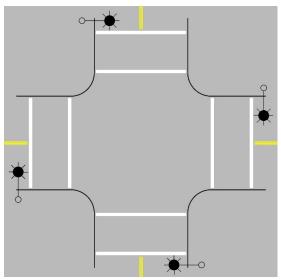


Figure 4.18 Lighting Placement (4 of 5) Intersection: Pedestrian Crossing Focused

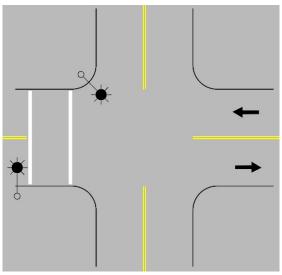


Figure 4.19 Lighting Placement (5 of 5) Intersection: Pedestrian Crossing Focused on One Leg

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]

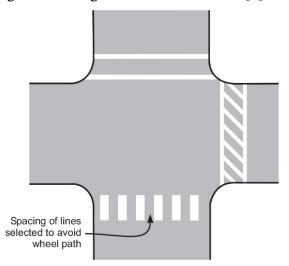


Figure 4.20 Crosswalk Marking Examples [2]

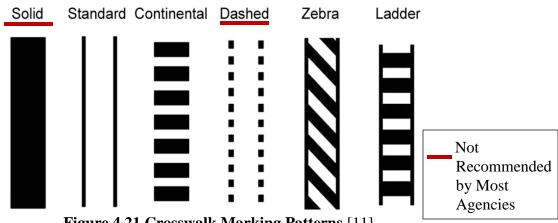


Figure 4.21 Crosswalk Marking Patterns [11]

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).



Figure 4.22 Standard Crosswalk



Figure 4.23 Continental Crosswalk

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



Figure 4.27 School 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:

- Bus stops to businesses and residences
- High density residential to bus stops and commercial/retail
- Hospitals and medical centers to bus stops and parking
- o Retirement communities to bus

stops and commercial/retail

- Schools/colleges/universities to residential 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

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										
LRRB Location:	Date:										
City, State:	Scenario:										
Reviewer(s):	Agency:										
Project #:					ID #:						
	The first step	o in unders	tanding the pe				ng location is o	comple	eting		
				the location	-						
			ire the crossin				Crossing 1			ft.	
		-	e if there is no			edian at the	Crossing 2			ft.	
			Crossing 1 and							<u>6</u>	
			an at crossing							ft.	
	-		ve crosswalk w	lath					Yes	ft.	No
	Raised Median Available? ADA Compliant Median Available (minimum 4' x 4' landing)?								Yes		No No
ics	Curb Ramps Available?								Yes		No
hetr	ADA Compliant Curb Ramp Available (width, grades, truncated domes)?							Yes		No	
Geometrics	Speed: Posted or 85 th percentile speed							_	mph	140	
Ğ	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										
			Sight Distance			ft.	provided?		Yes		No
	Direction 2:	Stopping Stopping	Sight Distance	(SSD)		ft.	provided?		Yes		No
	Direction 1:	Pedestria	n Sight Distanc	e (PedSD)		ft.	provided?		Yes		No
	Direction 2:	Pedestria	n Sight Distanc	e (PedSD)		ft.	provided?		Yes		No
Traffic and	Measure traffic and pedestrian volume in 15-minute increments on the roadway to be crossed.										
Pedestrian	Attach Counts vehicles: Daily pedestrians:				Daily Pk 15-min						
Data	AM Peak	Hourly		Pk 15-min							
	PM Peak	Hourly		Pk 15-min		Hourly Pk 15-m					
	Lighting:										
	Is street lighting present and does it light the crosswalk location? Crosswalk Pavement Markings: Is the pedestrian crossing currently marked?							Yes		No	
			of the marking		strian cross	Excellent	Good		Yes Fair		No
s	what is the		NUMBER OF STREET, STRE		L				Yes		Poor No
stic	Are the markings easily defined?							No			
teri	Do they need replacement? Yes What is the crosswalk marking pattern?						165		110		
ract								No			
Cha	Signing: Currently signed at crosswalk? Currently signed in advance of crosswalk?							Yes		No	
Site Characteristics		Distances? direction 1				ft.	direction 2			ft.	
	Enhancements: What enhancements are currently at										
Additional			the crossing lo	ocation?							
ldit	Adjacent Fac	ilities:	Distance to ne	earest marke	d crosswalk	?		ft.			
Ac	What pede	strian cont	rol devices are	present							
			nt marked cros								
			l-way stop, rou		-					ft.	
			n serve the sar		•				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 orgins and destinations.

draw or insert map of location being studied

Notes:

Sight Distance Calculations: Stopping sight distance (SSD), ft = 1.47St + 1.075S²/a

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

where: S = design speed, mph L = length of crossing, ft

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

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 <u>engineering study is needed to</u> <u>determine whether the location is suitable for a marked crosswalk</u>. 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 trafficcalming 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]

_		Vehicle ADT			Vehicle ADT	c		Vehicle ADT			Vehicle ADT	
		≥ 9,000		×	>9,000 to 12,000	0	^	>12,000-15,000			> 15,000	
Roadway Type (Number of Travel Lanes and Median Type)						Speed	Speed Limit**					
	≤ 48.3 km/h (30 mi/h)	56.4 km/h (35 mi/h)	64.4 km/h (40 mi/h)	≤ 48.3 km/h (30 mi/h)	56.4 km/h (35 mi/h)	64.4 km/h (40 mi/h)	≤ 48.3 km/h (30 mi/h)	56.4 km/h (35 mi/h)	64.4 km/h (40 mi/h)	≤ 48.3 km/h (30 mi/h)	56.4 km/h (35 mi/h)	64.4 km/h (40 mi/h)
Two lanes	U	C	٩	J	v	٩	v	C	z	v	۵.	z
Three lanes	U	C	٩	J	٩	٩	Ч	٩	z	٩	z	z
Multilane (four or more lanes) with raised median***	U	v	٩	U	٩	z	٩	٩	z	z	z	z
Multilane (four or more lanes) without raised median	U	٩	z	đ	٩	z	z	z	z	z	z	z
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 signt distance, complex or contraining designs, a substantial volume of heavy tucks, or other dangers, without first providing adequate design features adold traffic costrol devices. Adding to prevent the crosswalks should not be installed at locations that could present an increased safety risk to pedestrians, such as where there is poor signt distance, complex or contraining designs, a substantial volume of heavy tucks, or other dangers, without first providing adequate design features addor traffic costrol devices. Adding to previse the costrol of the crosswalks are installed. It is important to consider other endestrians (ling) enhancements (e.g., railed median, traffic signal, roadway marxwing, enhance down that first conting 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 alone should not be used at unsignalized locations.	nidblock locations v creased safety risk g crosswalks alone g median, traffic sic vidual cases for dei vidual (40 mi/h), marked c	with no traffic sign to pedestrians, s will not make cro mal, roadway nar ciding where to in crosswalks alone.	fic signals or stop signs, ians, such as where their ake crossings safer, nor ak narrowing, enhanced re to install crosswalks. alone should not be use	ic signals or stop signs on the approach to the cross lans, such as where there is poor sight distance, co ke crossings safet, nor will they necessarily result in a narrowing, enhanced overhead lighting, traffic.ce e to install crosswalks.	tance, complex of the crossing. Th tance, complex of the complex of the control if result in more ', traffic-calming n , traffic-calming n locations.	hey do not apply t r confusing desig vehicles stopping neasures, curb ex	o school crossings ins, a substantial v for pedestrians. W densions), as need	A two-way cente olume of heavy tr /hether or not ma Jed, to improve th	ar turn lane is not ucks, or other da rked crosswalks i le safety of the cr	considered a med ngers, without first are installed, it is ir ossing. These are	dian. Crosswalks t providing adequ mportant to consi general recomm	should not be ate design der other endations; goo
*** The raised median or crossing island must be at least 1.2 m (4 ft) wide (AASHTO) guidelines.	st be at least 1.2 m		.8 m (6 ft) long to	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	as a refuge area f	for pedestrians, ir.	accordance with I	MUTCD and Ame	erican Association	n of State Highway	r and Transportati	on Officials
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 crosswalks. The analysis is the study is needed to determine whether the location is suitable for a marked crosswalks an engineering study, as heat the study is needed to determine whether the location is suitable for a marked crosswalks an engineering study, as heat the study is needed to determine whether the location is suitable for a marked crosswalks and other factors may be sufficient at some locations, while a merine whether the location is suitable for a marked crosswalk and the factors may be sufficient at some locations bus of merine whether the location is a marked crosswalk and the related that a minimum of 20 pedestrian crossings perturbed that an intermine whether there of the pedestrian crossing to the installation of a marked crosswalk alone.	(cs. Marked crossw be sufficient at son k hour (or 15 or mo risk may occur if	alks must be insta ne locations, while ore elderly and/or crosswalks are a	alled carefully and e a more indepth child pedestrians added without or	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. s, while a more protection of pedeestrian volume, vehicle speed, sight distance, vehicle mix, and other factors may be needed at other sites. It is recommended that a minimum and/or child pedeestrians) be confirmed at a location before placing a high priority on the installation of a marked crosswalk alone. Ke and edd without other nedestrian facility enhancements. These locations should be closely monitored and enhanced with other nedestrian crossing improvements. If	e installing new n 1 volume, vehicle 1 location before 1 cilitv enhancem	marked crosswalk speed, sight dist placing a high pri nents. These loca	s, an engineering s ance, vehicle mix, a ority on the installa ntions should be clo	study is needed to and other factors tion of a marked of pselv monitored a	o determine whet may be needed á crosswalk alone. ind enhanced with	her the location is at other sites. It is r h other pedestrian	suitable for a ma recommended thi crossing improve	rked crosswall at a minimum ements. 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.	lk. ient, since pedest ovement to improve	rian crash risk m e crossing safetv	risk may be increased safetv for pedestrians.	I by providing ma	rked crosswalk	s alone. Consider	r using other treatn	, nents, such as tra	iffic-calming treat	ments, traffic signé	als with pedestria	n signals when
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 locations at a streetlight as opposed to an unlit 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).	e streets in downtov to an unlit crossing ore elderly pedestri	wn areas), installir I point nearby). W ans and/or childre	installing a marked cross by). While overuse of mi children per peak hour).	swalk may help cor larked crossings at	nsolidate multiple uncontrolled loca	e crossing points. ations should be a	Engineering judgm avoided, higher priv	nent should be us ority should be pla	ed to install cross aced on providing	swalks at preferred j crosswalk markin	d crossing location 1gs where pedest	ns (e.g., at a rian volume
Marked crosswalks and other pedestrian facilities (or lack of facilities) should be routinely monitored to determine what improvements are needed	ilities (or lack of fac	ilities) should be r	routinely monitore	ed to determine wh	at improvements	are needed.						

Table 11. Recommendations for installing marked crosswalks and other needed pedestrian improvements at uncontrolled locati

Table 5.1 Recommendations for Installing Marked Crosswalks at Uncontrolled Location

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_s) : 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.

$$t_w = L \ / \ S_p$$

 $t_c = t_s + t_w$

where:

 t_w = pedestrian walking time (s) L = crosswalk length (ft) S_p = average pedestrian walking speed (ft/s), default = 3.5 ft/s [2], [10]

where:

 t_c = critical headway (s) t_s = pedestrian start-up and end clearance time (s) t_w = 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 85th percentile travel speed along the roadway.

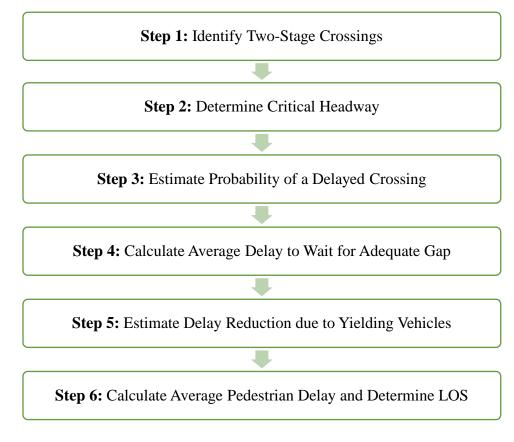
$$PedSD = 1.47 * S * t_c$$

where: PedSD = pedestrian sight distance (ft) t_c = critical headway (s) S = 85th %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.

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



Figure 6.4 Potential Two-Stage Crossing [14] St. Paul

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. [12]

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

Where:

 t_c = critical headway for a single pedestrian (s),

 S_p = average pedestrian walking speed (ft/s),

 \dot{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.

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

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]

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

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]

$$N_{c} = \frac{v_{p}e^{v_{p}t_{c}} + ve^{-vt_{c}}}{(v_{p} + v)e^{(v_{p} - v)t_{c}}}$$

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]

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

Ì

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]

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

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

$$n = INT\left(\frac{d_{gd}}{h}\right)$$

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*, 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

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

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.

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

(1) Fitzpatrick, K., S.M. Turner, M. Brewer, P.J. Carlson, B. Ullman, N.D. Trout, E.S. Park, J. Whitacre, N. Lalani, and D. Lord. NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings. Transportation Research Board of the National Academies, Washington D.C., 2006.

(2) Lewis, R., J.R. Ross, D.S. Serpico : Assessment of Driver Yield Rates Pre- and Post-RRFB Installation, Bend, Oregon. Oregon Department of Transportation, Washington D.C., 2011.
(3) Bolton & Menk Field Data Collection

(4) Transportation Research Board, HCM 2010 Highway Capacity Manual, Washington D.C.: National Academy of Sciences, 2010.

(5) Brewer, Marcus A., Kay Fitzpatrick. Before-and-After Study of the Effectiveness of Rectangular Rapid-Flashing Beacons Used with School Sign in Garland, Texas. Texas Transportation Institute, College Station, TX, April 2012.

(6) Kipp, Wendy M.E., Jennifer M. V. Fitch. Evaluation of SmartStud In-Pavement Crosswalk Lighting System and BlinkerSign Interim Report. Vermont Agency of Transportation, Report 2011-3, Montpelier, VT, February 2011. (Rate Normalized to High Visibility Markings and Signs at 35 mph)

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]

LOS	Control Delay (sec/pedestrian)	Comments
А	0-5	Usually no conflicting traffic
В	5-10	Occasionally some delay due to conflicting traffic
С	10-20	Delay noticeable to pedestrians, but not inconveniencing
D	20-30	Delay noticeable and irritating, increased likelihood of risk taking
Е	30-45	Delay approaches tolerance level, risk-taking behavior likely
F	>45	Delay exceeds tolerance level, high likelihood of pedestrian risk- taking

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.

2010 Highway Capacity Manual (HCM) Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations Intersection and Mid-Block Crossings

Introduction:

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

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

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

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

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

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

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

Introduction

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HCM Evaluation Worksheet

Figure 6.5 Highway Capacity Manual Evaluation Worksheet (Page 1)

2010 Highway Capacity Manual (HCM)

Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations

Intersection and Mid-Block Crossings

Date:
Scenario:
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: **Evaluation Inputs:** Input Table: defaults: L = crosswalk length (ft) L = S_p = average pedestrian walking speed (ft/s) 3.5 $S_p =$ $S_p =$ t_s = pedestrian start-up and end clearance time (s) 3.0 t_s = t_s = V = vehicular hourly volume (veh/hr) V = v_p = pedestrian flow rate (ped/s) 0* = $v_p =$ v = vehicular flow rate (veh/s) = V/3600 V/3600 υ= U = $W_c =$ 8.0 W_c = crosswalk width (ft) $W_c =$ INT(L/11) N = number of through lanes crossed (Integer) N = N =*no platooning observed Crossing 2: (only used for two-stage crossings) **Evaluation Inputs:** defaults: Input Table: L = crosswalk length (ft) L = S_p = average pedestrian walking speed (ft/s) 3.5 $S_p =$ $S_p =$ t_s = pedestrian start-up and end clearance time (s) t_s = 3.0 t_s = V = vehicular hourly volume (veh/hr) V = v_p = pedestrian flow rate (ped/s) 0* $v_n =$ $v_p =$ v = vehicular flow rate (veh/s) = V/3600 υ= V/3600 $2^{2} =$ W_c = crosswalk width (ft) W. = 8.0 $W_c =$ INT(L/11 N = number of through lanes crossed (Integer) N = N = *no platooning observed **Crossing Treatment Yield Rate** Input Table:

 M_v = motorist yield rate (decimal)

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

Results:

	Average Delay LOS	sec/ped	
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M_v =

HCM Evaluation Worksheet

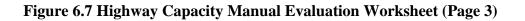
Figure 6.6 Highway Capacity Manual Evaluation Worksheet (Page 2)



Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

Crossing Location	Date:AAtA
City, State:	Scenario:
Reviewer(s):	Agency:
Step 1: Identify	Is there a median available for a two-stage crossing?
Two-Stage	If yes, does the median refuge meet ADA requirements (4' x 4' landing)?
Crossings	If yes, do pedestrians treat this as a two-stage crossing location?
	Critical headway is the time below which a pedestrian will not attempt to begin crossing the street. Pedestrians
	use judgement to determine whether the available headway is sufficent for a safe crossing.
	For a single pedestrian: where: t _c = critical headway for a single pedestrian (s)
	L = crosswalk length (ft)
	$t_c = \frac{L}{S_p} + t_s$ $S_p = \text{average pedestrian walking speed (ft/s)}$
	t _s = pedestrian start-up and end clearance time (s)
	crossing 1 crossing 2 $S_p = 3.5 \text{ ft/s}$
	$L = t_s = L = t_s = t_s = 3 \text{ sec}$
	$S_p = t_c = S_p = t_c =$
	If pedestrian platooning is observed, the spatial distribution of pedestrians should be computed:
	1. use field observations or estimate platoon size using equation:
	$v_p e^{v_p t_c} + v e^{-v t_c}$ where: N _c = total number of pedestrians in crossing platoon
	$N_{c} = \frac{v_{p}e^{v_{p}t_{c}} + ve^{-vt_{c}}}{(v_{p} + v)e^{(v_{p} - v)t_{c}}}$ where: N _c = total number of pedestrians in crossing platoon (ped)
Step 2:	v_p = pedestrian flow rate (ped/s)
Determine	crossing 1 crossing 2 v = vehicular flow rate across crossing (veh/s)
Critical Headway	$v_p = t_c = v_p = t_c = t_c = single pedestrian critical headway (s)$
,	$v = N_c = v = N_c =$
	2. compute spatial distribution:
	where: N_p = spatial distributions of pedestrians (ped)
	$N_p = INT \left[\frac{8.0(N_c - 1)}{W_c} \right]$ where N_p = spatial distributions of pedestrians (ped) N_c = total number of pedestrians in crossing platoon (ped)
	crossing 1 crossing 2 W _c = crosswalk width (ft)
	$N_c =$ $N_c =$ $8.0 =$ default clear width used by a single pedestrian
	$W_c = N_p = W_c = N_p = to avoid interference with other pedestrians (ft)$
	3. compute group critical headway: clear width, if other than 8:
	where $t = aroup critical headway(c)$
	$t_{c,G} = t_c + 2(N_p - 1)$ where: $t_{c,G} = \text{group citical headway (s)}$ $t_c = \text{single pedestrian critical headway (s)}$
	crossing 1 crossing 2 N _p = spatial distributions of pedestrians (ped)
	$N_p = $
	$t_c = t_{c,G} = t_c = t_{c,G} =$
	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.
Chan D. Fatimete	$P_b = 1 - e^{\frac{-t_{c,G}\nu}{L}}$ where: P_b = probability of blocked lane
Step 3: Estimate	r _d – probability of delayed crossing
Probability of a	$P_d = 1 - (1 - P_b)^L$ N = number of through lanes crossed
Delayed	crossing 1 crossing 2 t _{c,G} = group critical headway (s) = t _c , if no platooning
Crossing	$t_{c,G}$ = v = vehicular flow rate across crossing(veh/s)
	$v = P_b = v = P_b =$
	$N = P_d = N = P_d =$
Developed by Bolton	& Menk, Inc. for the LRRB. HCM Calculations Sheet 1 Page 3 of 5

HCM Evaluation Worksheet



		Uncontrolled	Pedestrian Evaluation		-	el of Service		
LRRB			Evaluation	WUIKS	neet			
	Ave	erage delay assumes that no	o motor vehicle	s yield an	d the peo			
		$d_g = \frac{1}{v} (e^{vt_{c,G}} - vt_g)$	(-1)		where:	d _g = average pedest		5)
		V	-			t _{c,G} = group critical		
		crossing 1		ossing 2		v = vehicular flow r	ate across cross	ing (veh/s)
Step 4: Calculate	t _{c,G} =		t _{c,G} =	T				
Average Delay	υ=	d _g =		d _g =]		
to Wait for		Average delay for a pede				nonzero delay.)	ing the intersed	tion
Adequate Gap		d	(0.8), and peace	-	where:	d _{ed} = average gap de	elav for nedestri	ans who incu
		$d_{gd} = \frac{a_g}{P_d}$			where.	nonzero delav	elay for pedestri	ans who mean
		crossing 1	cre	ossing 2		d _g = average pedest	rian gap delay (s	5)
	d _g =		d _g =]		P _d = probability of a		
	$\mathbf{P}_{d} =$	d _{gd} =	P _d =	d _{gd} =				•
	Whe	n a pedestrian arrives at a	crossing and fir		dequate	gap, that pedestrian	is delayed until	one of two
	situat	tions occurs: (a) a gap great	er than the crit	ical head	way is av	ailable, or (b) motor	vehicles yield a	nd allow the
	pede	strian to cross. While motor	rists are legally	required	to stop fo	or crossing pedestria	ns in MN at all i	ntersections
		and at all ma	rked crossings,	motorist	yield rate	es actually vary cons	iderably.	
	Some o	crossing treatments and yiel	d rates based o	n research	n are prov	vided on the next pag	ge.	
	Averag	e pedestrian delay			where:	d _p = average pedest		
		$\sum_{n=1}^{n} L(x_{n}) = 0$	$\int_{n} \sum_{n}^{n} r$	(m)		i = crossing event (
	a_p	$=\sum_{i=1}^{n}h(i-0.5)P(Y_i)+$	$\left(P_{a} - \sum P_{a} \right)$	$(Y_i)] a_g$	d	h = average headwa	<i>,</i>	
Step 5: Estimate		<i>i</i> =1	\ i=1	/		$P(Y_i) = probability$		field to
Delay Reduction	1	crossing 1		ossing 2		pedestrian on cross	-	
due to Yielding	<i>n</i> =	n =	h =	n =		$n = lnt(d_{gd}/h)$, aver		
Vehicles	1.0	d _p =		d _p =		events before an ad j = crossing event (/ailable, >0
(If yielding is		-Lane Crossing				$P(Y_j) = \text{probability}$		vield to
zero, then skip	Р	$Y(Y_i) = P_d M_y (1 - M_y)^{i}$	-1			pedestrian on cross		
	2. Two	-Lane Crossing	M _{ex} = m	otorist yie	eld rate (d			Í.
,						<i>y</i>		1
	F	$P(Y_i) = \left P_d - \sum_{i=0}^{i-1} P(Y_i) \right \left[\frac{(2F_i)^2}{2} \right]$	P _d	()))	-			
	3. Thre	e-Lane Crossing						
		$P(Y_i) = \left[P_d - \sum_{i=0}^{i-1} P(Y_i) \right] \left[\frac{P_b^3}{2} \right]$	$M_y^3 + 3P_b^2(1 -$	$P_{b})M_{y}^{2} +$	$3P_{b}(1-1)$	$P_b)^2 M_y$	Summ	nary
	P	$P(Y_i) = \left P_d - \sum_{i=0}^{p} P(Y_i) \right $		P_d			Average	
	4. Four	-Lane Crossing					LOS	
	P	$(Y_i) = \left[P_d - \sum_{j=0}^{i-1} P(Y_j)\right] \mathbf{x}$	$P_b^4 M_y^4 + 4P_b^3$ (1	$-P_b)M_y^3 + 6$	$P_{b}^{2}(1-P_{b})$	$^{2}M_{y}^{2}+4P_{b}(1-P_{b}^{3})M_{y}$		
		$L_i J = \begin{bmatrix} I d & \Delta J = 0 \end{bmatrix}^{K} \begin{pmatrix} I \\ J \end{bmatrix}^{K}$	L		Pd]		
	LOS	Control Delay (sec/ped)				Comments		
Step 6: Calculate				a				
Average	A	0-5	Usually no cor	-		onflicting to file		
Pedestrian Delay	B	5-10				onflicting traffic	ina	
& Determine	C D	10-20				but not inconvienend used chance of risk-ta		
LOS	E	20-30 30-45	,		0,	, risk-taking likely	iking	
	F	>45				th chance of risk-taki	ng	
		, Inc. for the LRRB.	Delay exceeds			ations Sheet 2	ъ	Page 4 of 5

HCM Evaluation Worksheet

Figure 6.8 Highway Capacity Manual Evaluation Worksheet (Page 4)



Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

	Crossing Treatment	a possible reduction in delay. Staged Pedestrian Yield Rate	Unstaged Pedestrian Yield Rate
	Crosswalk Markings and Signs	•	Ť
	Only ⁽¹⁾	7%	7%
	Median Refuge Islands ⁽¹⁾	34%	29%
	Pedestal Mounted Flashing Beacon (2-Lane, 35 mph) ⁽³⁾	N/A	57%
	Overhead Flashing Beacon (push-button activation) ⁽¹⁾	47%	49%
	Overhead Flashing Beacon (passive activation) ⁽¹⁾	31%	67%
= My	Pedestrian Crossing Flags ⁽¹⁾	65%	74%
Motorist Yield Rate = M_y	School Crossing Guards ⁽⁵⁾	N/A	86%
ield F	In-street Crossing Signs (25-30 mph) ⁽¹⁾	87%	90%
rist Y	Warning Sign with Edge Mounted LEDs ⁽⁶⁾	N/A	28%
Moto	In-road warning lights ⁽¹⁾	N/A	66%
2	High-visibility Signs and Markings (35 mph) ⁽¹⁾	17%	20%
	High-visibility Signs and Markings (25 mph) ⁽¹⁾	61%	91%
	Rectangular Rapid-Flash Beacon (RRFB) ⁽²⁾⁽⁴⁾	84%	81%
	School Crossing Guards with RRFB ⁽⁵⁾	N/A	91%
	Pedestrian Hybrid Beacon (HAWK) ⁽¹⁾	97%	99%
	(N/A: No Research Found	on Effect to Yielding Rate
Sources:	 Fitzpatrick, K., S.M. Turner, M. Brewer, F. NCHRP Report 562: Improving Pedestrian Scademies, Washington D.C., 2006. Lewis, R., J.R. Ross, D.S. Serpico : Assession of the second scale scale	afety at Unsignalized Crossings. Transport ment of Driver Yield Rates Pre- and Post-F	tation Research Board of the National
	Department of Transportation, Washington (3) Bolton & Menk Field Data Collection (4) Transportation Research Board, HCM 20 2010.		n D.C.: National Academy of Sciences,
	(5) Brewer, Marcus A., Kay Fitzpatrick. Befo with School Sign in Garland, Texas. Texas Tr (6) Kipp, Wendy M.E., Jennifer M. V. Fitch. E Interim Report. Vermont Agency of Transpo	ansportation Institute, College Station, TX valuation of SmartStud In-Pavement Cross	K, April 2012. sswalk Lighting System and BlinkerSign

HCM Evaluation Worksheet

Figure 6.9 Highway Capacity Manual Evaluation Worksheet (Page 5)

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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.

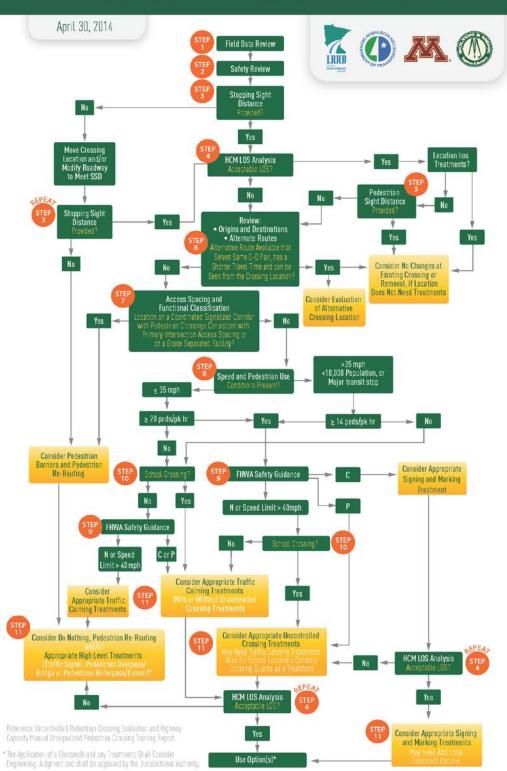
STEP 1

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
 - o Crossing Length
 - pedestrian exposure is reduced on shorter crossings
 - o Median Width
 - if used by pedestrians the median should be sufficient in size to handle the pedestrians using it
 - o Curb Ramps
 - curb ramps are required for all pedestrian crossing locations
 - o Americans with Disabilities Act (ADA) Requirements
 - ADA requirements for pedestrian crossings including grades, tactile surfaces/truncated domes, and landing areas.
 - o 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



UNCONTROLLED PEDESTRIAN CROSSING EVALUATION FLOWCHART

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
 - 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 trafficcalming 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]

		Vehicle ADT ≤ 9,000		6 <u>,</u>	Vehicle ADT >9,000 to 12,000	•	۸	Vehicle ADT >12,000-15,000			Vehicle ADT > 15,000	
Roadway Type (Number of Travel Lanes and Median Type)						Speed	Speed Limit**					
	≤ 48.3 km/h (30 mi/h)	56.4 km/h (35 mi/h)	64.4 km/h (40 mi/h)	≤ 48.3 km/h (30 mi/h)	56.4 km/h (35 mi/h)	64.4 km/h (40 mi/h)	≤ 48.3 km/h (30 mi/h)	56.4 km/h (35 mi/h)	64.4 km/h (40 mi/h)	≤ 48.3 km/h (30 mi/h)	56.4 km/h (35 mi/h)	64.4 km/h (40 mi/h)
Two lanes	U	U	٩	U	J	٩	C	U	z	U	۵.	z
Three lanes	U	U	٩	υ	ď	٩	٩	٩	z	٩	z	z
Multilane (four or more lanes) with raised median***	v	v	٩	U	٩	z	٩	٩	z	z	z	z
Multilane (four or more lanes) without raised median	U	٩	z	٩	ط	z	z	z	z	z	z	z
* 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 features and/or traffic could present an increased safety risk to pedestrians, such as where there is poor signt distance, complex or contusing 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 alone will not make crossings safer, nor will they necessarily result in more vehicles stopping for pedestrians. Whether or not marked crosswalks alone will not make crossings safer, nor will they necessarily result in more vehicles stopping for pedestrians. Whether or not marked crosswalks and will not make crossings are installed. It is important to comsider 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: whose the saked for stop of the crosswalks are installed. It is important to comsider other entitient is provident and and the support of the crosswalks and individual crassing crosswalks.	nidblock locations v creased safety risk g crosswalks alone d median, traffic sic vidual cases for dei (40 mi/h) marked o	with no traffic sign to pedestrians, s will not make cro paul, roadway nan ciding where to in crosswalks alone.	ials or stop signs uch as where the ssings safer, nor rowing, enhance, stall crosswalks. should not he use	on the approach to sre is poor sight dist will they necessari d overhead lighting,	the crossing. Th tance, complex o ly result in more v traffic-calming n ocations	iey do not apply t r confusing desig vehicles stopping neasures, curb e:	to school crossings ans, a substantial v. f for pedestrians. W xtensions), as neec	. A two-way cente olume of heavy tr /hether or not mai ded, to improve th	er turn lane is not ucks, or other da. rked crosswalks a le safety of the cr	considered a med ngers, without first are installed, it is ir ossing. These are	lian. Crosswalks : t providing adequ mportant to consi general recomm	should not be ate design der other endations; goo
*** The raised median or crossing island must be at least 1.2 m (4 ft) wide (AASHTO) guidelines.	st be at least 1.2 m	(4 ft) wide and 1.	8 m (6 ft) long to	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	is a refuge area f	or pedestrians, ir	າ accordance with ໃ	MUTCD and Ame	rican Association	ı of State Highway	and Transportati	on Officials
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 is a neighneering study is 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 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.	cs . Marked crossw be sufficient at som k hour (or 15 or mo	alks must be insta ne locations, while ore elderly and/or	alled carefully an a more indepth child pedestrians	d selectively. Before study of pedestrian i) be confirmed at a	e installing new n volume, vehicle location before p	narked crosswalk speed, sight distr olacing a high pri-	 (s, an engineering s ance, vehicle mix, s ority on the installal 	study is needed to and other factors tion of a marked (o determine whet may be needed ε crosswalk alone.	her the location is at other sites. It is r	suitable for a mai recommended the	ked crosswalk it a minimum
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, necessary, before adding a marked crosswalk.	risk may occur if lk.	crosswalks are	added without c	other pedestrian fa	scility enhancen	nents. These loc	ations should be clu	osely monitored a	ind enhanced wit	h other pedestrian	crossing improve	ements, if
N = Marked crosswalks alone are insufficient, since pedestrian crash warranted, or other substantial crossing improvement to improve crossing.	ient, since pedest ovement to improv	rian crash risk n e crossing safety	risk may be increase d safety for pedestrians.	risk may be increased by providing marked crosswalks alone. Consider using other treatments, such as traffic-calming treatments, traffic signals with pedestrian signals where safety for pedestrians.	rked crosswalk	s alone. Conside	r using other treatn	nents, such as tra	iffic-calming treat	ments, traffic sign	als with pedestria	n signals wher
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 point) as opposed to an unlit 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).	e streets in downtov to an unlit crossing tre elderly pedestri	wn areas), installir point nearby). W ans and/or childre	ng a marked cros hile overuse of m n per peak hour)	swalk may help cor arked crossings at).	nsolidate multiple uncontrolled loca	crossing points. ations should be	Engineering judgır avoided, higher priv	rent should be us ority should be pli	ed to install cross aced on providing	swalks at preferred crosswalk markin	d crossing location igs where pedest	ıs (e.g., at a rian volume

Table 11. Recommendations for installing marked crosswalks and other needed pedestrian improvements at uncontrolled locations. st

Table 7.1 Recommendations for Installing Marked Crosswalks at Uncontrolled Location



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

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		Signing and Marking Treatments (Treatments Should be Instified Through an Engineering Study)	ing Treatments Through an Engineering Study)			
				Motorist Yield Rate	field Rate	
Treatment	Advantages	Disadvantages	Recommended Locations	Staged Pedestrian	Unstaged Pedestrian	Cost
	Inexpensive	Very little effect at night3	Not usually recommended alone			
Crosswalk Markings Onlv	Helps define a crossing location	Speeds increase over time	Low volume and low speed roadways	NR	NR	\$500 to \$2,000
	Indicates to drivers that a crossing location is present	Not been shown to reduce crashes	Where justified			
	Inexpensive	Tend to be ignored unless pedestrians use the crossing consistently	Where unexpected entries into the roadway by pedestrians may occur			
Warning Signs	Helps define a crossing location	Proven to be ineffective at reducing crashes at uncontrolled intersections	Either at or before the crossing location	R	NR	\$300 to \$1,200
	Warning to drivers that a crossing location is present		Either with or without a marked crosswalk			
	Visual distance increased	Requires overhead structure	Multi-lane roadways			
Overhead Warning Signs location is present	Warning to drivers that a crossing location is present	Tend to be ignored unless pedestrians use the crossing consistently	Midblock crossing locations	R	NR	\$60,000 to \$75,000
	Signs easier to see when have multiple lanes of approach		Usually coupled with other measures such as RRFBs or beacons			
	May decrease vehicle speed	Can be expensive	Downtown/Urban conditions			
Colored Concrete/Brick Pavers		Not been shown to reduce crashes	Traffic signal locations	R	NR	\$10,000 to \$75,000
		Speeds increase over time	In conjunction with pavement markings			
	Inexpensive	Very little effect at night	Where justified			
Crosswalk Markings and Signs	Crosswalk Markings and Warning to drivers that a crossing Signs location is present	Not been shown to reduce crashes		7%	7%	\$800 to \$3,200
	May decrease vehicle speed	Speeds increase over time				
	Inexpensive	May make snow removal more difficult	Downtown/Urban conditions			
In-Street Crossing Signs (25 to 30 mph)	Additional Warning to drivers that a crossing location is present	Need consistent maintenance and replacement due to vehicle hits	Supplement warning signs at high pedestrian volume locations	87%	%06	\$500 to \$1,000
			In conjunction with pavement markings			
High Visibility Crosswalk	May decrease vehicle speed	Not been shown to reduce crashes	Where justified	61% (25mph)	91% (25 mph)	ς5 000 to \$50 000
Markings		Speeds increase over time	Urban conditions	17% (35 mph)	20% (35 mph)	
		NR = No Research Found on Effect to Yielding Rate	n Effect to Yielding Rate			

Uncontrolled Pedestrian Crossing Evaluation

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Table 7.2 Signing and Marking Treatments

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

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	'n	Uncontrolled Crossing Treatments (in conjunction with markings and signs) (Treatments Should be Justified Through an Engineering Study)	onjunction with markings and sign: Through an Engineering Study)	()		
				Motorist Yield Rate	ield Rate	
Treatment	Advantages	Disadvantages	Recommended Locations	Staged Pedestrian	Unstaged Pedestrian	Cost
	Decreases pedestrian crossing distance	May make snow removal more difficult	Wide two-lane roads and multi-lane roads with sufficient right-of-way			
Center Median with Refuge Island	Provides higher pedestrian visibility May be a hazard for motorists Reduces vehicle Speeds approaching the Small islands not recommended on high island	May be a hazard for motorists Small islands not recommended on high speed (>40 mph) roadways		34%	29%	Variable depending on length
	Reduces conflicts Increases usable gaps Reduces pedestrian exposure time					
School Crossing Guards	/ to Ing is	May require trained staff or local law enforcement, especially on high speed and high volume roadways	At school locations	ž	86%	Variable
	Inexpensive	No effect at night	Downtown/Urban locations			
Pedestrian Crossing Flags	Provides higher pedestrian visibility to drivers assuming the flag is held in a noticeable location	Requires pedestrian to actively use a flag High pedestrian volume locations Can be easily removed/stolen Shorter crossings are preferred Across low speed (<45 mph) roady	High pedestrian volume locations Across low speed (<45 mph) roadways	65%	74%	<\$500
Warning Sign with Edge Mounted LEDs	Highlights a crossing both at night and during the day	Requires pedestrian activation Minimal to no effect on speed	In conjunction with In-Road Warning Lights Downtown/Urban conditions	NR	28%	\$3,000 to \$8,000
In-Road Warning Lights	Highlights a crossing both at night and Snow plows can cause maintenance during the day issues Provides higher driver awareness when a No effect when road surface is covered pedestrian is present In snow Requires pedestrian activation		Downtown/Urban conditions	ж	66%	\$20,000 to \$40,000
Pedestal Mounted Pedestrian Flashing Signal Beacons	Provides higher driver awareness when a Requires pedestrian activation Not advisable on multi-lane str Not been shown to reduce cras	Requires pedestrian activation Not advisable on multi-lane streets Not been shown to reduce crashes	Low speed school crossings Two lane roadways Midblock crossing locations	NR	57% (2-Lane, 35 mph)	\$12,000 to \$18,000
Pedestrian Overhead Flashing Signal Beacons	Provides higher driver awareness when a Requires pedestrian activation pedestrian is present	Requires pedestrian activation	Multi-lane roadways Midblock crossing locations Lower speed roadways	active 47% passive 31%	active 49% passive 67%	\$75,000 to \$150,000
Rectangular Rapid Flash Beacons (RRFBs)	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	Requires pedestrian activation	Supplement existing pedestrian crossing warning signs School Crossings Midblock crossing locations Low and high speed roadways	84%	81%	\$12,000 to \$18,000
	aegrees	NR = No Research Found on Effect to Yielding Rate	n Effect to Yielding Rate			

Uncontrolled Pedestrian Crossing Evaluation

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Table 7.3 Uncontrolled Crossing Treatments

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

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		Traffic Calming Treatments	g Treatments			
				Motorist Yield Rate	'ield Rate	
Treatment	Advantages	Disadvantages	Recommended Locations	Staged Pedestrian	Unstaged Pedestrian	Cost
	Decreases pedestrian crossing distance	May make snow removal more difficult	Wide two-lane roads and multi-lane roads with sufficient right-of-way			
Center Median with	Provides higher pedestrian visibility May be a hazard for motorists Reduces vehicle speeds approaching the Small islands not recommended on high island Month Inconducase	May be a hazard for motorists Small islands not recommended on high enood (AMD much) cradures		34%	29%	Variable depending on
	Reduces conflicts					11121
	Increases usable gaps					
	Reduces pedestrian exposure time					
	Provides higher pedestrian visibility to vehicles	May make snow removal more difficult	Low speed/Urban environments			
Raised Crossings	Can reduce vehicle Speeds	May reduce emergency vehicle response times		NR	NR	\$5,000 to \$25,000
		Only appropriate In Low speed/Urban environments				
l iddations	Can be inexpensive	No effect during daylight	Targeted crossing locations not located	đ	đ	\$1 000 to \$10 000
	Highlights a crossing at night		un a su eet with continuous roadway lighting	2		
	Can be inexpensive	Does not provide a physical barrier	Four-lane undivided roadways			
Pavement Strining	May decrease vehicle speed	between modes	Locations with very long crossings			Variable denending on
(Road Diet)	May decrease illegal right side passing	Pedestrian crossing distance same as existing		NR	NR	length
	Can be an interim solution					
	Can be inexpensive Reduces pedestrian crossing distance	May make snow removal more difficult	Downtown/Urban conditions			
Curb Bump- Outs/Extensions	Provides higher pedestrian visibility to vehicles	Proximity of curb to through traffic may be a safety concern		NR	NR	\$5,000 to \$15,000 per crossing
	Reduces speed for turning vehicles					
	Decrease in illegal right side passing					
	Decrease pedestrian crossing distance	May require new pavement	Intersections with wide approaches			
Channelized Turn Lanes	Provides higher pedestrian visibility	Can be more challenging for visually impaired pedestrians	Intersections with right turn lanes and sufficient corner right-of-way			
(Corner Islands)	Decrease in illegal right side passing	Right turning drivers often fail to yield to Intersections with operational pedestrians	Intersections with operational improvement needs	NR	NR	\$50,000 to \$100,000
(Not Usually Recommended as a Pedestrian Crossing		Can increase right turn vehicle speeds				ber Intersection
(huauneau)		May make snow removal more difficult				
		Vehicle crashes may increase				
		NR = No Research Found on Effect to Yielding Rate	in Effect to Yielding Rate			

Uncontrolled Pedestrian Crossing Evaluation

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Table 7.4 Traffic Calming Treatments

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 7.20 Underpass



Figure 7.21 Overpass



Figure 7.19 Pedestrian Traffic Signal

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		High Level Treatments (Treatments Should be Justified Through an Engineering Study)	eatments hrough an Engineering Study)			
				Motorist Yield Rate	ield Rate	
Treatment	Advantages	Disadvantages	Recommended Locations	Staged Pedestrian	Unstaged Pedestrian	Cost
Pedestrian Hybrid	Provides higher driver awareness when a pedestrian is present	ner driver awareness when a Potential increase in vehicle crashes	Justified locations	240	2000	¢150 000 +> ¢200 000
Beacon	Has been shown to decrease pedestrian crashes	Has been shown to decrease pedestrian Can have spotty compliance rates due to crashes	Midblock crossing locations	%/6	%66	הההיההכל הו הההיהכדל
Traffic Signal	Provides higher driver awareness when a pedestrian is present	May increase crashes due to the driver	High pedestrian volume crossings	ψN N	Ν	\$100 000 to \$300 000
	Easily understandable	expectation of a green signal indication	Justified locations, meets signal warrants		<u>í</u>	
	Removes pedestrian/vehicle conflicts	Potential of the crossing not being used	Location with compatible grades			
		Very location specific	High pedestrian volume crossings			
Underpass Grade Separation		Very expensive	High volume roadways	NA	NA	\$800,000+
		Drainage within an underpass can be problematic	High speed roadways			
		Underpass would require lighting				
	Removes pedestrian/vehicle conflicts	Potential of the crossing not being used	Location with compatible grades			
Overpass Grade		Very location specific	High pedestrian volume crossings		Ň	
Separation		Very expensive	High volume roadways			71,200,000F
		Snow removal on overpass may be difficult	High speed roadways			
		NA = Not Applicable or No Research Found on Effect to Yielding Rates	Found on Effect to Yielding Rates			

Uncontrolled Pedestrian Crossing Evaluation

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Table 7.5 High Level Treatments

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:

- Minnesota Department of Transportation, "Minnesota's Best Practices for Pedestrian/Bicycle Safety," MnDOT Office of Traffic, Safety and Technology, Roseville, MN, September 2013.
- D. A. Noyce, "Best Practices Synthesis and Guidance in At-Grade Trail-Crossing Treatments," Minnesota Department of Transportation, St.Paul, MN, September 2013.

REPEAX STEP Sto

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

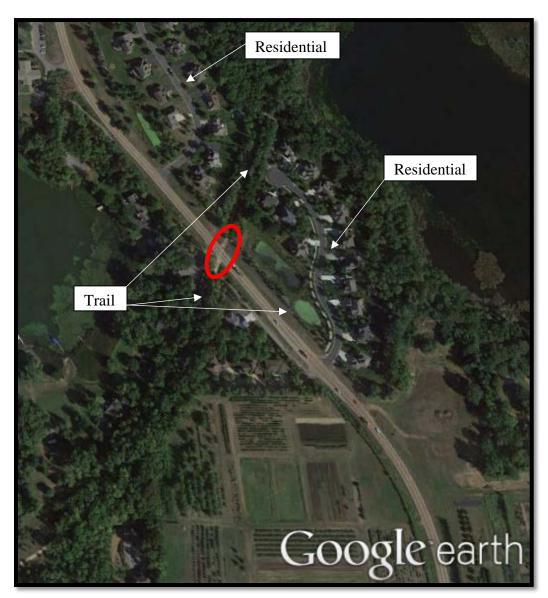
Using the information provided in Chapters 2 through 6, some examples from Minnesota are provided. The names of cities, streets, and other location specific information has been removed as these examples and results have not been approved by the jurisdictional authority.

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.

	Uncontrolled Pedestrian Crossing Data Collection Worksheet												
Location:	Example 1: Two-Lane Rural Highway				Date:								
City, State:	Any City, Minnesota			Scenario:		Trail Cr	ossing						
Reviewer(s):	,,,			Agency:									
Project #:					ID #:								
	The first ste	p in unders	tanding the pe	destrian nee	ds at a pote	ential crossir	ng location is a	comple	eting				
	_		a review of	the location	and adjacer	nt facilities.							
	Crossing Length: Measure the crossing distance from curb to curb.						Crossing 1 45 ft.						
	Fill in Crossing 1 distance if there is no median. If there is a median at the Crossing 2 0 ft.									ft.			
	crossing location, fill in Crossing 1 and 2 distances.												
	Median: width of median at crossing location Crossing Width: effective crosswalk width								0 ft.				
									;	ft.			
	Raised Mee	dian Availat	ole?						Yes	\checkmark	No		
S	A	DA Complia	nt Median Ava	ilable (minir	num 4' x 4'	landing)?			Yes	\checkmark	No		
tric	Curb Ramp	s Available	?						Yes	\checkmark	No		
me	A	DA Complia	nt Curb Ramp	Available (w					Yes	\checkmark	No		
Geometrics	Speed: Posted or 85 th percentile speed							4	5	mph			
Ŭ			l Sight Distand		0	alking speed	I	6.		ft/s			
	Is the cross	ing location	n within a hori	zontal or ver	tical curve?				Yes	\checkmark	No		
	Equations to	calculate th	e following are	located on the	e next page								
	Direction 1:	Stopping S	ight Distance	(SSD)	360	ft.	provided?	\checkmark	Yes		No		
	Direction 2:	Stopping S	ight Distance	(SSD)		ft.	provided?		Yes		No		
	Direction 1:	Pedestriar	n Sight Distanc	e (PedSD)	679	ft.	provided?	\checkmark	Yes		No		
		Direction 2: Pedestrian Sight Distance (PedSD) ft. provided?							Yes		No		
Traffic and	Measure trai	•	lestrian volum				,	crossed	J.				
Pedestrian	Attach Counts		hicles:	Daily		ped		Daily					
Data	AM Peak	Hourly	508	Pk 15-min	142	Hourly		Pk 15			ŝ		
	PM Peak	Hourly	341	Pk 15-min	94	Hourly	15	Pk 15	-min	5	5		
	Lighting:							_		_			
	-	•	nt and does it	•					Yes	1	No		
	Crosswalk Pa		•		estrian cross	Image: A start and a start	Yes		No				
	What is the		of the marking			Excellent	Good		Fair	\checkmark	Poor		
tics		Are the markings easily defined? Do they need replacement?							Yes		No		
erist								✓.	Yes		No		
acte							Contin						
Jar	Signing:								Yes	Ц	No		
e C	Currently signed in advance of crosswalk?					1.	direction 2		Yes		No		
Additional Site Characteristics	L	Distances		direction 1	547	ft.	458 ft.						
nal	Enhancemer	its:	What enhancements are c			· · ·			ng signs (text)				
itio		the crossing location?					dir 1: north, dir 2: south						
ddi		Adjacent Facilities: Distance to nearest marked crosswalk? 2,000 ft. What pedestrian control devices are present Traffic signal											
A													
		at the nearest adjacent marked crosswalk? Distance to nearest all-way stop, roundabout or signalized intersection 2,000 ft.											
		Distance to nearest all-way stop, roundabout or signalized intersection 2,000 ft. Could another location serve the same pedestrian crossing movement? Yes V No											
	Could another location serve the the movement more effectively?												

Developed by Bolton & Menk, Inc. in coordination with the Local Road Research Board. Worksheets made without charge and under no circumstances shall be sold by third parties for profit.

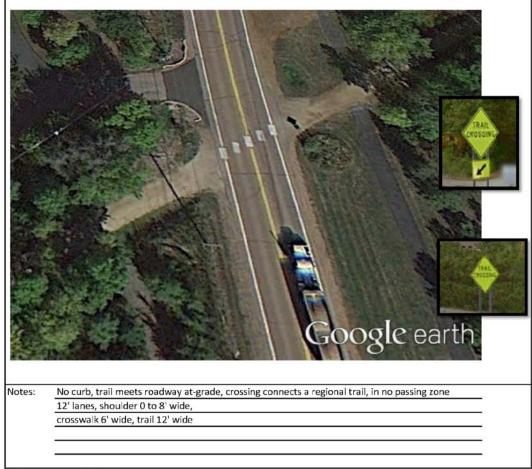
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Uncontrolled Pedestrian Crossing Data Collection Worksheet

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 orgins and destinations.

draw or insert map of location being studied



Sight Distance Calculations:

Stopping sight distance (SSD), ft = $1.47St + 1.075S^2/a$ Pedestrian sight distance (PedSD), ft = $1.47S(L / S_p + t_s)$

> where: S = design speed, mph L = length of crossing, ft

where:	defaults:
t = brake reaction time, s	2.5
a = deceleration rate, ft/s ²	11.2
$S_{\rm p}$ = average pedestrian walking speed, ft/s	3.5
\boldsymbol{t}_{s} = pedestrian start-up and end clearance time, \boldsymbol{s}	3.0

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] $a = deceleration rate (\frac{ft}{s^2}) [DEFAULT = 11.2 \frac{ft}{s^2}]$

$$SSD = 1.47 * 45 * 2.5 + 1.075 \frac{45^2}{11.2} = 359.7 \, ft \approx 360 \, ft$$

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

$$PedSD = 1.47V(\frac{L}{S_p} + t_s)$$

Where:

L = length of crossing (ft) $S_p = \text{average pedestrian walking speed } \left(\frac{\text{ft}}{s}\right) [DEFAULT = 3.5 \frac{ft}{s}]$

 t_s = pedestrian start – up and end clearance time (s) [**DEFAULT** = **3**.**0** sec]

Actual pedestrian walking speed collected: average 6.2 ft/s

$$PedSD = 1.47 * 45 * \left(\frac{45}{6.2} + 3.0\right) = 679 ft$$

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.

<u>HCM Analysis</u> *Determine inputs:*

V = 508 in AM, 341 in PM

Evaluation Inputs:		defaults:		Input	: Table:
L = crosswalk length (ft)				L =	45
S _p = average pedestrian walking speed (ft/s)	S _p =	3.5		S _p =	6.2
t_s = pedestrian start-up and end clearance time (s)	t _s =	3.0		t _s =	3
V = vehicular hourly volume (veh/hr)				V =	508
Peak 15-minute volume (veh)					142
v_p = pedestrian flow rate (ped/s)	v _p =	0*		v _p =	0
W _c = crosswalk width (ft)	W _c =	8.0		$W_c =$	6.0
N = number of lanes crossed	N =	INT(L/11)		N =	2

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 <u>NOT</u> 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:

$$t_c = t_{c,G} = \frac{L}{S_p} + t_s$$
$$t_{c,G} = \frac{45}{6.2} + 3.0 = 10.3 \, sec$$

Step 3: Estimate Probability of a delayed crossing

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

$$v = \frac{V}{PHF} = \frac{508}{\frac{508}{4*142}} = \frac{508}{.89} = 568\frac{veh}{hr} = 0.16 veh/s$$

Calculate the probability of a delayed crossing

$$P_b = 1 - e^{\frac{-10.0^{-1}}{N}}$$

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

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

$$P_d = 1 - (1 - 0.55)^2 = 0.80$$

-t_cv

Step 4: Calculate Average Delay to Wait for Adequate Gap

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

$$d_g = \frac{1}{0.16} \left(e^{0.16(10.3)} - 0.16(10.3) - 1 \right) = 15.4 \text{ sec}$$
$$d_{gd} = \frac{15.4}{0.56} = 19.2 \text{ sec}$$

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:

$$Delay = 12.3 \ sec = LOS \ C$$

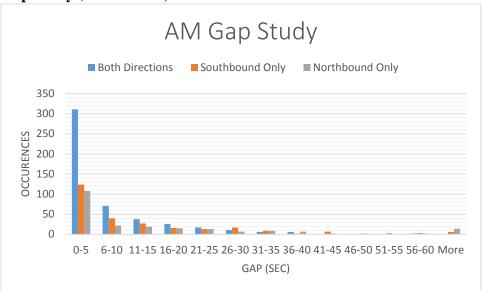
Analysis of the crossing indicates that the crossing is experiencing LOS C during the AM Peak Hour and LOS C in the PM Peak Hour. Pedestrian traffic is essentially equal in the AM and PM.

<u>Result</u> 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.

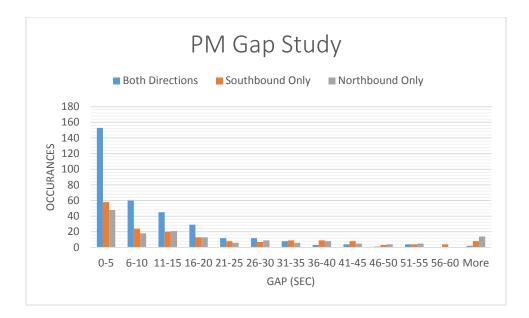
Some recommendations based on the field review.

- 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)



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.

Needed Gap = Crossing Time + Start/End Time =
$$\frac{45}{6.2}$$
 + 3 = 10.3 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.

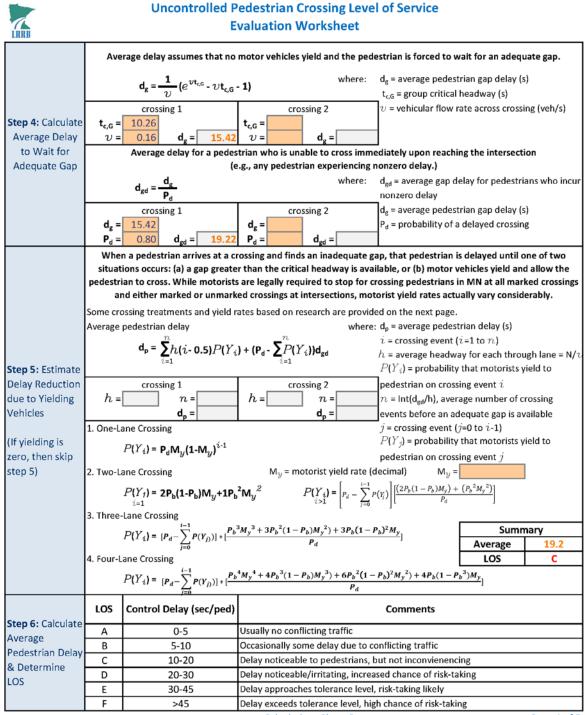


Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

LRRB	
Crossing Location	
City, State:	Any City, Minnesota Scenario: Trail Crossing, AM Peak Hour
Reviewer(s):	Agency:
Step 1: Identify	Is there a median available for a two-stage crossing?
Two-Stage	If yes, does the median refuge meet ADA requirements (4' x 4' landing)?
Crossings	If yes, does the median refuge need to meet ADA requirements (4' x 4' landing)? 🛛 🗌 Yes 🔽 No
Crossings Step 2: Determine Critical Headway	Critical headway is the time below which a pedestrian will not attempt to begin crossing the street. Pedestrians use judgement to determine whether the available headway is sufficent for a safe crossing. For a single pedestrian: $t_{c} = \frac{L}{S_{p}} + t_{s}$ where: t_{c} = critical headway for a single pedestrian (s) $t_{c} = \frac{L}{S_{p}} + t_{s}$ $L = crosswalk length (ft)$ S_{p} = average pedestrian walking speed (ft/s) $L = crossing 1$ $L = crossing 2$ $L = \frac{45}{S_{p}} = \frac{1}{6.2}$ $t_{c} = \frac{1}{10.3}$ $L = \frac{t_{s}}{t_{c}} = \frac{t_{s}}{t_{c}} = \frac{t_{s}}{t_{c}} = \frac{t_{s}}{t_{c}} = \frac{t_{s}}{t_{c}} = \frac{t_{s}}{t_{c}} = \frac{t_{s}}{t_{s}} = \frac{t_{s}}{t_{s}}} = \frac{t_{s}}{t_{s}} = \frac{t_{s}}{t_{s}}} = \frac{t_{s}}{t_{s}}} = \frac{t_{s}}{t_{s}} = \frac{t_{s}}}{t_{s}} = \frac{t_{s}}{t_{s}} = \frac{t_{s}}{t_{s}} = \frac{t_{s}}{t_{s}} = \frac{t_{s}}{t_{s}}} = \frac{t_{s}}{t_{s}} = \frac{t_{s}}{t_{s}} = \frac{t_{s}}{t_{s}} = \frac{t_{s}}{t_{s}} = \frac{t_{s}}{t_{s}} = \frac{t_{s}}}{t_{s}} = \frac{t_{s}}}{t_{s}} = \frac{t_{s}}{t_{s}} = \frac{t_{s}}{t_{s}} = \frac{t_{s}}{t_{s}} = \frac{t_{s}}{t_{s}} = \frac{t_{s}}{t_{s}} = $
	crossing 1crossing 2 $W_c = crosswalk width (ft)$ $N_c =$ $N_p =$ $N_c =$ $N_c = crosswalk width (ft)$ $W_c = 6$ $N_p =$ $N_p =$ $N_c = crosswalk width (ft)$ 3. compute group critical headway:clear width, if other than 8:ft. $t_{c,G} = t_c + 2(N_p-1)$ $t_c = single pedestrian critical headway (s)$
	$ \begin{array}{ c c c c c } \hline crossing 1 & crossing 2 \\ \hline N_p = & \\ \hline t_c = & 10.3 & t_{c,G} = & \\ \hline \end{array} \begin{array}{ c c c c } \hline N_p = & \\ \hline t_{c,G} = & \\ \hline \end{array} \begin{array}{ c c } \hline N_p = & \\ \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c c } \hline N_p = & \\ \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline N_p = & \\ \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline N_p = & \\ \hline \end{array} \begin{array}{ c } \hline N_p = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \end{array} \begin{array}{ c } \hline T_{c,G} = & \\ \hline \end{array} \end{array} $
	Probability that a pedestrian will not incur any crossing delay is equal to the likelihood that a pedestrian will
Step 3: Estimate Probability of a Delayed Crossing	encounter a gap greater than or equal to the critical headway immediately upon arrival at the intersection. $P_{b} = 1 \cdot e^{-t_{c,6}\upsilon/N}$ where: P_{b} = probability of blocked lane P_{d} = probability of delayed crossing $P_{d} = 1 \cdot (1 \cdot \mathbf{P}_{b})^{N}$ N = number of lanes crossed $t_{c,G}$ = group critical headway (s) = $t_{c_{i}}$ if no platooning υ = vehicular flow rate across crossing(veh/s)
	$\begin{array}{c c} \upsilon = & 0.16 \\ N = & 2 \end{array} \begin{array}{c c} P_b = & 0.56 \\ P_d = & 0.8 \end{array} \begin{array}{c c} \upsilon = & P_b = \\ N = & P_d = \\ \hline \\ Calculations Sheet 1 \end{array} \begin{array}{c c} P_{abc} = & 0.8 \end{array}$

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HCM Evaluation Worksheet



Calculations Sheet 2

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HCM Evaluation Worksheet



Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

LRRB	
Crossing Location:	Example 1:Two Lane Rural Highway Date:
City, State:	Any City, Minnesota Scenario: Trail Crossing, PM Peak Hour
Reviewer(s):	Agency:
Step 1: Identify	Is there a median available for a two-stage crossing?
Two-Stage	If yes, does the median refuge meet ADA requirements (4' x 4' landing)? 🛛 🗌 Yes 🗔 No
Crossings	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 sufficent for a safe crossing.
	For a single pedestrian: where: $t_c = critical headway for a single pedestrian (s)$
	$\mathbf{t}_{c} = \frac{\mathbf{L}}{\mathbf{S}_{p}} + \mathbf{t}_{s}$ $\mathbf{t}_{s} = \text{average pedestrian walking speed (ft/s)}$
	crossing 1 crossing 2 t _s = pedestrian start-up and end clearance time (s)
	$L = 45$ $t_s = 3$ $L = t_s = S_p = 3.5$ ft/s
	$S_p = 6.2$ $t_c = 10.3$ $S_p = t_c = t_s = 3 \sec t_s$
	If pedestrian platooning is observed, the spatial distribution of pedestrians should be computed: 1. use field observations or estimate platoon size using equation: $N_{c} = \frac{\upsilon_{p} e^{\upsilon_{p} t_{c}} + \upsilon e^{-\upsilon t_{c}}}{(\upsilon_{p} + \upsilon) e^{(\upsilon_{p} \cdot \upsilon) t_{c}}}$ where: N _c = total number of pedestrians in crossing platoon (ped)
Step 2:	$v_{\rm p}$ = pedestrian flow rate (ped/s)
Determine	crossing 1 crossing 2 v = vehicular flow rate across crossing (veh/s)
Critical Headway	$\begin{array}{c c} \upsilon_{p} = & t_{c} = 10.3 \\ \upsilon_{p} = & t_{c} = & t_{c} = & t_{c} = single pedestrian critical headway (s) \\ \upsilon_{p} = & v_{p} = & v_{p} = & v_{p} = & v_{p} = \\ \hline \end{array}$
	2. compute spatial distribution:
	$N_{p} = Int \left[\frac{8.0(N_{c}-1)}{W_{c}} \right] + 1$ where: N_{p} = spatial distributions of pedestrians (ped) N_{c} = total number of pedestrians in crossing platoon
	(ped)
	crossing 1 crossing 2 $W_c = crosswalk width (ft)$
	$N_c =$ $N_c =$ $N_c =$ $N_c =$ 8.0 = default clear width used by a single pedestrian
	si compare Bioda sinical negatia).
	$t_{c,G} = t_c + 2(N_p-1)$ where: $t_{c,G} = \text{group critical headway (s)}$
	$t_c = single pedestrian critical headway (s)$
	crossing 1 crossing 2 N _p = spatial distributions of pedestrians (ped)
	$t_c = 10.3$ $t_{c,G} = t_c = t_{c,G} =$
	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.
	$P_b = 1 \cdot e^{-t_{c,c}v/N}$ where: $P_b = \text{probability of blocked lane}$
Step 3: Estimate	P_d = probability of delayed crossing
Probability of a	$P_d = 1 - (1 - P_b)^N$ N = number of lanes crossed
Delayed	$t_{c,G}$ = group critical headway (s) = t_{c} , if no platooning
Crossing	crossing 1 crossing 2 v = vehicular flow rate across crossing(veh/s)
	$t_{c,G} = 10.3$ $t_{c,G} = 10.3$
	$v = 0.1$ $P_b = 0.41$ $v = P_b = 0.41$
	$N = 2$ $P_d = 0.66$ $N = P_d = 0.66$
	Calculations Sheet 1 Page 3 of 1

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HCM Evaluation Worksheet



Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

LILLD								
	Ave	rage delay assumes that	no motor veh	icles yield an	d the ped	estrian is forced to w	ait for an adequ	uate gap.
		1 . 21t. c			where:	d _g = average pedest	rian gap delay (s	5)
		$d_{g} = \frac{1}{\upsilon} (e^{\upsilon t_{c,G}} - \upsilon t_{G})$	_{,G} - 1)			t _{c,G} = group critical l		
		crossing 1		crossing 2		v = vehicular flow ra	ate across crossi	ing (veh/s)
Step 4: Calculate	t _{c,G} =		t _{c,G} =			_		
Average Delay	υ=	$0.10 d_g = 8.0$		d _g =	1			
to Wait for		Average delay for a peo					ng the intersecti	ion
Adequate Gap		4	(e.g., any pe	destrian expe	where:	nonzero delay.)	alay for podostri	ang who inque
		$d_{gd} = \frac{d_g}{P_d}$			where:	d _{gd} = average gap de nonzero delay	elay for pedestri	ans who incur
		crossing 1		crossing 2		d _g = average pedest	rian gap delay (s	5)
	d _g =		d _g =			P _d = probability of a		-
	P _d =	8.071 0.66 d _{gd} = 12.3	$P_{d} =$	d _{gd} =				
	Whe	n a pedestrian arrives at a			dequate g	ap, that pedestrian is	s delayed until o	one of two
		ions occurs: (a) a gap grea						
		ian to cross. While motor		-	-	÷.		-
		nd either marked or unma		-		-	ally vary consid	erably.
		ossing treatments and yiel	d rates based	on research a				
	Average	pedestrian delay		n.	where	: d _p = average pedest		
		$d_{p} = \sum_{i=1}^{n} h(i - 0.5)P(i)$	Y_{i}) + (P _d - \sum	$P(Y_i))d_{ed}$		<i>i</i> = crossing event (<i>i</i> <i>h</i> = average headwa		ugh Jane = N/2
Step 5: Estimate		<i>i=</i> 1	1	=1		$P(Y_i)$ = probability		•
Delay Reduction		crossing 1		crossing 2		pedestrian on crossi		
due to Yielding	h =	n =	h =	n =		$n = \ln(d_{gd}/h)$, avera	age number of c	rossing
Vehicles		d _p =		d _p =		events before an ad	equate gap is av	/ailable
	1. One-La	ane Crossing				j = crossing event (j		
(If yielding is		$P(Y_i) = P_d M_u (1-M_u)^{i-1}$				$P(Y_j)$ = probability		ield to
zero, then skip						pedestrian on crossi	ing event j	
step 5)		ane Crossing		= motorist y				
		$P(Y_1) = 2P_b(1-P_b)M_y + 1$	$P_b^2 M_y^2$	$P(Y_i) =$	$P_d - \sum P_d$	$P(Y_j) \left[\frac{(2P_b(1-P_b)M_y) + P_d}{P_d} \right]$	$(P_b^2 M_y^2)$	
		Lane Crossing		171	[<u>j=0</u>]r ·	,	
			$P_b{}^3M_v{}^3 + 3P_b{}^2$	$(1 - P_b)M_v^2)$	+ 3P _b (1 – 1	$(P_b)^2 M_{\gamma}$	Sumn	nary
		$P(Y_i) = [P_d - \sum_{j=0}^{i-1} P(Y_j)] * [$	- , -	P _d		<u> </u>	Average	12.3
	4. Four-L	ane Crossing					LOS	С
		$P(Y_i) = [P_d - \sum_{i=0}^{i-1} P(Y_{i})] *$	$P_b^4 M_y^4 + 4P_b^3$	$(1-P_b)M_y^3)$	$+6P_b^2(1-$	$(P_b)^2 M_y^2) + 4P_b(1 - P_b)^2$	$(b^{3})M_{y}$]	
		1-0			P_d		-	
	LOS	Control Delay (sec/pe	d)			Comments		
Step 6: Calculate	A	0-5	Usually no	conflicting tr	affic			
Average	B	5-10	Occasiona	Ily some dela	y due to c	onflicting traffic		
Pedestrian Delay	С	10-20	Delay noti	ceable to ped	lestrians, l	out not inconvienenci	ing	
& Determine LOS	D	20-30	Delay noti	ceable/irritat	ing, increa	sed chance of risk-ta	king	
203	E	30-45	Delay app	roaches toler	ance level	risk-taking likely		
	F	>45				h chance of risk-takir	ng	
			Calc	ulations She	pet 2			Page 4 of 5

Calculations Sheet 2

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HCM Evaluation Worksheet

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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.

~				ntrolled Pe							
LRRB		-			D						
Location:			Urban Street		Date:		Caturda	/ Neen			
City, State:		Any City,	Minnesota		Scenario:		Saturday	, Noon			
Reviewer(s):					Agency: ID #:						
Project #:	The first ste	n in unders	tanding the pe	destrian neg		ential crossin	ng location is	comple	ting		
	The motote	5 m anacis	0	the location			ig location is	compie	cing.		
	Crossing Len	oth: Measu	ire the crossin				Crossing 1	66	5	ft.	
	-	-	e if there is no	0			0	0		ft.	
		-	Crossing 1 and			solution de ene	Crossing 2	0		i ci	
	_		an at crossing l					0		ft.	
			e crosswalk w					8		ft.	
	Raised Med								Yes		No
			nt Median Ava	ailable (minir	num 4' x 4'	anding)?			Yes		No
rics	Curb Ramp								Yes		No
Geometrics			nt Curb Ramp	Available (w	idth, grades	s. truncated	domes)?		Yes		No
son	Speed:	e compile	ine car b hamp	ritundone (tr		85 th percenti		30		mph	
Ğ	•	rvature an	d Sight Distand	ces:		alking speed		3.		ft/s	
	· ·		n within a hori			0.			Yes	П,	No
		-	e following are						100		110
			Sight Distance		197	ft.	provided?	v	Yes		No
			Sight Distance		237	ft.	provided?		Yes		No
			n Sight Distanc		964	ft.	provided?		Yes		No
			n Sight Distanc	. ,		ft.	provided?		Yes		No
			lestrian volum		te incremer			crossed			
Traffic and	Attach Counts		hicles:	Daily	10,400	1	estrians:		Daily		
Pedestrian	AM Peak	Hourly		Pk 15-min		Hourly		Pk 15	-min		
Data	PM Peak	Hourly	690	Pk 15-min	219	Hourly	3	Pk 15	-min	-	3
	Lighting:										
	Is street lig	hting prese	nt and does it	light the cro	sswalk locat	tion?		\checkmark	Yes		No
	Crosswalk Pa	avement M	arkings:	Is the pede	estrian cross	sing currentl	y marked?		Yes	\checkmark	No
	What is the	condition	of the marking	gs?	Ľ	Excellent	Good	I 🗌	Fair		Poor
S		Are the m	arkings easily	defined?					Yes		No
Additional Site Characteristics		Do they n	eed replaceme	ent?					Yes		No
cter		What is th	e crosswalk m	arking patte	rn?						
arac	Signing:	Currently	signed at cross	swalk?					Yes	1	No
ĊŸ		Currently	signed in adva	nce of cross	valk?	_			Yes	\checkmark	No
ite		Distances	?	direction 1		ft.	direction 2			ft.	
als	Enhancemen	its:	What enhance	ements are d	urrently at						
ion			the crossing lo	ocation?							
ldit	Adjacent Fac	ilities:	Distance to ne	earest marke	d crosswalk	?		51	5	ft.	
Ad	What pede	strian cont	rol devices are	present			Traffic Signal				
	at the near	est adjacer	nt marked cros	swalk?							
	Distance to	nearest al	l-way stop, roι	undabout or	signalized ir	ntersection		51	5	ft.	
	Could anot	her locatio	n serve the sar	ne pedestria	n crossing r	novement?		\checkmark	Yes		No
	Could anot	her locatio	n serve the the	e movement	more effect	tively?			Yes	1	No

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Page 1 of 2

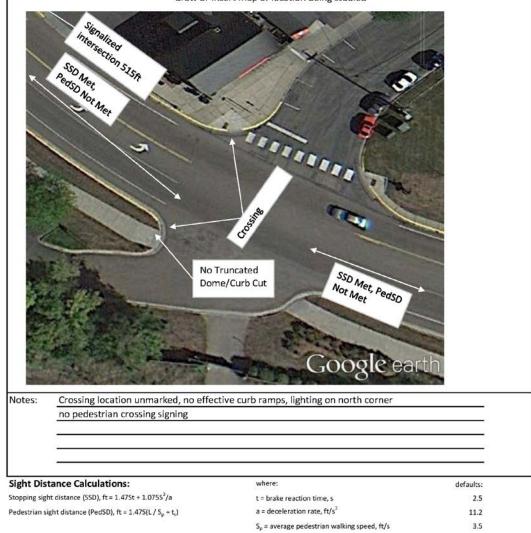


Uncontrolled Pedestrian Crossing

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 lighting units, curb ramps, truncated domes, presence of any other crosswalks or crossing locations parallel to and nearby the location being studied, adjacent intersection traffic control, parking, intersection width, lane lengths, shoulder widths, sign placement, and nearby orgins and destinations .

draw or insert map of location being studied



where: S = design speed, mph L = length of crossing, ft

Page 2 of 2

 t_s = pedestrian start-up and end clearance time, s

3.0

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] $a = deceleration rate <math>\left(\frac{ft}{s^2}\right)$ [DEFAULT = 11.2 $\frac{ft}{s^2}$]

$$SSD = 1.47 * 30 * 2.5 + 1.075 \frac{30^2}{11.2} = 197 \, ft$$

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

$$PedSD = 1.47V(\frac{L}{S_p} + t_s)$$

Where:

$$L = \text{length of crossing (ft)}$$

$$S_{p} = \text{average pedestrian walking speed } \left(\frac{\text{ft}}{\text{s}}\right) [DEFAULT = 3.5 \frac{ft}{\text{s}}]$$

$$t_{s} = \text{pedestrian start} - \text{up and clearance time (s) [DEFAULT = 3.0 sec]}$$

$$PedSD = 1.47 * 30 * \left(\frac{66}{3.5} + 3\right) = 964 \, ft$$

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.

<u>HCM Analysis</u> *Determine inputs:*

Evaluation Inputs:	de	faults:	Input	Table:
L = crosswalk length (ft)			L =	66
S _p = average pedestrian walking speed (ft/s)	S _p =	3.5	S _p =	3.5
t_s = pedestrian start-up and end clearance time (s)	t _s =	3.0	t _s =	3
V = vehicular hourly volume (veh/hr)			V =	690
Peak 15-minute volume (veh)				219
v_p = pedestrian flow rate (ped/s)	v _p =	0*	v _p =	0
W_c = crosswalk width (ft)	W _c =	8.0	$W_c =$	8
N = number of lanes crossed	N =	INT(L/11)	N =	2

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 <u>NOT</u> 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:

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

$$t_{c,G} = \frac{60}{3.5} + 3.0 = 21.9 \, sec$$

Step 3: Estimate Probability of a delayed crossing

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

$$v = \frac{V}{PHF} = \frac{690}{\frac{690}{4 * 219}} = 876 \frac{veh}{hr} = 0.24 \ veh/s$$

$$P_b = 1 - e^{\frac{-21.9(0.24)}{2}} = 0.93$$

$$P_d = 1 - (1 - 0.93)^2 = 0.99$$

Step 4: Calculate Average Delay to Wait for Adequate Gap

$$d_g = \frac{1}{v} (e^{vt_{c,G}} - vt_{c,G} - 1)$$
$$d_{gd} = \frac{d_g}{P_d}$$
$$d_g = \frac{1}{0.24} (e^{0.24(21.9)} - 0.24(21.9) - 1) = 765 \ sec$$

$$d_{gd} = \frac{764}{0.99} = 769 \, sec$$

There is no reduction in delay due to yielding vehicles

$$d_p = d_{gd} = 769 \ sec = LOS \ F$$

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:	
City, State:	Any City, Minnesota	Scenario:	Saturday, noon
Reviewer(s):		Agency:	
Step 1: Identify	Is there a median available for a two-stage crossing?		🗌 Yes 🗹 I
Two-Stage	If yes, does the median refuge meet ADA re	equirements (4' x 4' landir	ng)? 🗌 Yes 🗹 I
Crossings	If yes, does the median refuge need to me	et ADA requirements (4' x	4' landing)? Yes 🗸 I
	Critical headway is the time below which a pedestr	ian will not attempt to be	gin crossing the street. Pedestrians us
	judgement to determine whether th		
	For a single pedestrian:	where: t _c = critical l	neadway for a single pedestrian (s)
	. L	L = crosswal	k length (ft)
	$t_c = \frac{L}{S_p} + t_s$	S _p = average	pedestrian walking speed (ft/s)
	crossing 1 crossing	g 2 t _s = pedestri	an start-up and end clearance time (s)
	$L = 66$ $t_s = 3$ $L = 100$	t _s = S _p = 3.5	
	$S_p = 3.5$ $t_c = 21.9$ $S_p = 100$	t, = 3 se	ec.
	If pedestrian platooning is observed, the spatial distr	ibution of pedestrians sho	uld be computed:
	1. use field observations or estimate platoon size using the second seco		
		0 1	mber of pedestrians in crossing platoo
	$N_{c} = \frac{\mathcal{U}_{p} e^{\mathcal{U}_{p} t_{c}} + \mathcal{U} e^{-\mathcal{V} t_{c}}}{(\mathcal{U}_{p} + \mathcal{U}) e^{(\mathcal{U}_{p} \cdot \mathcal{U}) t_{c}}}$	(ped)	1 01
	(op of o	v_ = pedest	rian flow rate (ped/s)
Step 2:	crossing 1 crossing		r flow rate across crossing (veh/s)
Determine	$v_{\rm p} = $ $t_{\rm c} = 21.9$ $v_{\rm p} = $		edestrian critical headway (s)
Critical Headway	v = 0.24 N _e = $v =$	N _c =	, , ,
	2. compute spatial distribution:		
		where: N _n = spatial	distributions of pedestrians (ped)
	$N_{p} = Int \left[\frac{8.0(N_{c}-1)}{W_{c}} \right] + 1$		imber of pedestrians in crossing platoo
		(ped)	
	crossing 1 crossing		alk width (ft)
		,	t clear width used by a single pedestria
	$W_c = 8$ $N_p = W_c = 1$	N _p = to avoid inte	erference with other pedestrians (ft)
	3. compute group critical headway:		th, if other than 8:
		where: t _{c.6} = group (critical headway (s)
	$t_{c,G} = t_c + 2(N_p - 1)$		edestrian critical headway (s)
	crossing 1 crossing		distributions of pedestrians (ped)
	N _p = N _p =	, , , , , , , , , , , , , , , , , , ,	
		t _{c.G} =	
	Probability that a pedestrian will not incur any	-1	the likelihood that a pedestrian will
	encounter a gap greater than or equal to the c	• • •	
	D = = +t = = = = = = = = = = = = = = = =	where: P _b = probabi	lity of blocked lane
Step 3: Estimate	$\mathbf{P}_{\mathbf{b}} = 1 \cdot e^{-\mathbf{t}_{c,G} \mathcal{U} / \mathbf{N}}$		lity of delayed crossing
Probability of a		N = number	of lanes crossed
Delayed	$\mathbf{P}_{d} = 1 - (1 - \mathbf{P}_{b})^{N}$		critical headway (s) = t _c if no platoonin
Crossing	crossing 1 crossing		r flow rate across crossing(veh/s)
Ŭ	$t_{c,G} = 21.9$ $t_{c,G} = 1000$		
	v = 0.24 P _b = 0.93 $v =$	P _b =	
		rh-I I	
	$N = 2$ $P_d = 0.99$ $N = 1000$	$P_{d} =$	

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HCM Evaluation Worksheet



Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

	Ave	rage delay assumes that no	motor vehicles yield	and the ped	lestrian is forced to w	ait for an adequ	iate gap.
		1 , <i>v</i> t.		where:	d _g = average pedest	rian gap delay (s)
		$\mathbf{d}_{\mathbf{g}} = \frac{1}{\upsilon} (e^{\upsilon \mathbf{t}_{c,G}} - \upsilon \mathbf{t}_{c,G})$	- 1)		t _{c,G} = group critical	headway (s)	
		crossing 1	crossing	2	v = vehicular flow r	ate across crossi	ng (veh/s)
Step 4: Calculate	t _{c,G} =	21.86	$t_{c,G} = $ v = d		_		
Average Delay	υ=	8		=]		
to Wait for		Average delay for a pedes				ng the intersecti	on
Adequate Gap			e.g., any pedestrian ex	where:	d _{ed} = average gap de	alay for pedestri	ans who incur
		$d_{gd} = \frac{d_g}{P_d}$		where.	nonzero delav	city for pedestri	and who mean
		crossing 1	crossing	2	d _g = average pedest	rian gap delay (s)
	d _g =	764.6	d _g =		P _d = probability of a		
	P _d =	764.6 0.995 d _{gd} = 768.66	$P_d = d_{gd}$	=			
		n a pedestrian arrives at a c		nadequate g	gap, that pedestrian is	s delayed until o	ne of two
		ions occurs: (a) a gap greate		-		-	
	-	ian to cross. While motorists nd either marked or unmark	÷ · ·	-	÷.		-
			-		-	ally vary conside	erabiy.
		ossing treatments and yield r pedestrian delay	ates based on researd		e: d _o = average pedest	rian delay (s)	
	Average				<i>i</i> = crossing event (
		$d_{p} = \sum_{i=1}^{n} h(i - 0.5) P(Y_{i})$	$+ (P_d - \sum P(Y_i))d_g$	d	h = average headwa		igh lane = N/ v
Step 5: Estimate		2=1	1=1		$P(Y_i)$ = probability	that motorists y	ield to
Delay Reduction		crossing 1	crossing	2	pedestrian on cross	ing event i	
due to Yielding	h =	n =		. =	$n = \text{Int}(d_{gd}/h)$, avera	age number of c	rossing
Vehicles		d _p =	d,	=	events before an ad		ailable
(If vialating to	1. One-L	ane Crossing			j = crossing event ($jP(Y_j) = probability$		iald to
(If yielding is zero, then skip		$P(Y_i) = P_d M_y (1-M_y)^{i-1}$			pedestrian on crossi		
step 5)	2. Two-la	ane Crossing	M_{y} = motoris	vield rate (
5100 57		*	0				
		$P(Y_1) = 2P_b(1-P_b)M_y + 1P_b$	$M_y \sim P(I_{i>i})$	$P_d = \left P_d - \sum_{i=0}^{n} \right $	$P(Y_j) \left[\frac{(d + g(1 - f g)) P_d}{P_d} \right]$		
	3. Three	Lane Crossing		L ·			
		$P(Y_i) = [P_d - \sum_{i=0}^{t-1} P(Y_i)] * [\frac{P_b}{2}]$	${}^{3}M_{y}{}^{3} + 3P_{b}{}^{2}(1-P_{b})M_{y}$	$^{2}) + 3P_{b}(1 - $	$P_b)^2 M_y$	Summ	
		7=0	P_d		,	Average	768.7
		ane Crossing	4	3	- >2	LOS	F
		$P(Y_i) = [P_d - \sum_{i=0}^{i-1} P(Y_i)] * [\frac{P_b}{P_i}]$	${}^{\mathbf{y}}M_{\mathbf{y}}{}^{\mathbf{y}} + 4P_{b}{}^{\mathbf{y}}(1-P_{b})M_{\mathbf{y}}$	$\frac{3}{P} + 6P_b^2(1 - P_b)$	$(1 - P_b)^2 M_y^2 + 4P_b(1 - P_b)^2$	$\frac{b^3}{M_y}$]	
		1-4		• a			
	LOS	Control Delay (sec/ped)			Comments		
Step 6: Calculate	Α	0-5	Usually no conflicting	traffic			
Average Pedestrian Delay	В	5-10	Occasionally some de	lay due to c	conflicting traffic		
& Determine	С	10-20	, ,	,	but not inconvienenci	0	
LOS	D	20-30			ased chance of risk-ta	king	
	E	30-45	Delay approaches to				
	F	>45			gh chance of risk-takir	ng	D
			Calculations S	neet 7			Page 4 of 5

Calculations Sheet 2

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HCM Evaluation Worksheet

<u>Review Origins and Destination, Alternate Routes</u> *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:

$$\frac{505 ft}{3.5 \frac{ft}{s}} = 144 sec$$

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

$$30 + \frac{65 ft}{3.5 \frac{ft}{s}} = 49 sec$$

Walking Time back to Original Location:

$$\frac{505 ft}{3.5 \frac{ft}{s}} = 144 sec$$

Total Time:

$$144 + 49 + 144 = 337$$
 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.

<u>Speed and Pedestrian Use</u> 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.

<u>School Crossing</u> This is not a school crossing, **go to Step 9**.

<u>FHWA Safety Guidance</u> 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:

Evaluation Inputs:	de	faults:	Input	: Table:
L = crosswalk length (ft)			L =	38
S _p = average pedestrian walking speed (ft/s)	S _p =	3.5	$S_p =$	3.5
t_s = pedestrian start-up and end clearance time (s)	t _s =	3.0	t _s =	3
V = vehicular hourly volume (veh/hr)			V =	690
Peak 15-minute volume (veh)				219
v_p = pedestrian flow rate (ped/s)	v _p =	0*	v _p =	0
W_c = crosswalk width (ft)	W _c =	8.0	$W_c =$	8
N = number of through lanes crossed	N =	INT(L/11)	N =	2

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 <u>NOT</u> 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

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

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

$$v = \frac{V}{PHF} = \frac{690}{\frac{690}{4 * 219}} = 876 \frac{veh}{hr} = 0.24 veh/s$$

$$P_b = 1 - e^{\frac{-13.9(0.24)}{2}} = 0.81$$

$$P_d = 1 - (1 - 0.81)^2 = 0.96$$

Step 4: Calculate Average Delay to Wait for Adequate Gap

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

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

There is no reduction in delay due to yielding vehicles

$$d_p = d_{gd} = 102 \ sec = LOS \ F$$

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.

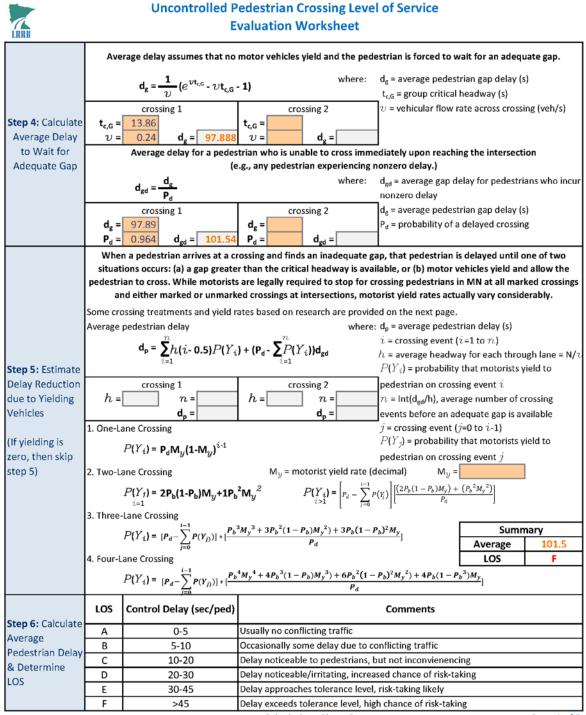


Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

LRRB			
Crossing Location	Example 2: Two Lane Urban Street	Date:	
City, State:	Any City, Minnesota	Scenario:	Saturday, noon, Curb Bump-Outs
Reviewer(s):		Agency:	
Step 1: Identify	Is there a median available for a two-stage crossing	2	🗌 Yes 🗹 No
Two-Stage	If yes, does the median refuge meet ADA	requirements (4' x 4' l	anding)? 🗌 Yes 🗹 No
Crossings	If yes, does the median refuge need to me	et ADA requirements	(4' x 4' landing)? 🗌 Yes 🔽 No
	Critical headway is the time below which a pedest	rian will not attempt	to begin crossing the street. Pedestrians use
	judgement to determine whether the	ne available headway	is sufficent for a safe crossing.
	For a single pedestrian:	where:t _c = crit	tical headway for a single pedestrian (s)
	$t_c = \frac{L}{S_c} + t_s$	L = cros	sswalk length (ft)
	S_p	S _p = ave	erage pedestrian walking speed (ft/s)
	crossing 1 crossin	ng 2t _s = pec	destrian start-up and end clearance time (s)
	$L = 38$ $t_s = 3$ $L = 100$	t _s = S _p	= 3.5 ft/s
	$S_p = 3.5$ $t_c = 13.9$ $S_p = 13.9$	t _c = t _s :	= 3 sec
	If pedestrian platooning is observed, the spatial dist	ribution of pedestrian	s should be computed:
	1. use field observations or estimate platoon size us	ing equation:	
	$v_n e^{v_p t_c} + v e^{-v t_c}$	where: $N_c = tot$	tal number of pedestrians in crossing platoon
	$N_{c} = \frac{\upsilon_{p} e^{\upsilon_{p} t_{c}} + \upsilon e^{-\upsilon t_{c}}}{(\upsilon_{p} + \upsilon) e^{(\upsilon_{p} \cdot \upsilon) t_{c}}}$	(ped)	
		$v_{\rm p} = pe$	edestrian flow rate (ped/s)
Step 2:	crossing 1 crossir		nicular flow rate across crossing (veh/s)
Determine	$v_{\rm p} =$ $t_{\rm c} = 13.9$ $v_{\rm p} =$	°	gle pedestrian critical headway (s)
Critical Headway	v = 0.24 N _c = $v =$	N _c =	, , ,
	2. compute spatial distribution:		
		where N = sr	patial distributions of pedestrians (ped)
	$N_p = Int \left[\frac{8.0(N_c-1)}{W_c} \right] + 1$		tal number of pedestrians in crossing platoon
		(ped)	tar number of pedestrians in crossing platoon
	crossing 1 crossir		osswalk width (ft)
	$\mathbf{N}_{c} = \mathbf{N}_{c}$		efault clear width used by a single pedestrian
			d interference with other pedestrians (ft)
	$W_c = 8 N_p = W_c = 0$	·•p	
	3. compute group critical headway:		
	$t_{c,G} = t_c + 2(N_p - 1)$	-,	oup critical headway (s)
			gle pedestrian critical headway (s)
	crossing 1 crossir	$\log 2$ $N_p = sp$	patial distributions of pedestrians (ped)
	$t_c = 13.9 t_{c,G} = t_c = $	t _{c,G} =	
	Probability that a pedestrian will not incur any		-
	encounter a gap greater than or equal to the	-	
	$\mathbf{P}_{\mathbf{b}} = 1 \cdot e^{-\mathbf{t}_{c,G} v / \mathbf{N}}$		obability of blocked lane
Step 3: Estimate	2	$P_d = pro$	obability of delayed crossing
Probability of a	$\mathbf{P}_{d} = 1 - (1 - \mathbf{P}_{b})^{N}$		mber of lanes crossed
Delayed			roup critical headway (s) = t_{c_r} if no platooning
Crossing	crossing 1 crossin	v = vet	nicular flow rate across crossing(veh/s)
	$t_{c,G} = 13.9$ $t_{c,G} = 13.9$		
	$v = 0.24$ $P_b = 0.81$ $v = 0.24$	P _b =	

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HCM Evaluation Worksheet



Calculations Sheet 2

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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.

Complete Field Review Worksheet.

				ntrolled Point Poi		-	1				
Location:	Exam	ole 3: Four-	Lane Divided S	Street	Date:						
City, State:			Minnesota		Scenario:						
Reviewer(s):					- Agency:						
Project #:					ID #:						
-	The first ste	p in unders	tanding the pe	destrian nee	ds at a pote	ential crossi	ng location is a	comple	eting		
			a review of	the location	and adjacer	nt facilities.					
	Crossing Len	gth: Measu	ire the crossin	g distance fr	om curb to	curb.	Crossing 1	11	12	ft.	
	Fill in Crossin	ig 1 distanc	e if there is no	median. If t	here is a me	edian at the	Crossing 2			ft.	
	crossing loca	tion, fill in (Crossing 1 and	2 distances.							
	Median: wid	th of media	in at crossing l	ocation						ft.	
	Crossing Wid	Ith : effectiv	e crosswalk w	idth				e	5	ft.	
	Raised Mee	dian Availat	ole?					1	Yes		No
s	A	DA Complia	nt Median Ava	ilable (minir	num 4' x 4'	landing)?			Yes	1	No
Geometrics	Curb Ramp	s Available	?					\checkmark	Yes		No
me	A	DA Complia	nt Curb Ramp	Available (w				\checkmark	Yes		No
jeo	Speed:				Posted or 8	85 th percent	ile speed	3	5	mph	
	Roadway Cu	rvature and	d Sight Distand	ces:	Average w	alking speed	l	4.	8	ft/s	
	Is the cross	ing location	n within a hori	zontal or ver	tical curve?				Yes		No
	Equations to	calculate th	e following are	located on the	e next page	_					
	Direction 1:	Stopping S	Sight Distance	(SSD)	246	ft.	provided?	1	Yes		No
	Direction 2:	Stopping S	ight Distance	(SSD)		ft.	provided?		Yes		No
	Direction 1:	Pedestriar	n Sight Distanc	e (PedSD)	1355	ft.	provided?		Yes	1	No
	Direction 2:	Pedestriar	n Sight Distanc	e (PedSD)		ft.	provided?		Yes		No
Traffic and	Measure trai	fic and ped	lestrian volum	e in 15-minu	te incremer	nts on the ro	adway to be	crossed	d		
Pedestrian	Attach Counts	ve	hicles:	Daily	15,000	ped	estrians:		Daily		
Data	AM Peak	Hourly	948	Pk 15-min	262	Hourly	6	Pk 15	5-min	3	3
Data	PM Peak	Hourly	841	Pk 15-min	227	Hourly	6	Pk 15	5-min	3	3
	Lighting:										
	Is street lig	hting prese	nt and does it	light the cro	sswalk loca	tion?		\checkmark	Yes		No
	Crosswalk Pa	avement M	arkings:	Is the pede	estrian cross	sing current	y marked?	1	Yes		No
	What is the		of the marking	-		Excellent	Good 🗸		Fair		Poor
ics			arkings easily					\checkmark	Yes		No
rist		,	eed replaceme						Yes	✓	No
cte		What is th	e crosswalk m	arking patte	rn?		Contin	ental			
ara	Signing:	Currently	signed at cross	walk?				\checkmark	Yes		No
5		Currently	signed in adva		valk?				Yes		No
Site		Distances	?	direction 1	527	ft.	direction 2	47		ft.	
al	Enhancemer	its:	What enhance	ements are o	urrently at	Sign	is and High Vi	sibility	Mark	ings	
tior			the crossing lo								
Additional Site Characteristics	Adjacent Fac		Distance to ne		d crosswalk	?		90)5	ft.	
Ă			rol devices are				Traffic signal				
			t marked cros								
			-way stop, rou		•			90		ft.	
			n serve the sar		+				Yes	\checkmark	No
	Could anot	her locatio	n serve the the	e movement	more effect	tively?			Yes	\checkmark	No

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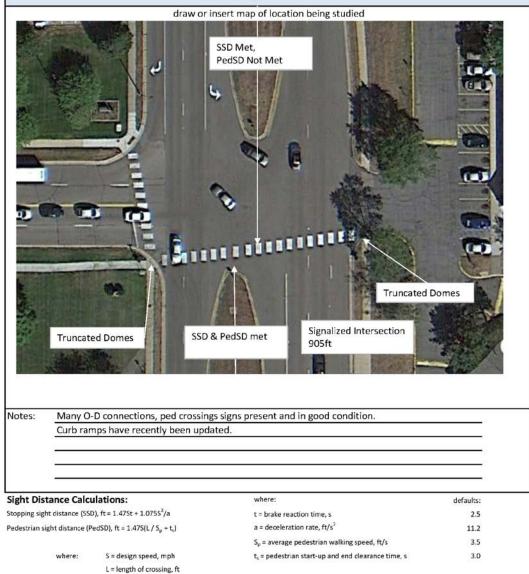
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Uncontrolled Pedestrian Crossing

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 orgins and destinations.



Page 2 of 2

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:

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

$$SSD = 1.47 * 35 * 2.5 + 1.075 \frac{35^2}{11.2} = 246.2 \, ft \approx 246 \, ft$$

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

$$PedSD = 1.47V(\frac{L}{S_p} + t_s)$$

Where:

$$L = \text{length of crossing (ft)}$$

$$S_{p} = \text{average pedestrian walking speed } \left(\frac{\text{ft}}{\text{s}}\right) [DEFAULT = 3.5 \frac{ft}{\text{s}}]$$

$$t_{s} = \text{pedestrian start} - \text{up and clearance time (s) [DEFAULT = 3.0 sec]}$$

$$PedSD = 1.47 * 35 * \left(\frac{112}{4.8} + 3\right) = 1,355 ft$$

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.

<u>HCM Analysis</u> *Determine inputs:*

V = 948 in AM peak hour, 841 in PM peak hour

Evaluation Inputs:	de	faults:	Input	: Table:
L = crosswalk length (ft)			L =	112
S _p = average pedestrian walking speed (ft/s)	S _p =	3.5	S _p =	4.8
t_s = pedestrian start-up and end clearance time (s)	t _s =	3.0	t _s =	3
V = vehicular hourly volume (veh/hr)			V =	948
Peak 15-minute volume (veh)				262
v_p = pedestrian flow rate (ped/s)	v _p =	0*	v _p =	0
W_c = crosswalk width (ft)	W _c =	8.0	$W_c =$	6
N = number of through lanes crossed	N =	INT(L/11)	N =	4

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 <u>NOT</u> 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:

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

$$t_{c,G} = \frac{112}{4.8} + 3.0 = 26.3 \, sec$$

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 lanes

$$v = \frac{V}{PHF} = \frac{948}{\frac{948}{4 * 262}} = 1048 \frac{veh}{hr} = 0.29 \ veh/s$$
$$P_b = 1 - e^{\frac{-26.3(0.29)}{4}} = 0.85$$
$$P_d = 1 - (1 - 0.85)^4 = 1.00$$

Step 4: Calculate Average Delay to Wait for Adequate Gap

$$d_g = \frac{1}{v} (e^{vt_{c,G}} - vt_{c,G} - 1)$$
$$d_{gd} = \frac{d_g}{P_d}$$
$$d_g = \frac{1}{0.29} (e^{0.29(26.3)} - 0.29(26.3) - 1) = 7,118 \text{ sec}$$
$$d_{gd} = \frac{7,118}{1.00} = 7,121 \text{ (rounding error)}$$

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.

$$d_p = \sum_{i=1}^n h(i - 0.5) P(Y_{i}) + [P_d - \sum_{i=1}^n P(Y_i)] * d_{gd}$$
$$h = \frac{N}{v} = \frac{4}{0.29} = 13.8$$
$$n = Int\left(\frac{d_{gd}}{h}\right) = Int\left(\frac{7,118}{13.8}\right) = 516$$

4-Lane Crossing i-1

$$P(Y_{i}) = [P_{d} - \sum_{j=0}^{l-1} P(Y_{j})] \\ * [\frac{P_{b}^{4}M_{y}^{4} + 4P_{b}^{3}(1 - P_{b})M_{y}^{3}) + 6P_{b}^{2}(1 - P_{b})^{2}M_{y}^{2}) + 4P_{b}(1 - P_{b}^{3})M_{y}}{P_{d}}]$$

$$P(Y_{1}) = 0.2679$$

$$P(Y_{2}) = 0.1961$$
...

Plug these into equation above to determine average pedestrian delay.

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

$$44.5 \ sec = LOS \ E$$

Delay is unacceptable, **go to Step 6 of the evaluation flowchart**. There are high visibility markings that are in good condition at the crossing.

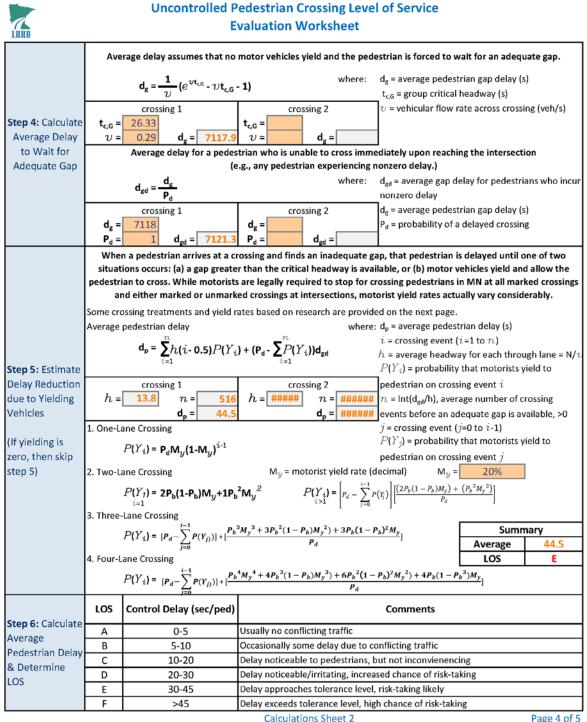


Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

n: Example 3: Four Lane Divided Street Date:
Any City, Minnesota Scenario: AM Peak Hour
Agency:
Is there a median available for a two-stage crossing?
If yes, does the median refuge meet ADA requirements (4' x 4' landing)?
If yes, does the median refuge need to meet ADA requirements (4' x 4' landing)? 🛛 🖓 Yes 🗌 N
Critical headway is the time below which a pedestrian will not attempt to begin crossing the street. Pedestrians us judgement to determine whether the available headway is sufficent for a safe crossing. For a single pedestrian: $t_c = \frac{L}{S_p} + t_s$ $t_c = \frac{L}{S_p} + t_s$ $t_c = \frac{L}{S_p} + t_s$ $t_c = \frac{L}{S_p} + t_s$ $L = \frac{L}{122}$ $L = \frac{112}{S_p} = \frac{1}{4.8}$ $t_c = \frac{2}{26.3}$ $L = \frac{L}{S_p} = \frac{L}{4.8}$ $t_c = \frac{2}{26.3}$ $L = \frac{L}{S_p} = \frac{L}{4.8}$ $L = \frac{L}{4.8}$
encounter a gap greater than or equal to the critical headway immediately upon arrival at the intersection. $P_{b} = 1 - e^{-t_{c,G}v/N}$ $P_{d} = 1 - (1-P_{b})^{N}$ $P_{d} = 1 - (1-P_{b})^{N}$ $rectar = 1 - (1-P_{b})^{N}$

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HCM Evaluation Worksheet



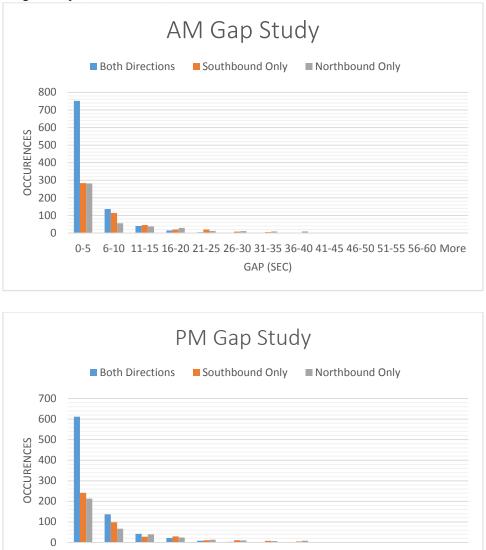
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HCM Evaluation Worksheet

How does this compare to a gap study?

Gap Study (If Available)

0-5



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.

6-10 11-15 16-20 21-25 26-30 31-35 36-40 41-45 46-50 51-55 56-60 More GAP (SEC)

Needed Gap = Crossing Time + Start/End Time =
$$\frac{112}{4.8}$$
 + 3.0 = 26.3 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:

$$\frac{905\,ft}{4.8\frac{ft}{s}} = 189\,sec$$

Wait Time and Crossing Time at Intersection:

Assume average wait time of 30 sec.

$$30 + \frac{125 ft}{4.8 \frac{ft}{s}} = 56 sec$$

Walking Time to Original Location:

$$\frac{905\,ft}{4.8\frac{ft}{s}} = 189\,sec$$

Total Time:

189 + 56 + 189 = 434 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.

<u>School Crossing</u> 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 in AM peak hour, 841 in PM peak hour

Evaluation Inputs:	defaults:	Input Table:	
L = crosswalk length (ft) – east side		L =	52
L = crosswalk length (ft) – west side		L =	25
S _p = average pedestrian walking speed (ft/s)	S _p = 3.5	$S_p =$	4.8
t_s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t _s =	3
V = vehicular hourly volume (veh/hr) – east side		V =	524
V = vehicular hourly volume (veh/hr) – west side		V =	424
Peak 15-minute volume (veh) – east side			150
Peak 15-minute volume (veh) – west side			112
v_p = pedestrian flow rate (ped/s)	v _p = 0*	v _p =	0
W_c = crosswalk width (ft)	W _c = 8.0	$W_c =$	6
N = number of lanes crossed – east side	N = INT(L/11)	N =	2
N = number of lanes crossed – west side	N = INT(L/11)	N =	2

AM Peak Hour

Step 1: Identify Two-Staged Crossings

This is now a two-stage crossing.

Step 2: Determine Critical Headway

Pedestrian Platooning is <u>NOT</u> 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:

$$t_c = t_{c,G} = \frac{L}{S_p} + t_s$$
$$t_{c,G} = \frac{52}{4.8} + 3.0 = 13.8 \text{ sec}$$
$$t_{c,G} = \frac{25}{4.8} + 3.0 = 8.2 \text{ sec}$$

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 lanes

$$v = \frac{V}{PHF} = \frac{524}{\frac{524}{4*150}} = 600 \frac{veh}{hr} = 0.17 \ veh/s$$

$$v = \frac{V}{PHF} = \frac{424}{\frac{424}{4*112}} = 448 \frac{veh}{hr} = 0.12 \ veh/s$$

$$P_b = 1 - e^{\frac{-13.8(0.17)}{2}} = 0.69 \qquad P_b = 1 - e^{\frac{-8.2(0.12)}{2}} = 0.39$$

$$P_d = 1 - (1 - 0.69)^2 = 0.90 \qquad P_d = 1 - (1 - 0.39)^2 = 0.63$$

Step 4: Calculate Average Delay to Wait for Adequate Gap

$$\begin{aligned} d_g &= \frac{1}{v} (e^{vt_{c,G}} - vt_{c,G} - 1) \\ d_{gd} &= \frac{d_g}{P_d} \\ d_g &= \frac{1}{0.17} (e^{0.17(13.8)} - 0.17(13.8) - 1) = 42 \ sec \\ d_g &= \frac{1}{0.12} (e^{0.12(8.2)} - 0.12(8.2) - 1) = 6 \ sec \end{aligned}$$

$$d_{gd} = \frac{42}{0.90} = 46 \sec \qquad d_{gd} = \frac{6}{0.63} = 9 \sec d_{gd}$$

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.

$$d_{p} = \sum_{i=1}^{n} h(i - 0.5)P(Y_{i}) + [P_{d} - \sum_{i=1}^{n} P(Y_{i})] * d_{gd}$$

$$h = \frac{N}{v} = \frac{2}{0.17} = 11.8 \qquad h = \frac{N}{v} = \frac{2}{0.12} = 16.7$$

$$n = Int\left(\frac{d_{gd}}{h}\right) = Int\left(\frac{46}{11.8}\right) = 3 \qquad n = Int\left(\frac{d_{gd}}{h}\right) = Int\left(\frac{9}{16.7}\right) = 0, but must be > 0, = 1$$

2-Lane Crossing - east side

$$P(Y_i) = \left[P_d - \sum_{j=0}^{i-1} P(Y_j) \right] \left[\frac{\left(2P_b(1-P_b)M_y\right) + \left(P_b^2 M_y^2\right)}{P_d} \right]$$
$$P(Y_1) = 0.0864$$
$$P(Y_2) = 0.0781$$
$$P(Y_3) = 0.0707$$

2-Lane Crossing – west side

$$P(Y_i) = \left[P_d - \sum_{j=0}^{i-1} P(Y_j) \right] \left[\frac{(2P_b(1 - P_b)M_y) + (P_b^2 M_y^2)}{P_d} \right]$$
$$P(Y_1) = 0.0852$$

Plug these into equation above to determine average pedestrian delay.

$$d_p = \sum_{i=1}^{3} 11.8(i - 0.5)P(Y_{i}) + [0.90 - \sum_{i=1}^{3} P(Y_i)] * 46 = 35.1 \, sec$$

$$d_p = \sum_{i=1}^{1} 16.7(i - 0.5)P(Y_{i}) + [0.63 - \sum_{i=1}^{1} P(Y_i)] * 9 = 5.7 \text{ sec}$$

$$40.8 \text{ sec} = LOS E$$

PM Peak Hour

Same process as AM Peak Hour:

$$Delay = 23.3 \ sec = LOS \ D$$

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.

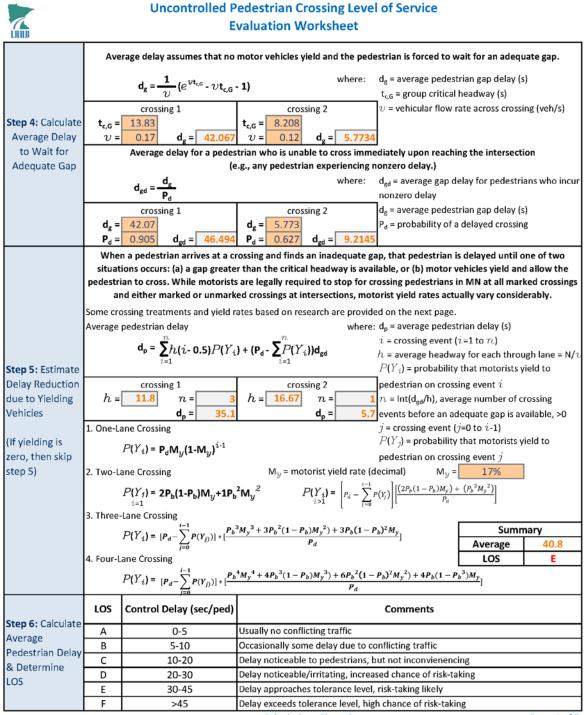
Evaluation Worksheet Crossing Location: Example 3: Four Lane Divided Street Date: City, State: Any City, Minnesota Scenario: AM Peak Hour, Median Reviewer(s): Agency: Step 1: Identify Yes No Is there a median available for a two-stage crossing? 1 \square Two-Stage If yes, does the median refuge meet ADA requirements (4' x 4' landing)? Yes \checkmark No Crossings If yes, does the median refuge need to meet ADA requirements (4' x 4' landing)? $\overline{}$ \Box No Yes Critical headway is the time below which a pedestrian will not attempt to begin crossing the street. Pedestrians use judgement to determine whether the available headway is sufficent for a safe crossing. For a single pedestrian: where: t_c = critical headway for a single pedestrian (s) L = crosswalk length (ft) t_c = -S_p = average pedestrian walking speed (ft/s) t_s = pedestrian start-up and end clearance time (s) crossing 2 crossing 1 S_p = 3.5 ft/s 52 25 L = 1 = t., = t. 4.8 t, = 3 sec 4.8 S_p = t. = 13.8 S = t, = 8.2 If pedestrian platooning is observed, the spatial distribution of pedestrians should be computed: 1. use field observations or estimate platoon size using equation: $N_{c} = \frac{\mathcal{U}_{p}e^{\mathcal{U}_{p}t_{c}} + \mathcal{U}e^{-\mathcal{U}t_{c}}}{(\mathcal{U}_{p} + \mathcal{U})e^{(\mathcal{U}_{p} - \mathcal{U})t_{c}}}$ where: N_c = total number of pedestrians in crossing platoon (ped) v_p = pedestrian flow rate (ped/s) Step 2: v = vehicular flow rate across crossing (veh/s) crossing 1 crossing 2 Determine $t_c = 13.8$ t_c = single pedestrian critical headway (s) t_c = 8.21 $v_p =$ $v_p =$ Critical Headway N_c = N_c = v = 0.17 υ= 0.12 2. compute spatial distribution: $N_p = Int \left[\frac{8.0(N_c-1)}{W_c} \right]$ where: N_p = spatial distributions of pedestrians (ped) N_c = total number of pedestrians in crossing platoon (ped) crossing 2 W_c = crosswalk width (ft) crossing 1 8.0 = default clear width used by a single pedestrian $N_c =$ $N_c =$ W. = to avoid interference with other pedestrians (ft) W. = 6 N_p = 6 N_p = clear width, if other than 8: ft. 3. compute group critical headway: where: t_{c,G} = group critical headway (s) $t_{c,G} = t_c + 2(N_p - 1)$ t_c = single pedestrian critical headway (s) crossing 1 crossing 2 N_p = spatial distributions of pedestrians (ped) N_p = N_p = 8.21 13.8 t_c = t_{c,G} = t_{c,G} = 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. where: P_b = probability of blocked lane $P_b = 1 - e^{-t_{c,G}v/N}$ Step 3: Estimate P_d = probability of delayed crossing Probability of a N = number of lanes crossed $P_{d} = 1 - (1 - P_{b})^{N}$ Delayed $t_{c,G}$ = group critical headway (s) = $t_{c,i}$ if no platooning Crossing crossing 1 crossing 2 v = vehicular flow rate across crossing(veh/s) 13.8 8.21 t_{c,G} = t_{c,G} = 0.17 0.69 0.12 0.39 v = P_b = υ= P_b = P_d = 0.9 0.6 P_d = N = N =

Uncontrolled Pedestrian Crossing Level of Service

Calculations Sheet 1

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Calculations Sheet 2

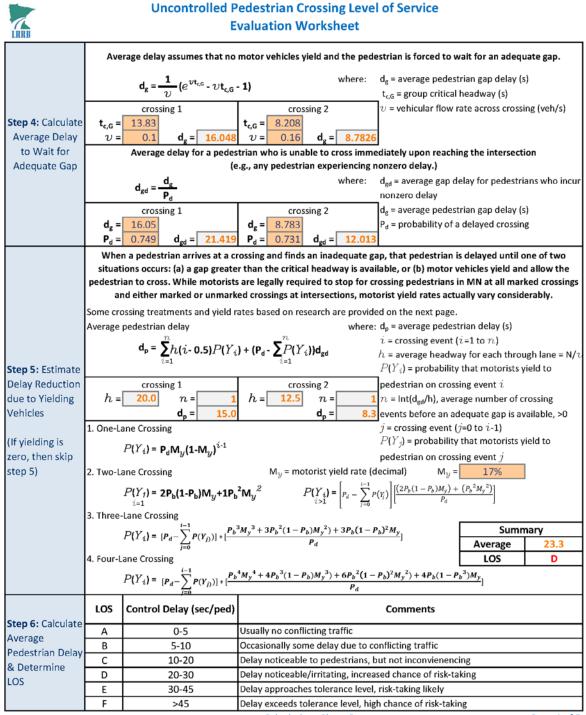
Developed by Bolton Menk, Inc. for the Local Road Research Board HCM Evaluation Worksheet

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HCM Evaluation Worksheet



Calculations Sheet 2

Page 4 of 5

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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										
LRRB			Da	ta Collect	ion work	sneet					
Location:	Example 4	Example 4: Four Lane Undivided Urban Street Date:									
City, State:		Scenario:									
Reviewer(s):					Agency:						
Project #:					ID #:						
	The first step	o in underst	tanding the pe	edestrian nee	ds at a pote	ential crossi	ng location is	comple	eting		
			a review of	the location	and adjacer	nt facilities.					
	Crossing Len	gth: Measu	re the crossin	g distance fro	om curb to	curb.	Crossing 1	6	0	ft.	
	Fill in Crossin	g 1 distance	e if there is no	median. If th	nere is a me	edian at the	Crossing 2			ft.	
	crossing loca	tion, fill in O	Crossing 1 and	2 distances.							
	Median: wid	th of media	n at crossing l	ocation						ft.	
	Crossing Wid	lth: effectiv	e crosswalk w	/idth				8	3	ft.	
	Raised Med	lian Availab	le?						Yes	' 🗸	No
	A	DA Complia	nt Median Ava	ailable (minin	num 4' x 4'	landing)?			Yes	\checkmark	No
ric	Curb Ramp	s Available?	>						Yes	\checkmark	No
net	A	OA Complia	nt Curb Ramp	Available (w	idth, grades	, truncated	domes)?		Yes	Image: A start of the start	No
Geometrics	Speed:					85 th percent		3	0	mph	
Ű	Roadway Curvature and Sight Distances:			ces:	Average walking speed			5.	.7	ft/s	
			-		-			I	Yes	'п	No
		Is the crossing location within a horizontal or vertical curve? Yes No Equations to calculate the following are located on the next page									
			ight Distance		197	ft.	provided?	5	Yes		No
			ight Distance			ft.	provided?		Yes	П	No
			Sight Distanc	. ,	597	ft.	provided?		Yes		No
			Sight Distance			ft.	provided?		Yes		No
			estrian volum	, ,	te incremer			crosser			110
Traffic and	Attach Counts	•	nicles:	Daily			estrians:		Daily		
Pedestrian	AM Peak	Hourly	1,183	Pk 15-min	329	Hourly			5-min	1	1
Data	PM Peak	Hourly	1,111	Pk 15-min	294	Hourly	43	-	5-min	1	
	Lighting:		_,		201	nearry	10	1.1.20		_	
		hting prese	nt and does it	light the cro	sswalk locat	tion?		~	Yes		No
	Crosswalk Pa	•		•		sing current	v marked?		Yes		No
			of the marking		Г.	Excellent	Good Good		Fair		Poor
Ś	vinacio ene		arkings easily	-					Yes	П	No
stic			ed replaceme						Yes		No
eri			e crosswalk m		m?				105		140
ract	Signing:		igned at cros	0.					Yes		No
hai	Signing.		signed in adva		valk?				Yes		No
te C		Distances?	-	direction 1		ft.	direction 2			ft.	140
l Sit	Enhancemen		What enhanc		urrently at	10.	direction 2			10.	
na	Linancemen		the crossing lo		unenuy ac						
Additional Site Characteristics	Adjacent Fac		Distance to ne		d crosswalk	2		22	0	ft.	
Add	-		ol devices are				Traffic Signal		-0	11.	
			t marked cros				Tranic Signal				
			-way stop, roi		ignalized in	terrection		22	0	ft.	
			serve the sai		-				Yes	П	No
					+						
	could anot	Could another location serve the the movement more effectively? Ves Ves No									

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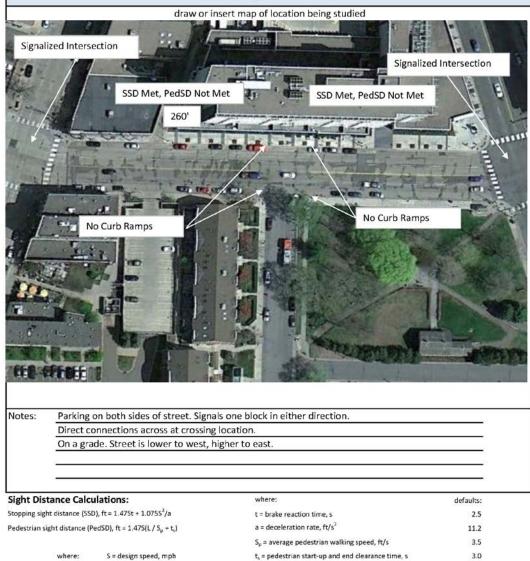
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Uncontrolled Pedestrian Crossing

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 orgins and destinations.



Page 2 of 2

L = length of crossing, ft

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 sec] $a = deceleration rate (\frac{ft}{s^2}) [DEFAULT = 11.2 \frac{ft}{s^2}]$

$$SSD = 1.47 * 30 * 2.5 + 1.075 \frac{30^2}{11.2} = 196.6 \, ft \approx 197 \, ft$$

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

$$PedSD = 1.47V(\frac{L}{S_p} + t_s)$$

Where:

$$L = \text{length of crossing (ft)}$$

$$S_{p} = \text{average pedestrian walking speed } \left(\frac{\text{ft}}{s}\right) [DEFAULT = 3.5 \frac{ft}{s}]$$

$$t_{s} = \text{pedestrian start} - \text{up and clearance time (s) [DEFAULT = 3.0 sec]}$$

$$PedSD = 1.47 * 30 * \left(\frac{60}{5.7} + 3.0\right) = 597 \, ft$$

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.

<u>HCM Analysis</u> *Determine inputs:*

V = 1,183 in AM peak hour and 1,111 in PM peak hour

Evaluation Inputs:	de	faults:	Input	: Table:
L = crosswalk length (ft)			L =	60
S _p = average pedestrian walking speed (ft/s)	S _p =	3.5	S _p =	5.7
t_s = pedestrian start-up and end clearance time (s)	t _s =	3.0	t _s =	3
V = vehicular hourly volume (veh/hr)			V =	1,183
Peak 15-minute volume (veh)				329
v_p = pedestrian flow rate (ped/s)	v _p =	0*	v _p =	0
W_c = crosswalk width (ft)	W _c =	8.0	$W_c =$	8
N = number of through lanes crossed	N =	INT(L/11)	N =	4

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:

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

$$t_c = \frac{60}{5.7} + 3 = 13.5 \, sec$$

Pedestrian Platooning is observed, so the spatial distribution of pedestrians should be computed:

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

$$N_{c} = \frac{v_{p}e^{v_{pt_{c}}} + ve^{-vt_{c}}}{(v_{p} + v)e^{(v_{p} - v)t_{c}}}$$

$$v_p = \frac{V_p}{PHF} = \frac{34}{\frac{34}{4*11}} = 44\frac{ped}{hr} = 0.01 \ ped/s$$

$$v = \frac{V}{PHF} = \frac{1183}{\frac{1183}{4*329}} = 1316 \ veh/hr = 0.37 \ veh/s$$

$$N_c = \frac{(0.01)e^{(0.012)(13.5)} + (0.37)e^{-(0.37)(13.5)}}{(0.01+0.37)e^{(0.01-0.37)(13.5)}} = 4.77 \ peds$$

2. Compute Spatial Distribution:

$$N_p = Int \frac{8.0(N_c - 1)}{W_c} + 1$$

$$\label{eq:Nc} \begin{split} N_c &= 5.32 \text{ peds (from above)} \\ W_c &= No \text{ crosswalk width} - \text{ so use 8ft} \end{split}$$

$$N_p = Int\left[\frac{8.0(5.32-1)}{8}\right] + 1 = 4 \ peds$$

3. Compute Group Critical Headway:

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

 $\label{eq:tc} \begin{array}{l} t_c = 18.6 \mbox{ s} \\ N_p = 29 \mbox{ peds (from above)} \end{array}$

$$t_{c.G} = 13.5 + 2(4 - 1) = 19.5 \, sec$$

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 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

$$d_g = \frac{1}{v} (e^{vt_{c,G}} - vt_{c,G} - 1)$$
$$d_{gd} = \frac{d_g}{P_d}$$
$$d_g = \frac{1}{0.37} (e^{0.37(19.5)} - 0.37(19.5) - 1) = 3,689$$

$$d_{gd} = \frac{3,689}{0.9993} = 3,691 \, sec$$

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 ($M_y=0$). Therefore, there is no reduction in delay due to yielding vehicles, and the average pedestrian delay is the same as in step 4.

$$d_p = d_{qd} = 3,691 \, sec = LOS \, F$$

PM Peak Hour

Same process as AM Peak Hour:

$$Delay = 1,886 sec = LOS F$$

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.

<u>Review Origins and Destinations, Alternate Routes</u> 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:

$$\frac{220 ft}{5.7 \frac{ft}{s}} = 39 sec$$

Wait Time and Crossing Time at Intersection:

Assume average wait time of 30 sec.

$$30 + \frac{65 ft}{5.7 \frac{ft}{s}} = 41 sec$$

Walking Time to Original Location:

$$\frac{220 ft}{5.69 \frac{ft}{s}} = 39 sec$$

Total Time:

$$39 + 41 + 39 = 119 sec$$

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.



LRRB	
Crossing Location	
City, State:	Scenario: AM Peak Hour
Reviewer(s):	Agency:
Step 1: Identify	Is there a median available for a two-stage crossing?
Two-Stage	If yes, does the median refuge meet ADA requirements (4' x 4' landing)?
Crossings	If yes, does the median refuge need to meet ADA requirements (4' x 4' landing)?
Step 2: Determine Critical Headway	Critical headway is the time below which a pedestrian will not attempt to begin crossing the street. Pedestrian use judgement to determine whether the available headway is sufficent for a safe crossing. For a single pedestrian: $t_{c} = \frac{L}{S_{p}} + t_{s}$ where: $t_{c} = critical headway for a single pedestrian (s)$ $t_{c} = \frac{L}{S_{p}} + t_{s}$ where: $t_{c} = critical headway for a single pedestrian (s)$ $t_{c} = \frac{L}{S_{p}} + t_{s}$ where: $t_{c} = critical headway for a single pedestrian (s)$ $t_{c} = pedestrian making speed (ft/s)$ $t_{c} = pedestrian start-up and end clearance time (s)$ $S_{p} = 3.5 ft/s$ $t_{s} = 3 sec$ If pedestrian platooning is observed, the spatial distribution of pedestrians should be computed: 1. use field observations or estimate platoon size using equation: $N_{c} = \frac{U_{p}e^{U_{p}t_{c}} + Ue^{-Ut_{c}}}{(U_{p} + U)e^{(U_{p}-U)t_{c}}}$ where: $N_{c} = total number of pedestrians in crossing platoon (ped)$ $U_{p} = \frac{0.01}{0.37}$ $N_{c} = \frac{13.5}{4.77}$ $U_{p} = \frac{U_{c}}{U_{p}} + \frac{13.5}{U_{p}}$ $U_{p} = \frac{Crossing 1}{U_{p} + U_{c}}$ where: $N_{p} = spatial distributions of pedestrians (ped)$ $N_{p} = Int\left[\frac{8.0(N_{c}-1)}{W_{c}}\right] + 1$ where: $N_{p} = spatial distributions of pedestrians (ped)$ $N_{c} = crossing 1$ $V_{c} = \frac{4.77}{8}$ $N_{p} = 4$ $V_{c} = N_{p} = \frac{1}{4.35}$ $V_{c} = \frac{1}{4.25}$ $V_{c} = \frac{1}{4.35}$ $V_{c} = \frac{1}{4.25}$ $V_{c} = \frac{1}{4.35}$ $V_{c} = \frac{1}{4.35}$ $V_{c} = \frac{1}{4.25}$ $V_{c} = \frac{1}{4.25}$ $V_{c} = \frac{1}{4.35}$ $V_{c} = \frac{1}{4.25}$ $V_{c} = \frac{1}{4.25}$ $V_{c} = \frac{1}{4.25}$ $V_{c} = \frac{1}{4.25}$ $V_{c} = \frac{1}{4.25$
	encounter a gap greater than or equal to the critical headway immediately upon arrival at the intersection.
	$P_b = 1 - e^{-t_{c,c}v/N}$ where: $P_b = probability of blocked lane$
Step 3: Estimate	P_d = probability of delayed crossing
Probability of a	$P_d = 1 - (1 - P_b)^N$ N = number of lanes crossed
Delayed	$t_{c,G} = \text{group critical headway (s)} = t_{c,I} \text{ in no platooning}$
Crossing	crossing 1crossing 2 v = vehicular flow rate across crossing(veh/s) $t_{c,G}$ = 19.5 $t_{c,G}$ = 19.5 $t_{c,G}$ = 19.5 v = 0.37 P_b = 0.84 v = 0.84 v = 0.37 P_b = 0.84 v = 0.84 N = 4 P_d = 1 N = 0.84
	N = 4 P _d = 1 N = P _d = 2 Calculations Sheet 1 Page 3 of 1

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HCM Evaluation Worksheet



	Ave	rage delay assumes that n	o motor vehicles yield a	nd the ped	estrian is forced to w	ait for an adequ	uate gap.	
		1 , vt.		where:	d _g = average pedest	rian gap delay (s	;)	
		$d_{g} = \frac{1}{\upsilon} (e^{\upsilon t_{c,G}} - \upsilon t_{c,G})$	3 - 1)		$t_{c,G}$ = group critical headway (s)			
		crossing 1	crossing 2		v = vehicular flow ra	ate across crossi	ng (veh/s)	
Step 4: Calculate	0,0	19.53	$t_{c,G} =$ 5 $v =$ d_g		_			
Average Delay	v =	0.37 d _g = 3688.						
to Wait for Adequate Gap		Average delay for a pede	estrian who is unable to (e.g., any pedestrian ex		, ,	ng the intersect	on	
Adequate Gap			(e.g., any pedesthan ex	where:	d _{gd} = average gap de	elav for nedestri	ans who incur	
		$d_{gd} = \frac{d_g}{P_d}$		merer	nonzero delay	city for pedestri		
		crossing 1	crossing 2		d _g = average pedest	rian gap delay (s	;)	
	d _g =	3689	$d_g = $ $P_d = $ d_{gd}		P _d = probability of a	delayed crossin	g	
	P _d =	0.999 d _{gd} = 3691.	$P_d = d_{gd}$	=				
		n a pedestrian arrives at a	-					
		ions occurs: (a) a gap great			, ,,			
	•	an to cross. While motoris nd either marked or unma	• • •	•	•••		-	
						any vary consid	ciably.	
	Some crossing treatments and yield rates based on research are provided on the next page. Average pedestrian delay $metric d_p$ = average pedestrian delay (s) i = crossing event (i=1 to n)							
	$\mathbf{d}_{\mathbf{p}} = \sum_{i=1}^{n} h(i - 0.5) P(Y_i) + (\mathbf{P}_{d} - \sum_{i=1}^{n} (Y_i)) \mathbf{d}_{gd} \qquad \qquad \begin{array}{l} i = \text{crossing event } (i = 1 \text{ to } n) \\ h = \text{average headway for each through lane} = N/n \end{array}$							
Step 5: Estimate	$P(Y_i)$ = probability that motorists yield to							
Delay Reduction		crossing 1	crossing 2		pedestrian on crossi	ing event i		
due to Yielding	<i>h</i> =	h = $n = $ $h = $ $n =$					-	
Vehicles		d _p =	d _p	=	events before an ad		/ailable, >0	
(If yielding is		ane Crossing			$j = \text{crossing event } (j = P(Y_j) = \text{probability})$		ield to	
zero, then skip		$P(Y_i) = P_d M_y (1-M_y)^{i-1}$			pedestrian on crossi			
step 5)	2. Two-La	ane Crossing	M _y = motorist	yield rate (
		$P(Y_1) = 2P_b(1-P_b)M_y + 1$	0			$(P_b^2 M_y^2)$]		
		<i>i=1 i=1 i=1</i>	$r_{b} w_{y} $ $r_{i>1}$	$-\left[P_d - \sum_{j=0}^{p_d}\right]$	$P(Y_j) = P_d$			
		Lane Crossing						
		$P(Y_i) = [P_d - \sum_{i=0}^{t-1} P(Y_{i})] * [-1]$	$P_b^{3}M_y^{3} + 3P_b^{2}(1-P_b)M_y^{2}$	$+3P_{b}(1-$	$P_b)^2 M_y$	Sumn		
		j=₀ ane Crossing	r a			Average LOS	3691.2 F	
		0	$A^{4}M^{4} + AB^{3}(1 - B)M^{3}$	$+6P_{1}^{2}(1 -$	$(1 - P_1)^2 M^2 + AP_1 (1 - P_2)$			
		$P(Y_i) = [P_d - \sum_{i=0}^{i-1} P(Y_i)] * [\frac{1}{2}]$	p my + H b (1 - Fb)My	P_d	r_{b} my $r_{rb}(1-r_{b})$]		
	LOS	Control Delay (sec/ped			Comments			
Step 6: Calculate	103	control belay (sec/ped			comments			
Average	Α	0-5	Usually no conflicting					
Pedestrian Delay	B	5-10	Occasionally some de		-	·		
& Determine	C	10-20		,	but not inconvienenci	0		
LOS	D E	20-30 30-45	Delay noticeable/irrit		ased chance of risk-tal	king		
	F	>45			gh chance of risk-taking)ø		
	r	245	Calculations S		prioritance of HSK-tdKII	'ъ	Page 4 of 5	

Calculations Sheet 2

Page 4 of 5

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Crossing Location: City, State: Reviewer(s): Step 1: Identify Two-Stage Crossings	For a single pedestrian: $t_{c} = \frac{L}{S_{p}} + t_{s}$	Scenario: Agency: ng? A requirements (4' x 4' landing)? meet ADA requirements (4' x 4' land estrian will not attempt to begin cro the available headway is sufficent where: t _c = critical headwa L = crosswalk lengt S _p = average pedes	ossing the street. Pedestrians use for a safe crossing. ay for a single pedestrian (s)
Reviewer(s): Step 1: Identify Two-Stage	If yes, does the median refuge meet AD If yes, does the median refuge need to a Critical headway is the time below which a peder judgement to determine whether For a single pedestrian: $t_c = \frac{L}{S_p} + t_s$ $L = \underbrace{60}_{crossing 1} t_s = \underbrace{3}_{crossing 2} L = \underbrace{1}_{crossing 3} t_s$	Agency: ng? A requirements (4' x 4' landing)? meet ADA requirements (4' x 4' land estrian will not attempt to begin cro • the available headway is sufficent where: t_c = critical headwa L = crosswalk lengtl S_p = average pedes sing 2 t_s = pedestrian star	Yes N Yes N Yes N Yes N Yes N N Sossing the street. Pedestrians use for a safe crossing. ay for a single pedestrian (s) h (ft) trian walking speed (ft/s)
Step 1: Identify Two-Stage	If yes, does the median refuge meet AD If yes, does the median refuge need to a Critical headway is the time below which a peder judgement to determine whether For a single pedestrian: $t_c = \frac{L}{S_p} + t_s$ $L = \underbrace{60}_{crossing 1} t_s = \underbrace{3}_{crossing 2} L = \underbrace{1}_{crossing 3} t_s$	hg? A requirements (4' x 4' landing)? meet ADA requirements (4' x 4' land estrian will not attempt to begin cro- the available headway is sufficent where: t_c = critical headwa L = crosswalk lengtl S _p = average pedes sing 2 t_s = pedestrian star	Yes N Nossing the street. Pedestrians use for a safe crossing. ay for a single pedestrian (s) h (ft) trian walking speed (ft/s)
Two-Stage	If yes, does the median refuge meet AD If yes, does the median refuge need to a Critical headway is the time below which a peder judgement to determine whether For a single pedestrian: $t_c = \frac{L}{S_p} + t_s$ $L = \underbrace{60}_{crossing 1} t_s = \underbrace{3}_{crossing 2} L = \underbrace{1}_{crossing 3} t_s$	A requirements (4' x 4' landing)? meet ADA requirements (4' x 4' land estrian will not attempt to begin cro- the available headway is sufficent where: t_c = critical headwa L = crosswalk lengtl S _p = average pedes: sing 2 t_c = pedestrian star	Yes N Nossing the street. Pedestrians use for a safe crossing. ay for a single pedestrian (s) h (ft) trian walking speed (ft/s)
-	If yes, does the median refuge need to the formation of	meet ADA requirements (4' x 4' land estrian will not attempt to begin cro- the available headway is sufficent where: t_c = critical headwa L = crosswalk lengtl S _p = average pedes sing 2 t_s = pedestrian star	ing)? Yes N possing the street. Pedestrians use for a safe crossing. ay for a single pedestrian (s) h (ft) trian walking speed (ft/s)
Crossings	Critical headway is the time below which a pede judgement to determine whether For a single pedestrian: $t_{c} = \frac{L}{S_{p}} + t_{s}$ $L = \underbrace{60}_{crossing 1} t_{s} = \underbrace{3}_{cross} L = \underbrace{1}_{crossing 1} t_{s}$	estrian will not attempt to begin cro the available headway is sufficent where: t_c = critical headwa L = crosswalk lengt S_p = average pedes sing 2 t_s = pedestrian star	ssing the street. Pedestrians use for a safe crossing. ay for a single pedestrian (s) h (ft) trian walking speed (ft/s)
	judgement to determine whether For a single pedestrian: $t_{c} = \frac{L}{S_{p}} + t_{s}$ $L = \underbrace{60}_{crossing 1} t_{s} = \underbrace{3}_{cross} L = \underbrace{1}_{crossing 1} t_{s}$	the available headway is sufficent where: $t_c = critical headwaL = crosswalk lengtlSp = average pedessing 2 t_s = pedestrian star$	for a safe crossing. ay for a single pedestrian (s) h (ft) trian walking speed (ft/s)
Step 2: Determine Critical Headway	If pedestrian platooning is observed, the spatial d 1. use field observations or estimate platoon size $N_{c} = \frac{\upsilon_{p} e^{\upsilon_{p} t_{c}} + \upsilon e^{-\upsilon t_{c}}}{(\upsilon_{p} + \upsilon) e^{(\upsilon_{p} \cdot \upsilon) t_{c}}}$ $\boxed{\begin{array}{c} & \\ \upsilon_{p} = & 0.02 \\ \upsilon = & 0.33 \end{array}}_{N_{c}} = \underbrace{\begin{array}{c} 13.5 \\ \upsilon = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} \upsilon_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} = \underbrace{\begin{array}{c} 13.5 \\ \upsilon = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} \upsilon_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.33 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.3 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.3 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \\ \upsilon = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_{p} = & 0.2 \end{array}}_{V_{c}} \underbrace{\begin{array}{c} u_$	$\mathbf{t_c} = \mathbf{t_s} = 3 \text{ sec}$ istribution of pedestrians should be using equation: where: N _c = total number of (ped) v_p = pedestrian flow v_p = pedestrian flow v_p = pedestrian flow v_c = single pedestri N _c = v_c = single pedestri N _c = total number of (ped) where: N _p = spatial distrib N _c = total number of (ped) w_c = crosswalk wid 8.0 = default clear width, if ot where: t _{c,6} = group critical t _c = single pedestri N _p = v_c = single pedestri	of pedestrians in crossing platoor w rate (ped/s) rate across crossing (veh/s) an critical headway (s) utions of pedestrians (ped) of pedestrians in crossing platoor th (ft) width used by a single pedestrian ce with other pedestrians (ft) ther than 8: ft. headway (s) an critical headway (s) utions of pedestrians (ped)
Step 3: Estimate Probability of a	encounter a gap greater than or equal to th $P_b = 1 - e^{-t_c c^2/N}$	e critical headway immediately upo where: P _b = probability of B P _d = probability of o N = number of lane	blocked lane delayed crossing
Delayed	$\mathbf{P}_{d} = 1 - (1 - \mathbf{P}_{b})^{N}$	t _{c,G} = group critical	headway (s) = t _c , if no platooning
Crossing	$\begin{array}{c c} crossing 1 & cross\\ t_{c,6} = & 19.5 & \\ \upsilon = & 0.33 & P_b = & 0.8 & \\ N = & 4 & P_d = & 1 & N = \end{array}$		rate across crossing(veh/s)

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	Ave	rage delay assumes that no	motor vehicles yie	ld and	the pede	estrian is forced to w	ait for an adequ	iate gap.
		1 - 1		v	where:	d _g = average pedesti	rian gap delay (s)
		$d_{g} = \frac{1}{\upsilon} (e^{\upsilon t_{c,G}} - \upsilon t_{c,G})$	- 1)			$t_{c,G}$ = group critical h	neadway (s)	
		crossing 1	crossi	ng 2		v = vehicular flow ra	ate across crossi	ng (veh/s)
Step 4: Calculate	t _{c,G} =		t _{c,G} =	_				
Average Delay	υ=	0.33 d _g = 1882.7		d _g =				
to Wait for		Average delay for a pede					ng the intersecti	on
Adequate Gap		. (e.g., any pedestriar	-	-			
		$d_{gd} = \frac{d_g}{P_d}$		v	where:	d _{gd} = average gap de nonzero delay	elay for pedestria	ans who incur
		rossing 1	crossi	0.9.2		d _g = average pedesti	rian gan delay (s	`
	d _e =		d =	ng z		$P_d = probability of a$		
	•	0.998 d _{ed} = 1885.7	$d_g =$ $P_d =$	d _{gd} =				Þ
	, v				equate ga	l an, that nedestrian is	delaved until o	ne of two
	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							
		an to cross. While motorist			-		-	
	ar	nd either marked or unmar	ed crossings at int	ersecti	ons, mot	orist yield rates actu	ally vary conside	erably.
	Some crossing treatments and yield rates based on research are provided on the next page. Average pedestrian delay $\mathbf{d}_{\mathbf{P}} = \sum_{i=1}^{n} h(i - 0.5) P(Y_i) + (\mathbf{P}_d - \sum_{i=1}^{n} (Y_i)) \mathbf{d}_{\mathbf{g}}$ $i = \text{crossing event } (i = 1 \text{ to } n.)$ $h = \text{average headway for each through lane}$							
		2=1 2=1						
Step 5: Estimate	$P(Y_i)$ = probability that motorists yield to							
Delay Reduction	crossing 1crossing 2pedestrian on crossing event i $h =$ $n =$							
due to Yielding Vehicles	11 -		///-	$d_p =$		events before an ad-		
venicies	1. One-La	ane Crossing		u _p -		j = crossing event (j		allable, 20
(If yielding is		5				$P(Y_j) = \text{probability}$		ield to
zero, then skip		$P(Y_i) = P_d M_y (1-M_y)^{i-1}$				pedestrian on crossi	ng event j	
step 5)	2. Two-L	ane Crossing	$M_y = moto$	rist yie	ld rate (d	ecimal) M ₃ =		
		$P(Y_1) = 2P_b(1-P_b)M_y + 1P_{i=1}$	2 _M 2 P	$(Y_{\lambda}) = $	$\begin{bmatrix} i & -1 \\ \sum n \end{bmatrix}$	(m) $[(2P_b(1-P_b)M_y) +$	$(P_b^2 M_y^2)$]	
		<i>i=1 i=1</i>		i>1	$P_d = \sum_{j=0}^{p} P_j$	(Y_j)]	
		Lane Crossing				,		
		$P(Y_i) = [P_d - \sum_{i=0}^{t-1} P(Y_i)] * [\frac{P_i}{2}]$	${}^{3}M_{y}{}^{3} + 3P_{b}{}^{2}(1-P_{b})$	$M_{y}^{2}) +$	$3P_{b}(1-P_{b})$	$(b)^2 M_y$]	Summ	
		7=0	,	ď			Average	1885.7
		ane Crossing	4		74		LOS	F
		$P(Y_i) = [P_d - \sum_{i=0}^{i-1} P(Y_i)] * [\frac{P_i}{2}]$	$h_{y}^{-M_{y}} + 4P_{b}^{-}(1-P_{b})$	$(M_y^\circ) +$	$\frac{6P_b^{-}(1-P_d)}{P_d}$	$P_b J^2 M_y^2 + 4P_b (1 - P_b)^2$	$\frac{(y^{y})M_{y}}{[}$	
					- a			
	LOS	Control Delay (sec/ped)				Comments		
Step 6: Calculate	Α	0-5	Usually no conflict	ting tra	ffic			
Average Pedestrian Delay	В	5-10	Occasionally some	e delay	due to co	onflicting traffic		
& Determine	С	10-20	Delay noticeable t	o pede	strians, b	ut not inconvienenci	ng	
LOS	D	20-30	Delay noticeable/	irritatin	increa	sed chance of risk-tal	king	
200	E	30-45	Delay approaches			<u> </u>		
	F	>45				h chance of risk-takin	g	
			Calculation	s Shoe	at 7			Page 4 of 5

Calculations Sheet 2

Page 4 of 5

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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.

Complete Field Review Worksheet.

				ntrolled P							
LRRB		Data Collection Worksheet									
Location:	Example	Example 5: Four Lane Undivided Highway Date:									
City, State:	Scenario: Noon Weekday						iy Evalu	ation			
Reviewer(s):		Agency:									
Project #:		ID #:									
	The first ste	p in unders	tanding the pe				ng location is	comple	ting		
				the location	-						
	-	-	ire the crossin	0			Crossing 1	52		ft.	
		-	e if there is no			edian at the	Crossing 2	65	5	ft.	
			Crossing 1 and								
			an at crossing					10		ft.	
	-		e crosswalk w	vidth				8		ft.	
	Raised Med							1	Yes		No
S			nt Median Av	ailable (minir	num 4' x 4'	landing)?			Yes	\checkmark	No
etric	Curb Ramp							\checkmark	Yes		No
ů.		DA Complia	nt Curb Ramp	Available (w					Yes	\checkmark	No
Geometrics	Speed:					85 th percent		45		mph	
Ŭ	Roadway Curvature and Sight Distances:				Average walking speed			5.6		ft/s	
		-	n within a hori			•			Yes		No
	Equations to calculate the following are located on the next page										
	Direction 1:	Stopping S	Sight Distance	(SSD)	360	-	provided?	1	Yes		No
	Direction 2:	Stopping S	Sight Distance	(SSD)	360	ft.	provided?	1	Yes		No
			n Sight Distand	. ,	813	ft.	provided?	\checkmark	Yes		No
			n Sight Distand		966	ft.	provided?	1	Yes		No
Traffic and			lestrian volum	e in 15-minu				crossed	ι.		
Pedestrian	Attach Counts		hicles:	Daily			estrians:		Daily		
Data	AM Peak	Hourly		Pk 15-min		Hourly		Pk 15			
	PM Peak	Hourly	698	Pk 15-min	237	Hourly	2	Pk 15	-min	2	2
	Lighting:							_		_	
		•	nt and does it	•				1	Yes		No
	Crosswalk Pa		•		estrian cros	sing currentl			Yes		No
	What is the		of the marking	-	L	Excellent	Good		Fair		Poor
tics			arkings easily						Yes		No
erist		,	eed replaceme		-				Yes		No
acte		What is the crosswalk marking pattern?									
lard	Signing:		signed at cros						Yes		No
5			signed in adva		valk?	1.			Yes	I	No
Site		Distances		direction 1		ft.	direction 2			ft.	
Jal	Enhancemen	nts:	What enhanc		urrently at		Traffic	Signal			
Additional Site Characteristics			the crossing l								
ddi	Adjacent Fac		Distance to no		d crosswall	(?		1,00	00	ft.	
A			rol devices are								
		•	nt marked cros					4.0	20	<u>.</u>	
			-way stop, ro		-			1,00		ft.	
			n serve the sa						Yes		No
	Could anot	Could another location serve the the movement more effectively? <u>Yes</u> <u>Yes</u> <u>Yes</u>									

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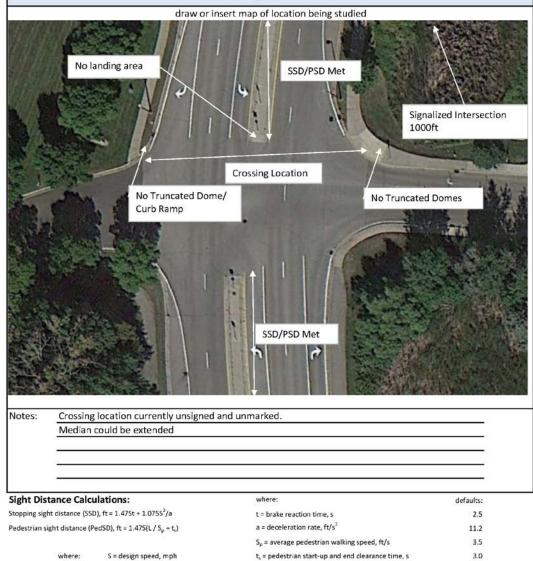
Page 1 of 2



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 lighting units, curb ramps, truncated domes, presence of any other crosswalks or crossing locations parallel to and nearby the location being studied, adjacent intersection traffic control, parking, intersection width, lane lengths, shoulder widths, sign placement, and nearby orgins and destinations.



where: S = design speed, mph L = length of crossing, ft

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

$$SSD = 360 ft$$
$$PedSD_{Total} = 1,700 ft$$

The SSD is met for this crossing, but PedSD is not.

HCM Analysis

Midday Peak Hour

Yield Rate = 0% (Unmarked Crossing) Delay = $3,026 \ sec = LOS \ F$

Result: Unacceptable Service Level, go to Step 6 of the Evaluation Flowchart.

<u>Review Origins and Destinations, Alternate Routes</u> 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.

Total Time = 601 sec

Average Measured Wait Time (Pedestrian Delay)

3,026 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.

<u>Speed and Pedestrian Use</u> 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.

<u>School Crossing</u> 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.

 $PedSD_{SB} = 813 ft$ $PedSD_{NB} = 966 ft$ Delay = 238 sec = LOS F

<u>Result</u> 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:

Evaluation Inputs:	defaults:	Input Table:				
L = crosswalk length (ft)		L =	127			
S _p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p =	5.6			
t _s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t, =	3			
V = vehicular hourly volume (veh/hr)		V =	698			
$\upsilon_{ m p}$ = pedestrian flow rate (ped/s)	υ _p = 0*	$v_{p} =$	0.00			
v = vehicular flow rate (veh/s) = V/3600	υ = V/3600	U =	0.26			
$W_c = crosswalk width (ft)$	W _c = 8.0	$W_c =$	8.0			
N = number of lanes crossed (Integer)	N = INT(L/11)	N =	4			
*no platooning observed						
Crossing 2: (only used for two-stage crossings)						

crossing z.	(only used for two-stage crossings)					
Evaluation Inputs:	defaults:	Input Table:				
L = crosswalk length (ft)		L=				
S _p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p =				
t_s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t _s =				
V = vehicular hourly volume (veh/hr)		V =				
$\upsilon_{ m p}$ = pedestrian flow rate (ped/s)	υ _p = 0*	U _p =				
υ = vehicular flow rate (veh/s) = V/3600	υ = V/3600	U =				
W_c = crosswalk width (ft)	W _c = 8.0	W _c =				
N = number of lanes crossed (Integer)	N = INT(L/11)	N =				
	; observed					
Crossing Treatment Yield Rate		Input Table:				
M_{y} = motorist yield rate (decimal)		M _y =				

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

Results:

Average Delay	3026.1		
LOS	F		

Inputs and Results

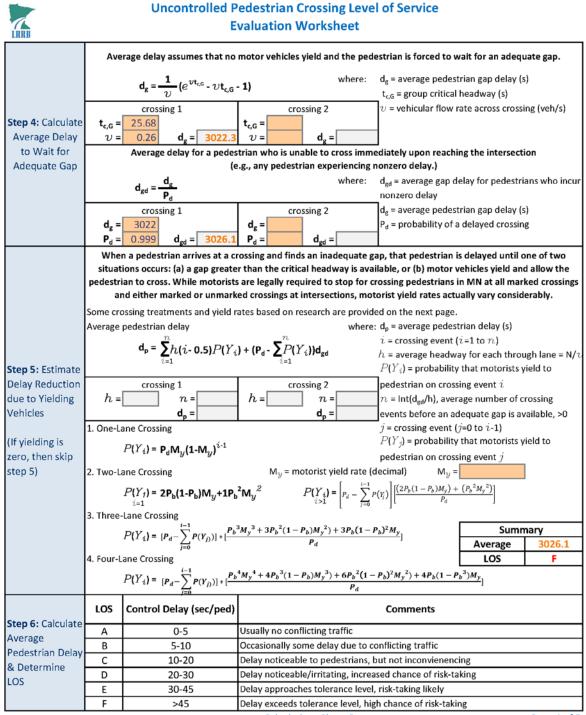
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LRRB	
Crossing Location	
City, State:	Scenario: Noon Peak Hour, Weekday
. ,	
-	
crossings	
Reviewer(s): Step 1: Identify Two-Stage Crossings Step 2: Determine Critical Headway	Agency:Is there a median available for a two-stage crossing?YesNIf yes, does the median refuge meet ADA requirements (4' x 4' landing)?YesNCritical headway is the time below which a pedestrian will not attempt to begin crossing the street. Pedestrians us judgement to determine whether the available headway is sufficent for a safe crossing.For a single pedestrian:where: $t_c = critical headway for a single pedestrian (s)t_c = \frac{L}{S_p} + t_sCrossing 1L = crosswalk length (ft)Sp = 3.6 t_c = 25.7Sp = 0.26t_c = 25.7Sp = 0.26t_c = 25.7Up = Wat + Up = WatWere: Nc = total number of pedestrians in crossing platoor(ped)Up = 0.26t_c = 25.7Up = 0.26Nc = 0.26Nc = 0.26Nc = 0.26Nc = 0.26Nc = 0.26Nc = 25.7Up = 0.26Nc = 25.7Up = 0.26Nc = 25.7Up = 0.26Nc = 25.7$
Step 3: Estimate Probability of a Delayed	$ P_b = 1 - e^{-t_{c,c} v/N} $
Crossing	$\begin{array}{c c} crossing 1 \\ t_{c,G} = & 25.7 \\ \upsilon = & 0.26 \\ N = & 4 \\ \end{array} \begin{array}{c c} P_b = & 0.81 \\ v = & P_b = \\ \hline N = & P_d = \\ \end{array} \begin{array}{c c} v = vehicular flow rate across crossing(veh/s) \\ v = vehicular flow rate across crossing(veh/s) \\ \hline v = vehicular flow rate acros cros$

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Calculations Sheet 2

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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:	Staged 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: East	
Evaluation Inputs:	defaults: Input Table:
L = crosswalk length (ft)	L = 52
S _p = average pedestrian walking speed (ft/s)	$S_p = 3.5$ $S_p = 5.6$
t_s = pedestrian start-up and end clearance time (s)	t _s = 3.0 t _s = 3
V = vehicular hourly volume (veh/hr)	V = 349
$v_{\rm p}$ = pedestrian flow rate (ped/s)	$v_{\rm p} = 0^*$ $v_{\rm p} = 0.00$
v = vehicular flow rate (veh/s) = V/3600	υ = V/3600 υ = 0.26
W_c = crosswalk width (ft)	W _c = 8.0 W _c = 8.0
N = number of lanes crossed (Integer)	N = INT(L/11) N = 2
	*no platooning observed
Creasing 2. West	
Crossing 2: West	(only used for two-stage crossings)
Evaluation Inputs:	(only used for two-stage crossings)
-	
Evaluation Inputs:	defaults: Input Table:
Evaluation Inputs: L = crosswalk length (ft)	defaults:Input Table:L =65
Evaluation Inputs: L = crosswalk length (ft) S _p = average pedestrian walking speed (ft/s)	defaults:Input Table: $L =$ 65 $S_p =$ 3.5 $S_p =$ 6
Evaluation Inputs: L = crosswalk length (ft) S _p = average pedestrian walking speed (ft/s) t _s = pedestrian start-up and end clearance time (s)	$\begin{tabular}{ c c c c c } \hline & & & & & & & & & & & & & & & & & & $
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)	$\begin{tabular}{ c c c c c } \hline & & & & & & & & & & & & & & & & & & $
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)	defaults: Input Table: $S_p = 3.5$ $S_p = 6$ $t_s = 3.0$ $t_s = 3$ $V_p = 0^*$ $V_p = 0.00$
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	$\begin{array}{c c c c c c c c c c c c c c c c c c c $

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:

Average Delay	237.6
LOS	F

Inputs and Results

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Input Table:

M₂₁ =

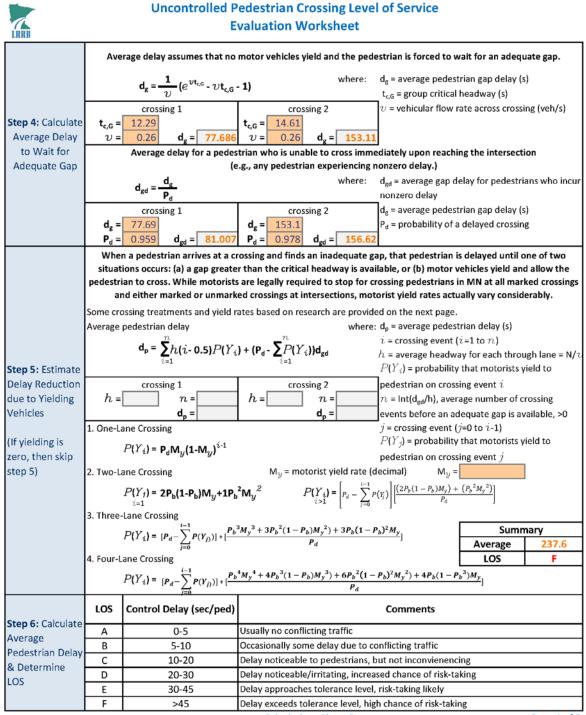
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mple 5: Four Lane Divided Urban H			
	Scenario:	Staged Crossing	
	Agency:		
a median available for a two-stage cros	-		es 🗌 No
If yes, does the median refuge meet			es ☑ No
If yes, does the median refuge need			es 🗌 No
$\mathbf{N}_{p} = \inf_{\mathbf{N}_{p} = 1} \begin{bmatrix} \mathbf{s} \cdot \mathbf{s} \\ \mathbf{t}_{s} = 1 \\ \mathbf{s} \cdot \mathbf{s} \end{bmatrix} \begin{bmatrix} \mathbf{t}_{s} \\ \mathbf{s} \\ \mathbf{s} \\ \mathbf{s} \end{bmatrix} = 1 \\ \mathbf{s} \cdot \mathbf{s} \end{bmatrix} \begin{bmatrix} \mathbf{t}_{s} \\ \mathbf{s} \\ \mathbf{s} \\ \mathbf{s} \\ \mathbf{s} \end{bmatrix} = 1 \\ \mathbf{s} \\ \mathbf{s} \\ \mathbf{s} \end{bmatrix} \begin{bmatrix} \mathbf{t}_{s} \\ \mathbf{s} \\ \mathbf{s} \\ \mathbf{s} \end{bmatrix} \begin{bmatrix} \mathbf{t}_{s} \\ \mathbf{s} \\ \mathbf{s} \\ \mathbf{s} \end{bmatrix} \begin{bmatrix} \mathbf{t}_{s} \\ \mathbf{s} \end{bmatrix} \begin{bmatrix} \mathbf{s} \\ \mathbf{s} $	The the available headway is where: $t_c = critic L = crossing S_p = avera Tossing 2 T_s = 3 6 t_c = 14.6T_c = 14.6$	sufficent for a safe crossing. al headway for a single pedestrivalk length (ft) age pedestrian walking speed (f strian start-up and end clearand 3.5 ft/s 8 sec should be computed: number of pedestrians in cross estrian flow rate (ped/s) ular flow rate across crossing (f e pedestrian critical headway (s) tial distributions of pedestrians number of pedestrians in cross swalk width (ft) ault clear width used by a single nterference with other pedestrive vidth, if other than 8: up critical headway (s) e pedestrian critical headway (s)	rian (s) ft/s) ce time (s) sing platoon veh/s) s) (ped) sing platoon e pedestrian rians (ft) ft. s) (ped)
counter a gap greater than or equal to $P_b = 1 - e^{-t_{c,G}v/N}$	-	liately upon arrival at the inter ability of blocked lane	section.
FP - T-6	P _d = prob	ability of delayed crossing	
$R = 1 (1 R)^{N}$	N = numb	per of lanes crossed	
$r_{d} = 1 - (1 - P_{b})$	t _{c,G} = gro	up critical headway (s) = t _c , if n	o platooning
t _{c,G} = 14	v = vehic		
	$ \begin{array}{c} 12.3 \\ 0.26 \\ 2 \end{array} \begin{array}{c} P_b = \begin{array}{c} 0.8 \\ 0.96 \end{array} \begin{array}{c} t_{c,G} = \begin{array}{c} 14.8 \\ 0.2 \\ 0.2 \end{array} \end{array} $	$P_{d} = 1 - (1 - P_{b})^{N}$ N = numb t _{c,G} = gro v = vehic 12.3 0.26 P_{b} = 0.8 v = 0.26 P_{b} = 0.85	$P_{d} = 1 - (1-P_{b})^{N}$ $rac{crossing 1}{t_{c,G} = group critical headway (s) = t_{c, if n}}$ $v = vehicular flow rate across crossing(vert)$

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HCM Evaluation Worksheet



Calculations Sheet 2

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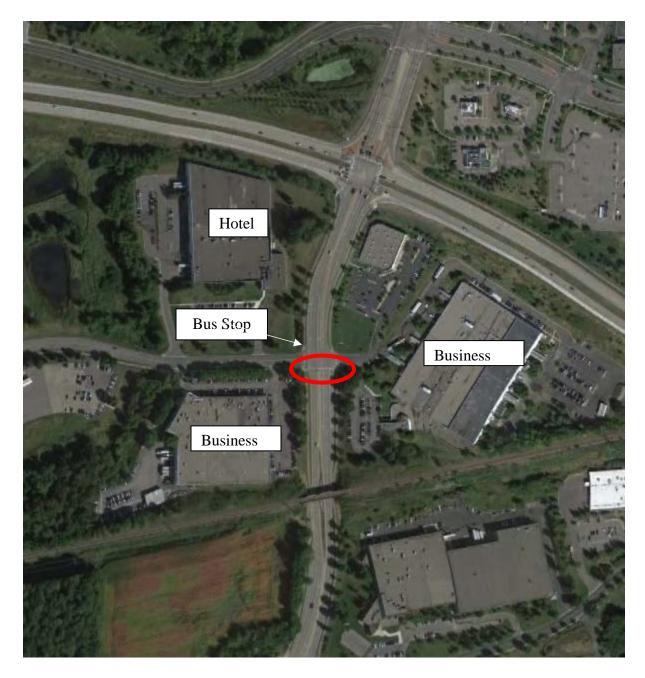
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Example 6: Four-Lane Divided Urban High Pedestrian Use Crossing

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.

1				ntrolled Pe ata Collect							
LRRB Location:		Eva	mple 6		Date:						
City, State:		EXd	mpie o		Scenario:		Noon W	eekdav	,		
Reviewer(s):					Agency:		10001110	cenau	/		
Project #:					ID #:						
rioject #.	The first ste	o in unders	tanding the pe	edestrian nee		ential crossir	ng location is	alamo	eting		
			0	the location			0		0		
	Crossing Len	gth: Measu	ire the crossin		-		Crossing 1	11	18	ft.	
		-	e if there is no	-						ft.	
		-	Crossing 1 and				5				
	0	,	an at crossing							ft.	
			e crosswalk w					e	;	ft.	
	Raised Med							- -	Yes		No
	A	DA Complia	nt Median Ava	ailable (minir	num 4' x 4'	anding)?			Yes	- -	No
Geometrics	Curb Ramp	-		,		0,		2	Yes		No
net			nt Curb Ramp	Available (w	idth, grades	, truncated	domes)?		Yes	2	No
eor	Speed:					35 th percent		4	0	mph	
Ű	Roadway Cu	rvature an	d Sight Distan	ces:	Average w	alking speed		5.	6	ft/s	
			n within a hori		0	0.			Yes		No
		-	e following are							_	
			Sight Distance		301	ft.	provided?	1	Yes		No
			Sight Distance			ft.	provided?	2	Yes		No
			n Sight Distanc		1415	ft.	provided?		Yes		No
			n Sight Distanc	. ,		ft.	provided?	2	Yes		No
			lestrian volum		te incremei	nts on the ro		crossed			
Traffic and	Attach Counts		hicles:	Daily	8,900	1	estrians:		Daily		
Pedestrian	AM Peak	Hourly		Pk 15-min		Hourly		Pk 15	5-min		
Data	PM Peak	Hourly	632	Pk 15-min	252	Hourly	29	Pk 15	5-min	1	.6
	Lighting:										
	Is street lig	hting prese	nt and does it	light the cro	sswalk loca	tion?		1	Yes		No
	Crosswalk Pa	avement M	arkings:	Is the pede	estrian cros	ing currentl	y marked?		Yes		No
	What is the	condition	of the marking	gs?	[Excellent	Good Good		Fair		Poor
S		Are the m	arkings easily	defined?				\checkmark	Yes		No
isti		Do they n	eed replaceme	ent?					Yes	\checkmark	No
cter	What is the crosswalk marking pattern? Continental										
arac						No					
Č		Currently	signed in adva	nce of crossv	valk?			\checkmark	Yes		No
ite		Distances	?	direction 1	475	ft.	direction 2	49	98	ft.	
als	Enhancements: What enhancements are currently at Pedestrian Flasher System, Side Mounted										
ion			the crossing le	ocation?							
Additional Site Characteristics	Adjacent Fac	ilities:	Distance to ne	earest marke	d crosswall	?		82	20	ft.	
Ad	What pede	strian cont	rol devices are	e present			Traffic Signal				
	at the nearest adjacent marked crosswalk?										
	Distance to nearest all-way stop, roundabout or signalized intersection 820 ft.										
	Could another location serve the same pedestrian crossing movement?										
	Could anot	her locatio	n serve the the	e movement	more effec	tively?			Yes	\checkmark	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 orgins and destinations.

draw or insert map of location being studied SSD/PedSD Met Signalized Intersection 820ft **Truncated Domes** Truncated Crosswalk m Flashing Beacon Flashing Beacon SSD/PedSD Met 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: where: defaults: Stopping sight distance (SSD), ft = 1.47St + 1.075S²/a t = brake reaction time, s 2.5 Pedestrian sight distance (PedSD), ft = 1.47S(L / S_p + t_s) a = deceleration rate, ft/s² 11.2 Sp = average pedestrian walking speed, ft/s 3.5 where: S = design speed, mph t_s = pedestrian start-up and end clearance time, s 3.0

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L = length of crossing, ft

Uncontrolled Pedestrian Crossing **Data Collection Worksheet** Example 6 Date: Location: Scenario: Noon Weekday, Staged Crossing City, State: 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. Crossing Length: Measure the crossing distance from curb to curb. Crossing 1 50 ft. Fill in Crossing 1 distance if there is no median. If there is a median at the Crossing 2 ft. 60 crossing location, fill in Crossing 1 and 2 distances. Median: width of median at crossing location 8 ft. Crossing Width: effective crosswalk width 6 ft. Raised Median Available? 1 Yes No ADA Compliant Median Available (minimum 4' x 4' landing)? \checkmark No Yes Geometrics Curb Ramps Available? \checkmark Yes No ADA Compliant Curb Ramp Available (width, grades, truncated domes)? \checkmark Yes No Posted or 85th percentile speed Speed: 40 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 \square Equations to calculate the following are located on the next page Direction 1: Stopping Sight Distance (SSD) 301 ft. provided? 1 Yes No Direction 2: Stopping Sight Distance (SSD) 301 ft. provided? 1 Yes No Direction 1: Pedestrian Sight Distance (PedSD) 701 ft. provided? \checkmark Yes No Direction 2: Pedestrian Sight Distance (PedSD) 806 provided? \checkmark ft. Yes No Measure traffic and pedestrian volume in 15-minute increments on the roadway to be crossed. **Traffic and** Attach Counts vehicles: Daily 8,900 pedestrians: Daily Pedestrian AM Peak Hourly Pk 15-min Hourly Pk 15-min Data PM Peak Hourly 632 Pk 15-min 252 Hourly 29 Pk 15-min 16 Lighting: Is street lighting present and does it light the crosswalk location? 1 Yes No **Crosswalk Pavement Markings:** Is the pedestrian crossing currently marked? Yes No What is the condition of the markings? Excellent Good Good Fair Poo Are the markings easily defined? ~ Yes No Additional Site Characteristics \checkmark Do they need replacement? Yes No Continental What is the crosswalk marking pattern? Signing: Currently signed at crosswalk? Yes No \checkmark Currently signed in advance of crosswalk? $\overline{\mathbf{v}}$ Yes No Distances? direction 2 ft. direction 1 475 ft. 498 Pedestrian Flasher System, Side Mounted Enhancements: What enhancements are currently at the crossing location? Distance to nearest marked crosswalk? Adjacent Facilities: 820 ft. What pedestrian control devices are present **Traffic Signal** at the nearest adjacent marked crosswalk? Distance to nearest all-way stop, roundabout or signalized intersection 820 ft. Could another location serve the same pedestrian crossing movement? Yes \checkmark No \square

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Could another location serve the the movement more effectively?

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 \checkmark

No

Yes

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

$$\begin{split} SSD &= 301 \ ft \\ PedSD_{Unstaged} &= 1,415 \ ft \\ PedSD_{SB} &= 701 \ ft \\ PedSD_{NB} &= 806 \ ft \end{split}$$

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.

Midday Peak Hour

Yield Rate = 25% (Flashing Beacons) Delay => 10000 sec = LOS F

Result: Unacceptable Service Level, go to step 6 of the evaluation flowchart.

<u>Review Origins and Destinations, Alternate Routes</u> 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.

<u>Access Spacing and Functional Classification</u> The crossing is not located in a signalized corridor.

<u>Speed and Pedestrian Use</u> 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.

$$Delay = 57 \ sec = LOS \ F$$

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.

 $Delay = 13 \ sec = LOS \ C$

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:	defaults:	Input Table:				
L = crosswalk length (ft)		L=	118			
S _p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p =	5.6			
t_s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t _s =	3			
V = vehicular hourly volume (veh/hr)		V =	632			
$\upsilon_{\rm p}$ = pedestrian flow rate (ped/s)	υ _p = 0*	$v_p =$	0.18			
v = vehicular flow rate (veh/s) = V/3600	υ = V/3600	U =	0.280			
W_c = crosswalk width (ft)	W _c = 8.0	W _c =	6.0			
N = number of lanes crossed (Integer)	N = INT(L/11)	N =	4			
	*no platooning observed					
Crossing 2:	(only used for two-stage crossings)					
Evaluation Inputs:	defaults:	Input Table:				
L = crosswalk length (ft)		L=				
S _p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p =				
t_s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t _s =				
V = vehicular hourly volume (veh/hr)		V =				
$\upsilon_{\rm p}$ = pedestrian flow rate (ped/s)	υ _p = 0*	υ _p =				
υ = vehicular flow rate (veh/s) = V/3600	υ = V/3600	υ =				
$W_c = crosswalk width (ft)$	W _c = 8.0	W _c =				
N = number of lanes crossed (Integer)	N = INT(L/11)	N =				
	*no platooning	observed				
Crossing Treatment Yield Rate		Input Tak	ole:			
M_y = motorist yield rate (decimal)		M _y =	25%			

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

Results:

Average Delay	#########
LOS	F

Inputs and Results

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LRRB	
Crossing Location:	Example 6 Date:
City, State:	Scenario:
Reviewer(s):	Agency:
Step 1: Identify	Is there a median available for a two-stage crossing?
Two-Stage	If yes, does the median refuge meet ADA requirements (4' x 4' landing)?
Crossings	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 sufficent for a safe crossing.
	For a single pedestrian: where: t _c = critical headway for a single pedestrian (s)
	t _c = L S _n + t _s L = crosswalk length (ft) S _p = average pedestrian walking speed (ft/s)
	$S_p = average pedestrian walking speed (ft/s)$
	crossing 1 crossing 2 t _s = pedestrian start-up and end clearance time (s)
	L = 118 $t_s = 3$ L = $t_s = S_p = 3.5$ ft/s
	$S_p = 5.6$ $t_c = 24.1$ $S_p = t_c = t_s = 3 \sec t_s$
	If pedestrian platooning is observed, the spatial distribution of pedestrians should be computed:
	1. use field observations or estimate platoon size using equation:
	$v_n e^{v_p t_e} + v e^{-v t_e}$ where: N _c = total number of pedestrians in crossing platoon
	$N_{c} = \frac{v_{p}e^{v_{p}t_{c}} + ve^{-vt_{c}}}{(v_{p} + v)e^{(v_{p} - v)t_{c}}}$ where: N _c = total number of pedestrians in crossing platoon (ped)
	v_p = pedestrian flow rate (ped/s)
Step 2:	crossing 1 crossing 2 v = vehicular flow rate across crossing (veh/s)
Determine	$v_{p} = 0.18$ $t_{c} = 24.1$ $v_{p} = t_{c} = t_{c}$ t single pedestrian critical headway (s)
Critical Headway	$v = 0.28$ N _c = 331 $v = N_c =$
	2. compute spatial distribution:
	$N_{p} = Int \left[\frac{8.0(N_{c}-1)}{W_{c}} \right] + 1$ where: N_{p} = spatial distributions of pedestrians (ped) N_{c} = total number of pedestrians in crossing platoon
	(ped)
	crossing 1 crossing 2 W _c = crosswalk width (ft)
	$N_c = 331$ $N_c = 8.0 = default clear width used by a single pedestrian$
	$W_c = 6$ $N_p = 440$ $W_c = N_p = 10$ to avoid interference with other pedestrians (ft)
	3. compute group critical headway: clear width, if other than 8: ft.
	where the group critical headway (s)
	$\mathbf{t}_{c,G} = \mathbf{t}_c + 2(\mathbf{N}_p-1)$ $\mathbf{t}_c = \text{single pedestrian critical headway (s)}$
	crossing 1 crossing 2 N _p = spatial distributions of pedestrians (ped)
	$N_p = 440$ $N_p = 100$
	$t_c = 24.1$ $t_{c,G} = 902$ $t_c = t_{c,G} =$
	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.
	L D same believe of blocks along
Step 3: Estimate	$\mathbf{P}_{b} = 1 \cdot e^{-\mathbf{t}_{c,c}v/\mathbf{N}}$ where: $\mathbf{P}_{b} = \text{probability of blocked lane}$ $\mathbf{P}_{d} = \text{probability of delayed crossing}$
Probability of a	N = number of lanes crossed
Delayed	$P_d = 1 - (1-P_b)^N$ $t_{c,G} = group critical headway (s) = t_c if no platooning$
Crossing	crossing 1 crossing 2 v = vehicular flow rate across crossing(veh/s)
Ŭ	$\mathbf{t}_{c,G} = \begin{array}{ c c } 902 \\ \mathbf{t}_{c,G} = \end{array}$
	$v = 0.28$ $P_b = 1$ $v = P_b =$
	$N = 4$ $P_d = 1$ $N = P_d =$
	Calculations Sheet 1 Page 3 of 5
	Calculations sheet 1 Page 3 of 5

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HCM Evaluation Worksheet



LINID								
	Ave	rage delay assumes that	no motor vehicle	es yield an	d the ped	estrian is forced to w	ait for an adeq	luate gap.
		1 , 21, 21, 6			where:	d _g = average pedest	rian gap delay ((s)
		$d_{g} = \frac{1}{v} (e^{v t_{c,G}} - v t)$	_{t,G} - 1)			t _{c,G} = group critical		
		crossing 1		rossing 2		v = vehicular flow r	ate across cross	sing (veh/s)
Step 4: Calculate	t _{c,G} =	902.1	t _{c,G} =					
Average Delay	υ =							
to Wait for		Average delay for a pe					ng the intersec	tion
Adequate Gap		d	(e.g., any pede	strian exp	where:	n onzero delay.) d _{gd} = average gap de	alay for podest	ians who incur
		$d_{gd} = \frac{d_g}{P_d}$			where.	nonzero delay	elay for pedesti	
		crossing 1	0	rossing 2		d _g = average pedest	rian gap delay ((s)
	d _g =	#####	d _g =			P _d = probability of a		
	P _d =	1 d _{gd} = 2E+1	$d_g =$ 10 $P_d =$	d _{gd} =	:			
	Whe	n a pedestrian arrives at	a crossing and fi	nds an ina	dequate g	ap, that pedestrian is	s delayed until	one of two
		ions occurs: (a) a gap gre				, , ,		
	· ·	ian to cross. While motor	÷ 1	-	-	÷.		-
		nd either marked or unm	-			-	ally vary consid	derably.
		ossing treatments and yie	d rates based or	research				
	Average	pedestrian delay	n.		where	: d _p = average pedest		
		$d_{p} = \sum_{i=1}^{n} h(i - 0.5) P(i - 0.5)$	Y_i) + (P _d - $\sum P$	(Y_i))d _{ed}		<i>i</i> = crossing event (<i>h</i> = average headwa		ugh lang = N/a
Step 5: Estimate		<i>i=</i> 1	<i>i</i> =1			$P(Y_i)$ = probability		• ·
Delay Reduction	<u> </u>	crossing 1		rossing 2		pedestrian on crossi		,
due to Yielding	h =		09 h = ####		######	$n = \ln(d_{gd}/h)$, avera	•	crossing
Vehicles		d _p = #####	##			events before an ad		
	1. One-L	ane Crossing				j = crossing event (j	j=0 to <i>i-</i> 1)	
(If yielding is		$P(Y_i) = \mathbf{P}_d \mathbf{M}_u (1 - \mathbf{M}_u)^{i-1}$				$P(Y_j)$ = probability	that motorists	yield to
zero, then skip		- 31 31				pedestrian on cross		
step 5)		ane Crossing		motorist y		• I	25%	
		$P(Y_1) = 2P_b(1-P_b)M_y + 2$	$(P_b^2 M_y^2)$	$P(Y_i)$	$= P_d - \sum_{i=1}^{n-1} P_i$	$P(Y_j) \left[\frac{(2P_b(1-P_b)M_y) + P_b}{P_b} \right]$	$(P_b^2 M_y^2)$	
		₂=1 Lane Crossing		271	<u>]]=0</u>	Jt ^r a	1	
			$P_b^3 M_v^3 + 3P_b^2 (1$	$(-P_b)M_{\gamma}^2)$	+ 3P _b (1 - 1	$(P_b)^2 M_{\gamma}$	Sum	mary
		$P(Y_i) = [P_d - \sum_{j=0}^{t-1} P(Y_{j})] *$		P _d			Average	##########
	4. Four-L	ane Crossing					LOS	F
		$P(Y_i) = \left[P_d - \sum_{i=1}^{i-1} P(Y_{j_i})\right] *$	$P_b^4 M_y^4 + 4P_b^3 (1)$	$(-P_b)M_y^3)$	+ 6P _b ² (1 -	$(P_b)^2 M_y^2) + 4P_b(1 - P_b)^2$	$M_{y_{1}}^{3})M_{y_{1}}$	
					P_d		1	
	LOS	Control Delay (sec/pe	d)			Comments		
Step 6: Calculate	A	0-5	Usually no co	onflicting to	raffic			
Average	B	5-10				onflicting traffic		
Pedestrian Delay	C	10-20			,	out not inconvienenci	ing	
& Determine		20-30				sed chance of risk-ta	-	
LOS	E	30-45			0.	, risk-taking likely	2	
	F	>45				h chance of risk-takir	ng	
	-	-	Calcul	ations She	eet 2			Page 4 of 5

Calculations Sheet 2

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Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations

Intersection and Mid-Block Crossings

Crossing Location:	Example 6	Date:	
City, State:		Scenario:	Staged Crossing, Overhead Beacons
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:	defaults:	Input Table:	
L = crosswalk length (ft)		L =	50
S _p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p =	5.6
t _s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t _s =	3
V = vehicular hourly volume (veh/hr)		V =	316
$\upsilon_{ m p}$ = pedestrian flow rate (ped/s)	υ _p = 0*	$v_p =$	0.18
υ = vehicular flow rate (veh/s) = V/3600	<i>υ</i> = V/3600	U =	0.280
W_c = crosswalk width (ft)	W _c = 8.0	$W_c =$	6.0
N = number of through lanes crossed (Integer)	N = INT(L/11)	N =	2
	*no platooninį	observed	
Crossing 2: East	(only used for two-stage cro	nssings)	
	(only used for two stuge er	5551165)	
Evaluation Inputs:	defaults:		Table:
			Table: 60
Evaluation Inputs:		Input	
Evaluation Inputs: L = crosswalk length (ft)	defaults:	Input L =	60
Evaluation Inputs: L = crosswalk length (ft) S _p = average pedestrian walking speed (ft/s)	defaults: S _p = 3.5	L = S _p =	60 6
Evaluation Inputs: L = crosswalk length (ft) S _p = average pedestrian walking speed (ft/s) t _s = pedestrian start-up and end clearance time (s)	defaults: S _p = 3.5	L = S _p = t _s =	60 6 3
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)	$\frac{\text{defaults:}}{S_p = 3.5}$ $t_s = 3.0$	L = S _p = t _s = V =	60 6 3 316
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)	$\frac{\text{defaults:}}{S_p = 3.5}$ $t_s = 3.0$ $v_p = 0^*$	$ \frac{lnput}{L =} \\ S_p = \\ t_s = \\ V = \\ U_p = $	60 6 3 316 0.18
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	$\frac{\text{defaults:}}{S_p = 3.5}$ $t_s = 3.0$ $\upsilon_p = 0^*$ $\upsilon = V/3600$	Input L = Sp = ts = V = V p = v =	60 6 3 316 0.18 0.28
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)	$defaults:$ $S_{p} = 3.5$ $t_{s} = 3.0$ $\upsilon_{p} = 0^{*}$ $\upsilon = V/3600$ $W_{c} = 8.0$	Input L = $S_p =$ $t_s =$ V = $v_p =$ v = $w_c =$ N =	60 6 3 316 0.18 0.28 6.0

 M_y = motorist yield rate (decimal)

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

Results:

Average Delay	57.2
LOS	F

Inputs and Results

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47%

M₂₁ =

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LRRB	
Crossing Location	Example 6 Date:
City, State:	Scenario: Staged Crossing with Overhead Beacons
Reviewer(s):	Agency:
Step 1: Identify	Is there a median available for a two-stage crossing?
Two-Stage	If yes, does the median refuge meet ADA requirements (4' x 4' landing)?
Crossings	If yes, does the median refuge need to meet ADA requirements (4' x 4' landing)? 🛛 🗹 Yes 🗌 No
Step 2: Determine	Critical headway is the time below which a pedestrian will not attempt to begin crossing the street. Pedestrians use judgement to determine whether the available headway is sufficent for a safe crossing. For a single pedestrian: $t_c = \frac{L}{S_p} + t_s$ $t_c = \frac{L}{S_p} + t_s$ $t_c = \frac{L}{S_p} + t_s$ $t_c = \frac{L}{S_p} + t_s$ $L = \frac{50}{5.6}$ $t_c = 11.9$ $t_c = \frac{9}{5.6}$ $t_c = 11.9$ $t_c = 10.10$ $t_c = 10.1$
Critical Headway	$ \begin{array}{c c} \upsilon_{p} = & 0.18 \\ \upsilon = & 0.28 \\ \end{array} \begin{array}{c} t_{c} = & 11.9 \\ v = & 0.28 \\ \end{array} \begin{array}{c} \upsilon_{p} = & 0.18 \\ v = & 0.28 \\ \end{array} \begin{array}{c} t_{c} = & 13.7 \\ v = & 0.28 \\ \end{array} \begin{array}{c} t_{c} = & \text{single pedestrian critical headway (s)} \end{array} \end{array} \begin{array}{c} t_{c} = & \text{single pedestrian critical headway (s)} \end{array} \end{array}$ 2. compute spatial distribution: $ \begin{array}{c} N_{p} = & \text{Int} \left[\begin{array}{c} 8.0(N_{c} - 1) \\ W_{c} \end{array} \right] + 1 \\ v_{c} = & \text{table for a single pedestrian single pedestrian single pedestrian (ped)} \end{array} \right] $ $ \begin{array}{c} \text{where: } N_{p} = & \text{spatial distributions of pedestrians (ped)} \\ N_{c} = & \text{table for a single pedestrian single pedestrian (ped)} \\ N_{c} = & 11.1 \\ N_{c} = & 18.3 \\ \end{array} \end{array}$
	$ \begin{array}{c} W_c = \begin{array}{c} 14.1 \\ W_c = \begin{array}{c} 6 \end{array} \\ N_p = \begin{array}{c} 14 \\ W_c = \begin{array}{c} 6 \end{array} \\ N_p = \begin{array}{c} 24 \\N_p = \begin{array}{c} 24 $
	$ \begin{array}{c} \text{crossing 1} \\ \textbf{N}_{\textbf{p}} = \begin{array}{c} 14 \\ \textbf{t}_{c} = \begin{array}{c} 11.9 \end{array} \\ \textbf{t}_{c,G} = \begin{array}{c} 37.9 \end{array} \\ \textbf{t}_{c} = \begin{array}{c} 24 \\ 13.7 \end{array} \\ \textbf{t}_{c,G} = \begin{array}{c} 59.7 \end{array} \\ \textbf{N}_{p} = \begin{array}{c} \text{spatial distributions of pedestrians (ped)} \end{array} $
	Probability that a pedestrian will not incur any crossing delay is equal to the likelihood that a pedestrian will
Step 3: Estimate	encounter a gap greater than or equal to the critical headway immediately upon arrival at the intersection. $P_{b} = 1 \cdot e^{-\mathbf{t}_{c}c^{D}/N}$ where: $P_{b} = \text{probability of blocked lane}$ $P_{d} = \text{probability of delayed crossing}$
Probability of a Delayed	$P_{d} = 1 - (1-P_{b})^{N}$ $T_{c,G} = \text{group critical headway (s)} = t_{c} \text{ if no platooning}$
Crossing	$\begin{array}{ c c c c c c c c } \hline crossing 1 & crossing 2 \\ \hline t_{c,G} = & 37.9 \\ \hline \upsilon = & 0.28 \\ \hline N = & 2 \\ \hline P_d = & 1 \\ \hline N = & 2 \\ \hline P_d = & 1 \\ \hline N = & 2 \\ \hline P_d = & 1 \\ \hline N = & 2 \\ \hline P_d = & 1 \\ \hline \end{array} \\ \begin{array}{ c c c c c c c c c c c c c c c c c c c$
	Calculations Sheet 1 Page 3 of 5

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LIULD									
	Ave	rage delay assume	s that no	motor vehicles	yield an	d the pede	estrian is forced to w	vait for an adequ	iate gap.
		. 1 . art.		- 1		where:	d _g = average pedest	rian gap delay (s	.)
		$d_g = \frac{1}{v} (e^{vt_c})$	v^{s} - $v t_{c,G}$	- 1)			t _{c,G} = group critical		
		crossing 1			ssing 2		v = vehicular flow r	ate across crossi	ng (veh/s)
Step 4: Calculate	t _{c,G} =	37.93		t _{c,G} = 59.71					
Average Delay	υ =	6	146193	υ = 0.28	8	7E+07	-		
to Wait for		Average delay fo					ediately upon reachi	ng the intersecti	on
Adequate Gap		d	(e	.g., any pedestr	ian expe	where:		alay for podestri	ans who incur
		$d_{gd} = \frac{d_g}{P_d}$				where.	d _{gd} = average gap de nonzero delay	elay for pedestri	ans who mean
				cro	ssing 2			rian gap delay (s	.)
	d _g =	1E+05		$d_{g} = 7E+07$			P _d = probability of a		
	P _d =	1 d _{gd} =	146196	$d_{g} = \frac{7E+07}{P_{d}}$	d _{gd} =	7E+07			
	Whe						ap, that pedestrian is	s delayed until o	ne of two
						•	ilable, or (b) motor v		
						-	rossing pedestrians i		-
				-			orist yield rates actu	ally vary consid	erably.
		-	nd yield r	ates based on re	search a		ed on the next page.		
	Average	pedestrian delay n		n		where:	<pre>i d_p = average pedest i = crossing event (</pre>		
		d _p = ∑h(i-0	.5)P(Y _i) + (P _d - $\sum_{i=1}^{n} P(Y)$	$i))d_{gd}$		h = average headwa		igh lane = N/2
Step 5: Estimate		i=1		<i>i</i> =1	-		$P(Y_i)$ = probability		• ·
Delay Reduction		crossing 1		cro	ssing 2		pedestrian on crossi		
due to Yielding	h =	7.1 n =	20467	h = 7.143		9E+06	$n = \ln(d_{gd}/h)$, avera	age number of c	rossing
Vehicles		d _p =	28.4		d _p =	28.7	events before an ad	lequate gap is av	ailable, >0
	1. One-L	ane Crossing					j = crossing event (j		
(If yielding is		$P(Y_i) = P_d M_u (1-1)$	M) ⁱ⁻¹				$P(Y_j)$ = probability		ield to
zero, then skip			g,				pedestrian on cross		
step 5)		ane Crossing				ield rate (d		47%	
		$P(Y_1) = 2P_b(1-P_b)$)M _y +1P _b	²M _y 2	$P(Y_i) =$	$P_d - \sum P$	$\left(Y_{j}\right)\left[\frac{\left(2P_{b}(1-P_{b})M_{y}\right)+P_{d}}{P_{d}}\right]$	$(P_b^*M_y^*)$	
		lane Crossing			121	[]=0]r	,	
	I		Pb	${}^{3}M_{y}{}^{3} + 3P_{b}{}^{2}(1-b)$	$(P_b)M_y^2)$	+ 3P _b (1 – F	$(P_b)^2 M_{\gamma}$	Sumn	nary
		$P(Y_i) = [P_d - \sum_{j=0}^{t-1} P(y_j)]$	(Y _{j)})]*[P _d]	Average	57.2
		ane Crossing						LOS	F
		$P(Y_i) = [P_d - \sum^{i-1} P_i]$	$(Y_{j})] * [\frac{P_b}{2}]$	${}^{4}M_{y}{}^{4} + 4P_{b}{}^{3}(1 - 1)$	$(P_b)M_y^3)$	$+6P_b^2(1-P_d)$	$P_b)^2 M_y^2) + 4P_b(1 - P_b)^2$	$\frac{b^{3}}{M_{y}}]$	
	LOS	Control Delay (s				u	Comments		
Step 6: Calculate	A	0-5		Usually no conf	licting tr	affic			
Average	В	5-10			0		onflicting traffic		
Pedestrian Delay	C	10-20					out not inconvienenci	ing	
& Determine	D	20-30					sed chance of risk-ta	-	
LOS	E	30-45				-	risk-taking likely	~	
	F	>45					h chance of risk-takir	ng	
		-		Calculati	ons She	oot 2			Page 4 of 5

Calculations Sheet 2

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Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations

Intersection and Mid-Block Crossings

Crossing Location:	Example 6	Date:	
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:	defaults:	Input	Table:
L = crosswalk length (ft)		L =	50
S _p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p =	5.6
t_s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t _s =	3
V = vehicular hourly volume (veh/hr)		V =	316
$\upsilon_{ m p}$ = pedestrian flow rate (ped/s)	υ _p = 0*	$v_p =$	0.18
υ = vehicular flow rate (veh/s) = V/3600	υ = V/3600	U =	0.280
W_c = crosswalk width (ft)	W _c = 8.0	$W_c =$	6.0
N = number of through lanes crossed (Integer)	N = INT(L/11)	N =	2
	*no platoonin	g observed	
Crossing 2: East	(only used for two-stage cr	ossings)	
Evaluation Inputs:	defaults:	Input	Table:
			Tubic:
L = crosswalk length (ft)		L=	60
L = crosswalk length (ft) S _p = average pedestrian walking speed (ft/s)	S _p = 3.5	· · ·	
0 ()	$S_{p} = 3.5$ t _s = 3.0	L=	60
S_p = average pedestrian walking speed (ft/s)		L = S _p =	60 6
S _p = average pedestrian walking speed (ft/s) t _s = pedestrian start-up and end clearance time (s)		L = S _p = t _s =	60 6 3
S _p = average pedestrian walking speed (ft/s) t _s = pedestrian start-up and end clearance time (s) V = vehicular hourly volume (veh/hr)	t _s = 3.0	L = S _p = t _s = V =	60 6 3 316
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)	$v_p = 0^*$	$L =$ $S_{p} =$ $t_{s} =$ $V =$ $U_{p} =$	60 6 3 316 0.18
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	$v_p = 0^*$ v = V/3600	$L = S_p = t_s = V = U_p = U = U = V$	60 6 3 316 0.18 0.28
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)	$t_{s} = 3.0$ $\upsilon_{p} = 0^{*}$ $\upsilon = \sqrt{3600}$ $W_{c} = 8.0$	L = $S_p =$ $t_s =$ V = $v_p =$ v = $W_c =$ N =	60 6 3 316 0.18 0.28 6.0

 M_v = motorist yield rate (decimal)

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

Results:

Average Delay	13.1
LOS	С

Inputs and Results

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84%

M₂₁ =

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Crossing Location: City, State: Reviewer(s): Step 1: Identify Two-Stage Crossings	If yes, does the median ref Critical headway is the time below judgement to determ For a single pedestrian: $t_c = \frac{L}{S_p} + t_s$ $L = 50$ $t_s = 3$	The second state of the s	✓ Yes □ N
Reviewer(s): Step 1: Identify Two-Stage	If yes, does the median ref If yes, does the median ref Critical headway is the time below judgement to determ For a single pedestrian: $t_c = \frac{L}{S_p} + t_s$ $L = 50$ $t_s = 3$	Agency: -stage crossing? fuge meet ADA requirements (4' x fuge need to meet ADA requirements which a pedestrian will not atter hine whether the available head where: $t_c = t_c$ L = $S_p = t_s = 3$	✓ Yes N x 4' landing)? ✓ Yes N ents (4' x 4' landing)? ✓ Yes N mpt to begin crossing the street. Pedestrians use way is sufficent for a safe crossing. = critical headway for a single pedestrian (s) crosswalk length (ft) = average pedestrian walking speed (ft/s) = pedestrian start-up and end clearance time (s)
Step 1: Identify Two-Stage	If yes, does the median ref If yes, does the median ref Critical headway is the time below judgement to determ For a single pedestrian: $t_c = \frac{L}{S_p} + t_s$ $L = 50$ $t_s = 3$	-stage crossing? Tuge meet ADA requirements (4' x Tuge need to meet ADA requirements which a pedestrian will not atten nine whether the available head where: $t_c = t_c$ L = $S_p = t_s = 3$	x 4' landing)? Yes N ents (4' x 4' landing)? Yes N mpt to begin crossing the street. Pedestrians use way is sufficent for a safe crossing. = critical headway for a single pedestrian (s) crosswalk length (ft) = average pedestrian walking speed (ft/s) edestrian start-up and end clearance time (s)
Two-Stage	If yes, does the median ref If yes, does the median ref Critical headway is the time below judgement to determ For a single pedestrian: $t_c = \frac{L}{S_p} + t_s$ $L = 50$ $t_s = 3$	tuge meet ADA requirements (4' x tuge need to meet ADA requirements which a pedestrian will not atten- nine whether the available heads where: $t_c = t_c = t_c$ L = $t_s = t_s = t_s$ L = $t_s = t_s = t_s$	x 4' landing)? Yes N ents (4' x 4' landing)? Yes N mpt to begin crossing the street. Pedestrians use way is sufficent for a safe crossing. = critical headway for a single pedestrian (s) crosswalk length (ft) = average pedestrian walking speed (ft/s) edestrian start-up and end clearance time (s)
-	If yes, does the median ref Critical headway is the time below judgement to determ For a single pedestrian: $t_c = \frac{L}{S_p} + t_s$ $L = 50$ $t_s = 3$	tuge need to meet ADA requireme which a pedestrian will not attern nine whether the available heads where: $t_c =$ L = $S_p =$ crossing 2 $L =$ 60 $t_s =$ 3	ents (4' x 4' landing)? ✓ Yes N mpt to begin crossing the street. Pedestrians use way is sufficent for a safe crossing. = critical headway for a single pedestrian (s) crosswalk length (ft) = average pedestrian walking speed (ft/s) = pedestrian start-up and end clearance time (s)
Crossings	Critical headway is the time below judgement to determ For a single pedestrian: $t_c = \frac{L}{S_p} + t_s$ crossing 1 $L = 50$ $t_s = 3$	which a pedestrian will not attern nine whether the available heads where: $t_c = t_c$ $L = t_s$ $L = 60$ $t_s = 3$	mpt to begin crossing the street. Pedestrians use way is sufficent for a safe crossing. = critical headway for a single pedestrian (s) crosswalk length (ft) = average pedestrian walking speed (ft/s) = pedestrian start-up and end clearance time (s)
	judgement to determ For a single pedestrian: $t_{c} = \frac{L}{S_{p}} + t_{s}$ $crossing 1$ $L = 50$ $t_{s} = 3$	the whether the available heads where: $t_c = t_c$ $L = t_s$ $t_s = t_s$ $L = t_s = t_s$	way is sufficent for a safe crossing. = critical headway for a single pedestrian (s) crosswalk length (ft) = average pedestrian walking speed (ft/s) = pedestrian start-up and end clearance time (s)
Step 2: Determine Critical Headway	$v = 0.28 N_{c} = 11.1$ 2. compute spatial distribution: $N_{p} = Int \left[\frac{8.0(N_{c}-1)}{W_{c}} \right]$ $v_{c} = 11.1$ $W_{c} = 6 N_{p} = 14$ 3. compute group critical headway: $t_{c,G} = t_{c} + 2(N_{p}-1)$ $v_{c} = 14$ $t_{c} = 11.9$ $t_{c,G} = 37.9$ Probability that a pedestrian w	platoon size using equation: where: N_c : $v_p = 0.18$ $t_c = 13.7$ $t_c = 0.28$ $N_c = 18.3$ $v = 0.28$ $N_c = 18.3$ $v_c = 18.3$ $v_c = 0.24$ $v_c = 0.24$ $v_c = 0.24$ $v_c = 0.24$	<pre>t_s = 3 sec trians should be computed: = total number of pedestrians in crossing platoon ed) = pedestrian flow rate (ped/s) = vehicular flow rate across crossing (veh/s) = single pedestrian critical headway (s) = spatial distributions of pedestrians (ped) = total number of pedestrians in crossing platoon ed) = crosswalk width (ft) = default clear width used by a single pedestrian avoid interference with other pedestrians (ft) clear width, if other than 8: ft. = group critical headway (s) = single pedestrian critical headway (s) = spatial distributions of pedestrians (ped) = spatial distributions of pedestrians (ped)</pre>
Step 3: Estimate Probability of a	$\mathbf{P}_{\mathbf{b}} = 1 \cdot e^{-\mathbf{t}_{c,G} v / \mathbf{N}}$	where: P _b = P _d =	<pre>immediately upon arrival at the intersection. = probability of blocked lane = probability of delayed crossing = number of lanes crossed</pre>
Delayed	$P_{d} = 1 - (1 - P_{b})^{N}$		$_{\rm S}$ = group critical headway (s) = t _c , if no platooning
Crossing	$\begin{array}{c} crossing 1 \\ t_{c,6} = \begin{array}{c} 37.9 \\ \mathcal{U} = \begin{array}{c} 0.28 \\ N \end{array} \begin{array}{c} P_{b} = \begin{array}{c} 1 \\ P_{d} \end{array} \begin{array}{c} 1 \\ 1 \end{array}$		= vehicular flow rate across crossing(veh/s)

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HCM Evaluation Worksheet



21112							
	Ave	erage delay assumes that no	motor vehicles yield and	the pede	estrian is forced to w	ait for an adequ	ate gap.
		1 , vt.c		where:	d _g = average pedest	rian gap delay (s)
		$d_{g} = \frac{1}{\upsilon} (e^{\upsilon t_{c,G}} - \upsilon t_{c,G})$	- 1)		$t_{c,G}$ = group critical	headway (s)	
		crossing 1	crossing 2		v = vehicular flow ra	ate across crossi	ng (veh/s)
Step 4: Calculate		37.93	$\mathbf{t}_{c,G} = \begin{array}{c} 59.71\\ \upsilon = \begin{array}{c} 0.28 \end{array} \mathbf{d}_{g} = \end{array}$				
Average Delay	υ =			7E+07]		
to Wait for Adequate Gap		Average delay for a pedes	trian who is unable to cr .g., any pedestrian expe			ng the intersecti	on
Adequate Gap				where:	d _{gd} = average gap de	alay for nedestria	ans who incur
		$d_{gd} = \frac{d_g}{P_d}$			nonzero delay	and the pedestri	ins the mean
		crossing 1	crossing 2		d _g = average pedest	rian gap delay (s)
	d _g =	1E+05	$d_{g} = \frac{7E+07}{P_{d}}$ $P_{d} = \frac{1}{d_{gd}}$		$P_d = probability of a$	delayed crossing	g
	P _d =	1 d _{gd} = 146196	$P_d = 1 d_{gd} =$	7E+07			
		n a pedestrian arrives at a c	-			•	
		ions occurs: (a) a gap greate		•			
	L.	ian to cross. While motorist nd either marked or unmark	• • •	•	•••		-
		ossing treatments and yield r				any vary conside	crabiy.
		pedestrian delay	ates based on research an		d _o = average pedest	rian delav (s)	
	, weidge		_ <i>n</i>	where.	i = crossing event (1		
		$d_{p} = \sum_{i=1}^{n} h(i - 0.5) P(Y_{i})$) + ($P_d - \sum P(Y_i)$)d _{gd}		h = average headwa		gh lane = N/ v
Step 5: Estimate		L=1	<i>c=</i> 1		$P(Y_i)$ = probability	that motorists y	ield to
Delay Reduction		crossing 1	crossing 2		pedestrian on crossi	-	
due to Yielding	h =	7.1 <i>n</i> = 20467			n = Int(d _{gd} /h), avera		
Vehicles		d _p = 6.5	d _p =	6.6	events before an ad		ailable, >0
(If yielding is		ane Crossing			j = crossing event(j) $P(Y_j) = \text{probability}(j)$		ield to
zero, then skip		$P(Y_i) = P_d M_y (1-M_y)^{i-1}$			pedestrian on crossi		
step 5)	2. Two-L	ane Crossing	M_y = motorist yie	ld rate (d		84%	
		$P(Y_1) = 2P_b(1-P_b)M_y + 1P_b$	*			$(P_b^2 M_y^2)$]	
		<i>i</i> =1	$y $ $I(I_i) - i>1$	$\left[P_d - \sum_{j=0}^{p}\right]^p$	(Y_j)		
		-Lane Crossing					
		$P(Y_i) = [P_d - \sum_{i=0}^{t-1} P(Y_{ij})] * [\frac{P_b}{2}]$	$\frac{^{3}M_{y}^{3} + 3P_{b}^{2}(1-P_{b})M_{y}^{2}) + P_{z}}{P_{z}}$	3P _b (1 – P	$P_b)^2 M_y$	Summ	
		iane Crossing	r d			Average LOS	13.1 C
		0	^{4}M $^{4} \pm AP$ $^{3}(1 - P) M^{3} \pm$	$6P_{1}^{2}(1 -$	$(P_1)^2 M_1^2 + 4P_1(1 - P_1)^2$		
		$P(Y_i) = [P_d - \sum_{i=0}^{i-1} P(Y_i)] * [\frac{P_b}{2}]$	<i>my</i> (1 <i>b</i>) <i>my</i>) (1 <i>b</i>) (1 <i></i>	$\frac{OF_b}{P_d}$	<i>i b) my</i>) i ti b(1 i i j	<u>,)///y</u>]	
	LOS	Control Delay (sec/ped)			Comments		
Step 6: Calculate		control belay (sec/peu)			comments		
Average	A	0-5	Usually no conflicting tra				
Pedestrian Delay	B	5-10	Occasionally some delay		-		
& Determine	C D	10-20	Delay noticeable to pede	,		<u> </u>	
LOS	E	20-30 30-45	Delay noticeable/irritatir Delay approaches tolera	-		ning .	
	F	>45	Delay exceeds tolerance		<u> </u>	ng	
			Calculations Shee			0	Page 4 of 5

Calculations Sheet 2

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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.

			Uncol	ntrolled P	edestriar	Crossing					
LRRB	Data Collection Worksheet										
Location:	Example 7			Date:							
City, State:					Scenario:		School C	rossing	5		
Reviewer(s):					Agency:						
Project #:					ID #:						
	The first ste	p in underst	0				ng location is a	comple	ting		
	<u> </u>			the location	-		<u> </u>			<i>c</i> .	
	-	-	re the crossin	0			Crossing 1	40		ft. ft.	
		-	e if there is no			edian at the	Crossing 2			π.	
	0	,	crossing 1 and							<i>c</i> .	
			n at crossing l							ft.	
			e crosswalk w	llath				6		ft.	
		dian Availab		·	4141				Yes		No
S			nt Median Ava	ailable (minir	num 4' x 4'	landing)?			Yes		No
etri		s Available?							Yes		No
Geometrics		DA Compliai	nt Curb Ramp	Available (w		s, truncated 85 th percent			Yes		No
Ğ	Speed:							30		mph	
			Sight Distant			alking speed	1	4.	-	ft/s	
		•	within a hori						Yes	1	No
			e following are			6	· · · · · · · · · · · · · · · · · · ·				
			ight Distance		197	ft.	provided?	I	Yes		No
			ight Distance		E 40	ft.	provided?		Yes		No
			Sight Distanc		543	ft.	provided?		Yes		No
			Sight Distanc	. ,	to in even even	ft.	provided?		Yes		No
Traffic and	Attach Counts		icles:	e in 15-minu Daily	5,600		adway to be estrians:		ı. Daily		
Pedestrian	Attach counts	Hourly	496	Pk 15-min	181	· · ·		Pk 15			5
Data	PM Peak	Hourly	521	Pk 15-min Pk 15-min		Hourly Hourly	6	Pk 15			5 4
	Lighting:	Houriy	521	PK 15-min	100	Houriy	D	PK 15	-min	-	+
		hting proco	nt and does it	light the cre	cowalk loca	tion?			Yes		No
	Crosswalk Pa	÷ .		+		sing current	v marked?	 ✓ ✓ 	Yes		No
			of the marking		Strian cros	Excellent	Good		Fair	Н	Poor
s			arkings easily	-	L		0000		Yes	Н	No
stic			ed replaceme						Yes		No
eri			e crosswalk m		rn?		Contin	ental	103	Ŀ	140
act	Signing:		igned at cross				contain		Yes		No
Chai	5.8		igned in adva		valk?				Yes		No
te		Distances?	-	direction 1		ft.	direction 2			ft.	
1 Si	Enhancemer		What enhance		urrently at		isibility marki	ngs in-			
ona	Lindificence		the crossing lo		arrenty at		school cross	-			
litic	Adjacent Fac		Distance to ne		d crosswall	 ?	5011001 01000			ft.	
Additional Site Characteristics			ol devices are								
			t marked cros								
			-way stop, rol		signalized in	ntersection		200	00	ft.	
			serve the sar		•				Yes		No
			serve the the		+				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 orgins and destinations.

draw or insert map of location being studied SSD/PedSD Met Thru/Stop Crosswalk No Truncated School Crosswalk No Truncated Dome/ Crosswalk Curb Cut SSD/PedSD Met Notes: No Ped Ramps In Street School Crosing signs and crossing guards. Sight Distance Calculations: where: defaults: Stopping sight distance (SSD), ft = 1.47St + 1.075S²/a t = brake reaction time, s 2.5 Pedestrian sight distance (PedSD), ft = 1.47S(L / S_p + t_s) a = deceleration rate, ft/s² 11.2 S_p = average pedestrian walking speed, ft/s 3.5

> where: S = design speed, mph L = length of crossing, ft

> > Page 2 of 2

 $t_{\rm s}$ = pedestrian start-up and end clearance time, ${\rm s}$

3.0

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

$$SSD = 197 ft$$

 $PedSD = 543 ft$

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 sec = LOS B

PM Peak Hour

Yield Rate = 86% (Crossing Guards) Delay = 7.9 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.

Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations

Intersection and Mid-Block Crossings

Crossing Location:	Example 7	Date:	
City, State:		Scenario:	School Crossing, AM
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:

crossing 1.			
Evaluation Inputs:	defaults:	Input	Table:
L = crosswalk length (ft)		L =	40
S_p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p =	3.5
t _s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t _s =	3
V = vehicular hourly volume (veh/hr)		V =	496
$v_{\rm p}$ = pedestrian flow rate (ped/s)	υ _p = 0*	$v_p =$	0.01
v = vehicular flow rate (veh/s) = V/3600	υ = V/3600	υ =	0.200
W_c = crosswalk width (ft)	W _c = 8.0	$W_c =$	6.0
N = number of lanes crossed (Integer)	N = INT(L/11)	N =	2
	*no platoonin	g observed	
0			

Crossing 2:	(only used for two-stage o	crossings)
Evaluation Inputs:	defaults:	Input Table:
L = crosswalk length (ft)		L=
S_p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p =
t_s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t _s =
V = vehicular hourly volume (veh/hr)		V =
$\upsilon_{\rm p}$ = pedestrian flow rate (ped/s)	$v_p = 0^*$	$v_{p} =$
υ = vehicular flow rate (veh/s) = V/3600	υ = V/3600	U =
W_c = crosswalk width (ft)	W _c = 8.0	W _c =
N = number of lanes crossed (Integer)	N = INT(L/11)	N =
	*no platoon	ing observed
Crossing Treatment Yield Rate		Input Table:
M_y = motorist yield rate (decimal)		M _y = 86%

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

Results:

Average Delay	7.3
LOS	В

Inputs and Results

Page 2 of 5

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Crocking I	
Crossing Location:	
City, State:	Scenario:
Reviewer(s):	Agency:
Step 1: Identify	Is there a median available for a two-stage crossing?
Two-Stage	If yes, does the median refuge meet ADA requirements (4' x 4' landing)?
Crossings	If yes, does the median refuge need to meet ADA requirements (4' x 4' landing)?
Step 2: Determine Critical Headway	Critical headway is the time below which a pedestrian will not attempt to begin crossing the street. Pedestrians use judgement to determine whether the available headway is sufficent for a safe crossing. For a single pedestrian: $t_c = \frac{L}{S_p} + t_s$ $t_c = \frac{L}{S_p} + t_s$ $t_c = \frac{L}{S_p} + t_s$ $L = \frac{40}{0.5}$ $t_c = \frac{14.4}{14.4}$ $S_p = \frac{t_c}{S_p} = \frac{t_c}{S_p} = \frac{14.4}{14.4}$ $S_p = \frac{t_c}{S_p} = \frac{14.4}{14.4}$ $S_p = \frac{t_c}{S_p} = \frac{14.4}{14.4}$ $S_p = \frac{t_c}{S_p} = $
	(ped) $W_{c} = crossing 1$ $W_{c} = 1.41$ W_{c}
	$N_p = 1$ $N_p = 1$
	$t_c = 14.4$ $t_{c,G} = 14.4$ $t_c = t_{c,G} = 14.4$
Step 3: Estimate	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. $\mathbf{P}_{b} = 1 \cdot e^{-\mathbf{t}_{c,G} v/N}$ where: $\mathbf{P}_{b} = \text{probability of blocked lane}$ $\mathbf{P}_{d} = \text{probability of delayed crossing}$
Probability of a Delayed	$P_d = 1 - (1-P_b)^N$ $T_{c,G} = group critical headway (s) = t_c, if no platooning$
Crossing	crossing 1 crossing 2 v = vehicular flow rate across crossing(veh/s)
	$ \begin{array}{c} \mathbf{t}_{c,G} = & 14.4 \\ \upsilon = & 0.2 \\ \mathbf{N} = & 2 \end{array} \begin{array}{c} \mathbf{P}_{b} = & 0.76 \\ \mathbf{P}_{d} = & \mathbf{P}_{b} = \\ \mathbf{N} = & \mathbf{P}_{d} = \end{array} \begin{array}{c} \mathbf{P}_{b} = & \mathbf{P}_{b} = \\ \mathbf{P}_{d} = & \mathbf{P}_{d} = \end{array} $

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HCM Evaluation Worksheet



LIULD										
	Ave	erage delay assume	s that no	motor vel	hicles yi	eld and	the ped	estrian is forced to w	vait for an adequ	uate gap.
		. 1 . 24					where:	d _g = average pedest	trian gap delay (s	5)
		$d_g = \frac{1}{v} (e^{vt_{c_s}})$	$^{\mathrm{s}}$ - $v \mathbf{t}_{c,G}$	- 1)				t _{c,G} = group critical		
		crossing 1			cross	ing 2		v = vehicular flow r		ing (veh/s)
Step 4: Calculate	t _{c,G} =			t _{c,G} =						
Average Delay	υ=	<u></u>	70.153	υ=		d _g =				
to Wait for		Average delay fo	-					ediately upon reachi	ng the intersect	ion
Adequate Gap		d	(e	e.g., any po	edestria		where:	nonzero delay.)	alay for podoctri	ang who ingur
		$d_{gd} = \frac{d_g}{P_d}$					where.	d _{gd} = average gap d nonzero delay	elay for pedestri	ans who mean
		crossing 1			cross	ing 2		d _g = average pedest	trian gap delay (s	5)
	d _g =	70.15		d _g = P _d =		0		P _d = probability of a		
	P _d =	0.944 d _{gd} =	74.3	P _d =		d _{gd} =				
	Whe	n a pedestrian arriv	ves at a ci	rossing an	d finds a	an inad	lequate g	ap, that pedestrian i	s delayed until o	one of two
							•	ilable, or (b) motor v	•	
				-			-	rossing pedestrians i		-
					-			torist yield rates actu		erably.
		-	nd yield r	ates based	d on rese	earch a		ed on the next page.		
	Average	pedestrian delay n			n		where	: d _p = average pedest <i>i</i> = crossing event (
		$d_{p} = \sum_{i=1}^{n} h(i - 0)$.5)P(Y _i) + (P _d - 2	$P(Y_i)$))d _{gd}		h = average headwa		rgh lane = N/2
Step 5: Estimate		<i>i</i> =1			i=1	-		$P(Y_i)$ = probability		
Delay Reduction		crossing 1			cross	ing 2		pedestrian on cross		
due to Yielding	h =	10.0 <i>n</i> =	7	h = #			######	$n = \text{Int}(d_{gd}/h)$, aver	age number of c	rossing
Vehicles		d _p =	7.3					events before an ad		
	1. One-L	ane Crossing						j = crossing event (,	
(If yielding is		$P(Y_i) = P_d M_u (1-I)$	М _и) ⁱ⁻¹					$P(Y_j) = \text{probability}$		rield to
zero, then skip step 5)		- 0	9.		- mot	orict vi	eld rate (d	pedestrian on cross		1
step 5)		ane Crossing			~			*	86%	1
		$P(Y_1) = 2P_b(1-P_b)$	M_y +1 P_b	² M _y ²	F	$P(Y_i) = \sum_{i>1}^{n}$	$P_d - \sum_{i=0}^{n} P_i$	$P(Y_j)\left[\frac{(2P_b(1-P_b)M_y)+P_d}{P_d}\right]$	(P _b -M _y -)	
		-Lane Crossing					[]=0]		
		$P(Y_i) = [P_d - \sum_{i=0}^{i-1} P(i)]$	P_b	$^3M_y^3 + 3P_b$	$p^2(1-P_b$	$(M_y^2) +$	3P _b (1 - 1	$(P_b)^2 M_{y_1}$	Sumr	nary
		$\prod_{j=0}^{n} \left(\prod_{j=0}^{n} \left(\prod_{j=0}^{n} \right)^{j} \right) \right)$	∙рл∗∟			P_d		1	Average	7.3
		ane Crossing							LOS	В
		$P(Y_i) = \left[P_d - \sum_{i=1}^{i-1} P(i)\right]$	$(Y_{\bar{I}})] * [\frac{P_b}{P_b}]$	${}^4M_y{}^4 + 4P_l$	$b^{3}(1 - P_{b})$	$(M_y^3) +$	$+6P_b^2(1-P_d)$	$(P_b)^2 M_y^2) + 4P_b(1-P_b)$	$\frac{(b^3)M_y}{m_y}$]	
	LOS	Control Delay (s						Comments		
Step 6: Calculate	A	0-5		Usually n	o conflic	ting tra	affic			
Average	B	5-10		,		0		onflicting traffic		
Pedestrian Delay	C	10-20						out not inconvienenc	ing	
& Determine LOS	D	20-30		Delay not	iceable/	/irritati	ng, increa	sed chance of risk-ta	iking	
103	E	30-45		Delay app	proaches	s tolera	ince level	, risk-taking likely		
	F	>45		Delay exc	eeds to	erance	e level, hig	h chance of risk-taki	ng	
				Cal	culatio	ns She	et 2			Page 4 of 5

Calculations Sheet 2

Page 4 of 5

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Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations

Intersection and Mid-Block Crossings

Crossing Location:	Example 7	Date:	
City, State:		Scenario:	School Crossing, PM
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:	def	aults:	
L = crosswalk length (ft)			
S_p = average pedestrian walking speed (ft/s)	S _p =	3.5	
t _s = pedestrian start-up and end clearance time (s)	t _s =	3.0	
V = vehicular hourly volume (veh/hr)			
$v_{\rm p}$ = pedestrian flow rate (ped/s)	$v_n =$	0*	

 υ = vehicular flow rate (veh/s) = V/3600

- W_c = crosswalk width (ft)
- N = number of lanes crossed (Integer)

defaults:		Input	Table:
		L =	40
$S_p = 3.5$ $t_s = 3.0$		S _p = t _s =	3.5
t _s = 3.0		t _s =	3
		V =	521
$v_{p} = 0^{*}$ v = V/3600		$v_p =$	0.00
υ = V/3600		υ=	0.180
W _c = 8.0		$W_c =$	6.0
N = INT(L/11)		N =	2
*no plat	tooning	observed	

Crossing 2: (only used for two-stage crossings) Input Table: Evaluation Inputs: defaults: L = crosswalk length (ft) L = S_p = average pedestrian walking speed (ft/s) 3.5 $S_p =$ $S_p =$ t_s = pedestrian start-up and end clearance time (s) t_s = 3.0 t_s = V = vehicular hourly volume (veh/hr) V = 0* v_p = pedestrian flow rate (ped/s) $v_p =$ $v_p =$ v = vehicular flow rate (veh/s) = V/3600 υ= V/3600 2) = W_c = crosswalk width (ft) $W_c =$ 8.0 $W_c =$ N = number of lanes crossed (Integer) INT(L/11 N = N = *no platooning observed **Crossing Treatment Yield Rate** Input Table: M_v = motorist yield rate (decimal) M₂₁ = 86%

y , , ,

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

Results:

Average Delay	7.9
LOS	В

Inputs and Results

Page 2 of 5

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Judgement to determine whether the available headway is sufficent for a safe crossin For a single pedestrian:For a single pedestrian:where: $t_{c} = ritical headway for a single pedt_{c} = \frac{t}{2_{b}} + t_{c}t_{c} = \frac{t}{2_{b}} + t_{c}b_{c} = crossing 2t_{c} = \frac{t}{2_{b}} - \frac{t}{2_{c}} = $	LRRB	
Agency:Agency:Step 2:CrossingsIf yes, does the median refuge meet ADA requirements (4' x 4' landing)?CrossingsCritical headway is the time below which a pedestrian will not attempt to begin crossing the term below which a pedestrian will not attempt to begin crossing the term below which a pedestrian wallable headway is sufficient for a single pedestrian:where: t, = critical headway for a single pedestrian:where: t, = pedestrian walking spectors ing tcrossing 1t, = pedestrian platooning is observed, the spatial distribution of pedestrians should be computed:1. use field observations or estimate platoon size using equation:Net $\frac{v_{p}e^{-v_{p}+v_{k}+ve^{-v_{k}+v}}{(v_{p}+v)e^{0/v_{p}+v_{k}+ve^{-v_{k}+v}}}$ Crossing 1v, = erossing 1Ne =Step 3: EstimateProbability that a pedestrian will not incur any crossing 2	Crossing Location	Date:
Step 1: Identify Two-Stage CrossingsIs there a median available for a two-stage crossing? If yes, does the median refuge meet ADA requirements (4' x 4' landing)? If yes, does the median refuge meet ADA requirements (4' x 4' landing)? If yes, does the median refuge need to meet ADA requirements (4' x 4' landing)? Critical headway is the time below which a pedestrian will no a tetrmpt to begin crossing the street. Judgement to determine whether the available headway is sufficent for a safe crossin for a single pedestrian: where: t_c = critical headway for a single pedestrian walking spectrossing 1 $t_c = \frac{t_c}{S_p} = \frac{t_c}{2}$ $t_c = \frac{t_c}{2} = $		Scenario:
Two-StageIf yes, does the median refuge neet ADA requirements (4' x 4' landing)?CrossingsIf yes, does the median refuge neet to meet ADA requirements (4' x 4' landing)?Critical headway is the time below which a pedestrian will not attempt to begin crossing the street.judgement to determine whether the available headway is sufficent for a single pedestrian:Where: t_ = critical headway for a single pedestrianWhere: t_ = critical headway for a single pedestrian start-up and end cleart_ = $\frac{1}{S_p} + t_s$ Crossing 2L = $\frac{40}{40}$ t_ = $\frac{1}{2}$ L = $\frac{1}{40}$ L = $\frac{1}{4$	Reviewer(s):	Agency:
CrossingsIf yes, does the median refuge need to meet ADA requirements (4' x 4' landing)?Critical headway is the time below which a pedestrian will not attempt to begin crossing the street. judgement to determine whether the available headway is sufficent for a safe crossin For a single pedestrian: 	Step 1: Identify	Is there a median available for a two-stage crossing?
Critical headway is the time below which a pedestrian will not attempt to begin crossing the street. judgement to determine whether the available headway is sufficient for a single pedestrian: where: $t_c = critical headway for a single pedestrian:t = \frac{t}{5_p} = t,t_c = t,t_c = \frac{t}{5_p} = t,t_c = t,t_c = \frac{t}{5_p} = t,$	Two-Stage	If yes, does the median refuge meet ADA requirements (4' x 4' landing)?
Judgement to determine whether the available headway is sufficent for a safe crossin For a single pedestrian:Where: $t_{z} = critical headway for a single pedestriant_ = \frac{L}{2}, L$	Crossings	If yes, does the median refuge need to meet ADA requirements (4' x 4' landing)? 🛛 🗌 Yes 🗌 No
Step 3: Estimate Probability of a Delayed $P_b = 1 - e^{-t_{c,G}v/N}$ where: $P_b = probability of blocked laneP_d = probability of delayed crossingN = number of lanes crossedt_{c,G} = group critical headway (s) = t_{c,G}$	Determine	$t_{c} = \frac{L}{S_{p}} + t_{s}$ $L = crosswalk length (ft)$ $S_{p} = average pedestrian walking speed (ft/s)$ $t_{s} = pedestrian start-up and end clearance time (s)$ $S_{p} = 3.5 \text{ ft/s}$ $t_{s} = 3 \text{ sec}$ If pedestrian platooning is observed, the spatial distribution of pedestrians should be computed: 1. use field observations or estimate platoon size using equation: $N_{c} = \frac{U_{p}e^{U_{p}t_{v}} + Ue^{-Ut_{c}}}{(U_{p} + U)e^{(U_{p} + U)t_{c}}}$ where: $N_{c} = \text{total number of pedestrians in crossing platoon (ped)}$ $U_{p} = \text{pedestrian flow rate (ped/s)}$ $U_{p} = \frac{U_{p}e^{U_{p}t_{v}} + Ue^{-Ut_{c}}}{U_{p} + U)e^{(U_{p} + U)t_{c}}}$ where: $N_{c} = \text{total number of pedestrians in crossing platoon (ped)}$ $U_{p} = \text{pedestrian flow rate (ped/s)}$ $U_{p} = \text{lost}\left[\frac{B.O(N_{c}-1)}{W_{c}}\right] + 1$ where: $N_{p} = \text{spatial distributions of pedestrians in crossing platoon (ped)}$ $N_{c} = 1.22$ $W_{c} = 0$ $N_{p} = 1$ $W_{c} = N_{p} = 1$ $W_{c} = N_{p} = 1$ $W_{c} = 0$
Delayed $P_d = 1 - (1-P_b)$ $t_{c,G} = \text{group critical headway (s)} = t_{c,F}$		$P_{b} = 1 - e^{-t_{c,c} \omega/N}$ where: P_{b} = probability of blocked lane
Crossing crossing 1 crossing 2 v = vehicular flow rate across crossin	Delayed	$\mathbf{P}_{d} = 1 - (1 - \mathbf{P}_{b})^{T}$ $\mathbf{t}_{c,G} = \text{group critical headway (s)} = \mathbf{t}_{c,i} \text{ if no platooning}$
$ \begin{array}{c} t_{c,G} = 14.4 \\ \upsilon = 0.18 \\ N = 2 \end{array} \begin{array}{c} t_{c,G} = \\ \upsilon = 0.73 \\ P_{d} = 0.93 \end{array} \begin{array}{c} t_{c,G} = \\ \upsilon = \\ P_{b} = \\ P_{d} = \\ P_{d} = \\ \end{array} $	Crossing	$t_{c,G} = 14.4$ $v = 0.18$ $P_b = 0.73$ $v = P_b = 0.73$

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HCM Evaluation Worksheet



LIUID										
	Ave	rage delay assume	es that no	motor ve	hicles yi	ield and	the ped	estrian is forced to w	vait for an adequ	uate gap.
		1 , <i>v</i> t					where:	d _g = average pedest	trian gap delay (s	5)
		$d_g = \frac{1}{v} (e^{vt})$	$v_{c,G}$ - $v_{c,G}$	- 1)				t _{c,G} = group critical		
		crossing 1		_	cross	sing 2		v = vehicular flow r	rate across cross	ing (veh/s)
Step 4: Calculate	t _{c,G} =	14.43		t _{c,G} =						
Average Delay	υ=	6	54.601			d _g =				
to Wait for		Average delay for	-					ediately upon reachi	ng the intersect	ion
Adequate Gap			(e	.g., any p	edestria	-	where:	nonzero delay.)	alau fan wadaatui	ana wha in our
		$d_{gd} = \frac{a_g}{P_d}$					where.	d _{gd} = average gap d nonzero delay	elay for pedestri	ans who incur
		crossing 1			cross	sing 2		d _g = average pedest	trian gap delay (s	5)
	d _g =	54.6		d, =				$P_d = probability of a$		
	°	0.926 d _{gd} =	58.995	$P_d =$		d _{gd} =				-
	Whe					an inad	lequate g	ap, that pedestrian i	s delayed until o	one of two
							-	ilable, or (b) motor v	-	
	-			-			-	rossing pedestrians i		-
					-			torist yield rates actu		erably.
		Some crossing treatments and yield rates based on research are provided on the next page.								
	Average	Average pedestrian delay where: d_p = average pedestrian delay (s)								
		$\mathbf{d}_{\mathbf{p}} = \sum_{i=1}^{n} h(i - 0.5) P(Y_i) + (\mathbf{P}_{d} - \sum_{i=1}^{n} P(Y_i)) \mathbf{d}_{gd} $ i = crossing event (i = 1 to n) h = average headway for each through lane = N/2								
Step 5: Estimate		<i>i</i> =1			i=1	-		$P(Y_i)$ = probability	,	° ,
Delay Reduction		crossing 1			cross	sing 2		pedestrian on cross		
due to Yielding	h =	11.1 <i>n</i> =	5	h = #	####	<i>n</i> =	#######	$n = \text{Int}(d_{gd}/h)$, aver	age number of c	rossing
Vehicles		d _p =	7.9					events before an ac		
	1. One-La	ane Crossing						j = crossing event (r .	
(If yielding is		$P(Y_i) = P_d M_y(1-$	M ₂₁) ⁱ⁻¹					$P(Y_j) = \text{probability}$		rield to
zero, then skip		Ŭ	g,					pedestrian on cross		1
step 5)		ane Crossing			~		eld rate (d	•	86%	1
		$P(Y_1) = 2P_b(1-P_b)$)M _y +1P _b	$^{2}M_{y}^{2}$	F	$P(Y_i) =$	$P_d - \sum I$	$P(Y_j)\left[\frac{(2P_b(1-P_b)M_y)+P_d}{P_d}\right]$	$(P_b^*M_y^*)$	
		Lane Crossing					[j=0], "		
			Pb	${}^{3}M_{y}{}^{3} + 3P_{b}$	$^{2}(1-P_{b})$	$(M_y^2) +$	3P _b (1 - 1	$(P_b)^2 M_{y_b}$	Sumr	nary
		$P(Y_i) = [P_d - \sum_{j=0}^{t-1} P_j]$	(Y _{j)})] * [P _d]	Average	7.9
	4. Four-L	ane Crossing							LOS	В
		$P(Y_i) = [P_i - \sum_{j=1}^{i-1} P_j]$	$P(Y_{0})] * [\frac{P_{b}}{P}]$	${}^{4}M_{y}{}^{4} + 4P_{1}$	$b^{3}(1-P_{i})$	$M_{y}^{3}) +$	+ 6P _b ² (1 -	$(P_b)^2 M_y^2) + 4P_b(1-P_b)^2$	$(b^3)M_y$	
			(-))/1 (-				P_d		,	
	LOS	Control Delay (s	ec/ped)					Comments		
Step 6: Calculate	A	0-5		Usually n	o confli	cting tra	affic			
Average	B	5-10		,				onflicting traffic		
Pedestrian Delay	C	10-20						out not inconvienenc	ing	
& Determine LOS	D	20-30		Delay not	iceable	/irritati	ng, increa	sed chance of risk-ta	iking	
105	E	30-45		Delay app	oroache	s tolera	ince level	, risk-taking likely		
	F	>45		Delay exc	eeds to	lerance	e level, hig	h chance of risk-taki	ng	
				Cal	culatio	ns She	et 2			Page 4 of 5

Calculations Sheet 2

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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.

			Uncol	ntrolled P	e <mark>destr</mark> iar	Crossing	1				
IRRB			Da	ta Collect	ion Worl	ksheet					
Location:		Exar	nple 8		Date:						
City, State:					Scenario:						
Reviewer(s):					Agency:						
Project #:					ID #:						
	The first step	o in underst	anding the pe	edestrian nee	ds at a pote	ential crossi	ng location is	comple	ting		
			a review of	the location	and adjace	nt facilities.					
	–	-	re the crossin	0			Crossing 1	75	5	ft.	
		0	e if there is no		nere is a me	edian at the	Crossing 2			ft.	
	_		Crossing 1 and							1.	
		Aedian: width of median at crossing location 0 ft.									
	-		e crosswalk w	idth				8		ft.	
	Raised Med								Yes	\checkmark	No
S			nt Median Ava	ailable (minir	num 4' x 4'	landing)?			Yes	\checkmark	No
etri	Curb Ramp								Yes		No
Geometrics		DA Complia	nt Curb Ramp	Available (w					Yes		No
Geo	Speed:					85 th percent		35		mph	
			Sight Distant		-	alking speed	1	4.1		ft/s	
		-	within a hori			, 			Yes	1	No
			e following are			6					
			ight Distance		246	ft.	provided?		Yes		No
			ight Distance		075	ft.	provided?		Yes		No
			Sight Distanc	. ,	975	ft. ft.	provided?	\checkmark	Yes		No
			Sight Distanc		to incromo		provided?		Yes		No
Traffic and	Attach Counts		nicles:	Daily	8,400		estrians:		Daily		
Pedestrian	AM Peak	Hourly	402	Pk 15-min	140	Hourly		Pk 15		1	2
Data	PM Peak	Hourly	585	Pk 15-min	180	Hourly	4	Pk 15			3
	Lighting:	110 0.11	000	1120	200	nearry		11120			
		nting prese	nt and does it	light the cro	sswalk loca	tion?		1	Yes		No
	Crosswalk Pa	vement Ma	arkings:	Is the pede	strian cros	sing current	ly marked?		Yes	\checkmark	No
	What is the	condition	of the marking	gs?	[Excellent	Good		Fair		Poor
S		Are the ma	arkings easily	defined?					Yes		No
isti		Do they ne	ed replaceme	ent?					Yes		No
ctel		What is the	e crosswalk m	arking patte	rn?						
ara	Signing:	Currently s	igned at cross	swalk?					Yes	\checkmark	No
S		Currently s	igned in adva	nce of cross	valk?	_			Yes		No
site		Distances?	1	direction 1		ft.	direction 2			ft.	
al	Enhancemen	ts:	What enhanc	ements are c	urrently at						
Additional Site Characteristics			the crossing lo								
ddi	Adjacent Fac		Distance to ne		d crosswall	?		3,2	50	ft.	
۲			ol devices are				Traffic Signal				
		•	t marked cros		L					6	
			-way stop, rou		-			3,2		ft.	
			serve the same		+				Yes		No
	Could anot	ner location	serve the the	e movement	more effec	tively?			Yes	\checkmark	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 orgins and destinations.

draw or insert map of location being studied No Truncated Dome/ Curb Cut SSD/PedSD Met **Crossing Location** SSD Met, PedSD Not Met No Truncated Dome/ Curb Cut Notes: Crossing location currently unmarked and unsigned. No ped Sight Distance Calculations: where: defaults: Stopping sight distance (SSD), ft = 1.47St + 1.075S²/a t = brake reaction time, s 2.5 Pedestrian sight distance (PedSD), ft = 1.47S(L / S_a + t_s) a = deceleration rate, ft/s² 11.2 Sp = average pedestrian walking speed, ft/s 3.5

where: S = design speed, mph L = length of crossing, ft

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 $t_{\rm s}$ = pedestrian start-up and end clearance time, ${\rm s}$

3.0

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

$$SSD = 246 ft$$

 $PedSD = 975 ft$

The SSD and PedSD are met for this crossing.

HCM Analysis

AM Peak Hour

Yield Rate = 0%Delay = $110 \ sec = LOS \ F$

PM Peak Hour

Yield Rate = 0%Delay = $202 \ sec = LOS \ F$

<u>Review Origins and Destinations, Alternative Routes</u> *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.

<u>Access Spacing and Functional Classification</u> 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.

Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations

Intersection and Mid-Block Crossings

Crossing Location:	Example 8	Date:	
City, State:		Scenario:	AM 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:	defaults:	Input	Table:
L = crosswalk length (ft)		L =	75
S _p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p =	4.7
t _s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t _s =	3
V = vehicular hourly volume (veh/hr)		V =	402
$\upsilon_{ m p}$ = pedestrian flow rate (ped/s)	υ _p = 0*	$v_{p} =$	0.00
v = vehicular flow rate (veh/s) = V/3600	υ = V/3600	υ =	0.160
W_c = crosswalk width (ft)	W _c = 8.0	$W_c =$	8.0
N = number of through lanes crossed (Integer)	N = INT(L/11)	N =	4
	*no platoon	ng observed	
Crossing 2:	(only used for two-stage o	rossings)	

Crossing 2: (only used for two-stage crossings)					
Evaluation Inputs:	defaults:	Input Table:			
L = crosswalk length (ft)		L =			
S _p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p =			
t_s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t _s =			
V = vehicular hourly volume (veh/hr)		V =			
$\upsilon_{ m p}$ = pedestrian flow rate (ped/s)	υ _p = 0*	U _p =			
υ = vehicular flow rate (veh/s) = V/3600	υ = V/3600	U =			
W_c = crosswalk width (ft)	W _c = 8.0	W _c =			
N = number of lanes crossed (Integer)	N = INT(L/11)	N =			
	*no platooni	ng observed			
Crossing Treatment Yield Rate		Input Table:			
M_y = motorist yield rate (decimal)		M _y =			

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

Results:

Average Delay	109.9
LOS	F

Inputs and Results

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LRRB	
Crossing Location	:Date:
City, State:	Scenario:
Reviewer(s):	Agency:
Step 1: Identify	Is there a median available for a two-stage crossing?
Two-Stage	If yes, does the median refuge meet ADA requirements (4' x 4' landing)?
Crossings	If yes, does the median refuge need to meet ADA requirements (4' x 4' landing)?
Step 2: Determine Critical Headway	Critical headway is the time below which a pedestrian will not attempt to begin crossing the street. Pedestrians use judgement to determine whether the available headway is sufficent for a safe crossing. For a single pedestrian: $t_c = \frac{L}{S_p} + t_s$ $t_c = \frac{L}{S_p} + t_s$ $t_c = \frac{L}{S_p} + t_s$ $t_c = \frac{L}{S_p} + t_s$ $L = \frac{75}{S_p} = \frac{4.7}{4.7}$ $t_c = \frac{19}{19}$ $S_p = \frac{t_c}{S_p} = \frac{t_c}{S_p} = \frac{1}{S_p} = \frac{1}{S_p}$
	$t_{c,G} = t_c + 2(N_p-1)$ $t_c = single pedestrian critical headway (s)$ $crossing 1$ $N_p = spatial distributions of pedestrians (ped)$
	$N_p = $ $t_c = 19$ $t_{c,G} = $ $t_c = $ $t_{c,G} = $ $t_{c,G} = $
	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.
	$P_b = 1 - e^{-t_{c,c}v/N}$ where: $P_b = probability of blocked lane$
Step 3: Estimate	P_d = probability of delayed crossing
Probability of a	$P_d = 1 - (1 - P_b)^N$ N = number of lanes crossed
Delayed	$t_{c,G}$ = group critical headway (s) = t_c , if no platooning
Crossing	$ \begin{array}{ c c c c c } \hline crossing 1 & crossing 2 \\ \hline t_{c,G} = & 19 \\ \hline \upsilon = & 0.16 \\ N = & 4 \\ \end{array} \begin{array}{ c c c c c } \hline t_{c,G} = & & & \\ \hline \upsilon = & P_b = & \\ \hline N = & P_d = & \\ \hline P_d = & \\ \hline \end{array} \begin{array}{ c c } \hline \upsilon = & vehicular flow rate across crossing(veh/s) \\ \hline \upsilon = & P_b = & \\ \hline P_d = & \\ \hline \end{array} \begin{array}{ c c } \hline \upsilon = & vehicular flow rate across crossing(veh/s) \\ \hline \end{array} \end{array} $
	Calculations Sheet 1 Page 3 of 5

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HCM Evaluation Worksheet



Step 4: Calculate Average delay assumes that no motor vehicles yield and the pedestrian is forced to wait for an adequate gap. $d_{x} = \frac{1}{v} \cdot (e^{vr_{x}} - vt_{x,0} - 1)$ where: $d_{x} = average pedestrian gap delay (s)$ $t_{x,0} = group critical headway (s)Step 4: CalculateAverage Delayto Wait forAdequate Gapt_{x,0} = \frac{18.96}{p_{x}}0.16t_{x,0} = 10.16ue vt_{x,0} - 1t_{x,0} = \frac{19.96}{p_{x}}WereAdequate Gapd_{x} = \frac{10.96}{p_{x}}0.16d_{x} = \frac{10.9.56}{p_{x}}0.16d_{x} = \frac{10.9.56}{p_{x}}0.16ue vt_{x,0} - 10.16WereAdequate Gapd_{x} = \frac{10.9.56}{p_{x}}0.16d_{x} = \frac{10.9.56}{p_{x}}1.9.50d_{x} = \frac{10.9.56}{p_{x}}1.9.50$								
$ \begin{array}{ c c c c } \hline c_{ca} = \frac{1}{\sqrt{c}} (e^{-i\omega_{ca}} - 1) \\ \hline c_{ca} = group critical headway (s) \\ \hline crossing 1 \\ \hline c_{ca} = \frac{1}{\sqrt{c}} (e^{-i\omega_{ca}} - 1) \\ \hline c_{ca} = group critical headway (s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline d_{a} = \frac{1}{p_{a}} (104.56) \\ \hline d_{a} = \frac{104.56}{p_{a}} (q_{a} = 0.55) \\ \hline d_{a} = 0.55 \\ \hline$		Ave	rage delay assumes that no	motor vehicles yield an	d the ped	estrian is forced to w	ait for an adequ	ate gap.
$ \begin{array}{ c c c c } \hline c_{ca} = \frac{1}{\sqrt{c}} (e^{-i\omega_{ca}} - 1) \\ \hline c_{ca} = group critical headway (s) \\ \hline crossing 1 \\ \hline c_{ca} = \frac{1}{\sqrt{c}} (e^{-i\omega_{ca}} - 1) \\ \hline c_{ca} = group critical headway (s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline v = vehicular flow rate across crossing (veh/s) \\ \hline d_{a} = \frac{1}{p_{a}} (104.56) \\ \hline d_{a} = \frac{104.56}{p_{a}} (q_{a} = 0.55) \\ \hline d_{a} = 0.55 \\ \hline$			1 , vt.		where:	d _g = average pedesti	rian gap delay (s)
Step 4: Calculate Average DelayAverage Delay to Wait for Adequate Gap $t_{e,g} = 10.4.5$ 			$a_g = \frac{1}{v} (e^{-v_{c,G}} - v_{c,G})$	- 1)		0		
to Wait for Adequate Gap Adequate Gap Adequate Gap $\frac{d_{ga} = \frac{d_{g}}{P_{a}} \qquad \text{where:} d_{ga} = where$			v	v		v = vehicular flow ra	ate across crossi	ng (veh/s)
to Wait for Adequate Gap Adequate Gap Adequate Gap $\frac{d_{ga} = \frac{d_{g}}{P_{a}} \qquad \text{where:} d_{ga} = where$		t _{c,G} =	18.96	t _{c,G} =				
Adequate Gap(e.g., any pedestrian experiencing nonzero delay.) $d_{gl} = \frac{1}{p_{d}}$ where: $d_{gl} = \operatorname{average pedestrian gap delay for pedestrians who incurnonzero delayd_{gl} = \frac{104.6}{p_{d}}d_{gl} = \frac{109.85}{p_{d}}d_{gl} = \frac{1}{p_{d}}d_{gl} = \operatorname{average pedestrian gap delay (s)}p_{e} = porbability of a delayed crossingWhen a pedestrian arrives at a crossing and finds an inadequate gap, that pedestrian is delayed until one of twosituations occurs: (a) a gap greater than the critical headway is available, or (b) motor vehicles yield and allow thepedestrian to cross. While motorists are legally required to stop for crossing pedestrians in MN at all marked crossingand either marked or unmarked crossings at intersections, motority yield rates actually vary considerably.Some crossing treatments and yield rates based on research are provided on the next page.Average headway for each through lane = N/LP_1(Y_1) = probability that motorists yield toP_1(Y_1) = probability that motorists yield toP_1(Y_1) = probability that motorists yield toP_1(Y_1) = probability that motorists yield toP_2(Y_1) = probability that motorists yield toP_2(Y_1) = probability that motorists yield topedestrian on crossing event ih = \frac{1}{p_1} = \frac{1}{p_1} + \frac{1}{p_2} \frac{1}{p_2} \left[\frac{p_1(Y_1) - p_1(P_1)}{p_2} + \frac{p_2(Y_1) - probability that motorists yield topedestrian on crossing event jStep 5:2. Two-Lane CrossingM_y = motorist yield rate (decimal) M_y = \frac{1}{p_2} + \frac{1}{p_2} (1 - p_2)M_y^2 + 4P_0(1 - P_0)^2M_z^2) + 4P_0(1 - P_0^2M_y^2) + $	- · ·	υ =				J		
$\frac{d_{xd} = \frac{d_{x}}{p_{d}}}{crossing 1}$ $\frac{d_{y} = \frac{104.6}{p_{d}}}{d_{y} = \frac{109.6}{p_{d}}}$ $\frac{d_{y} = \frac{104.6}{p_{d}}}{d_{y} = \frac{109.6}{p_{d}}}$ $\frac{d_{y}}{p_{d}} = \frac{104.6}{p_{d}}}{d_{y} = \frac{109.6}{p_{d}}}$ $\frac{d_{y}}{p_{d}} = \frac{104.6}{p_{d}}}{d_{y} = \frac{109.6}{p_{d}}}$ $\frac{d_{y}}{p_{d}} = \frac{104.6}{p_{d}}}{d_{y}} = \frac{109.8}{p_{d}}$ $\frac{d_{y}}{p_{d}} = \frac{109.6}{p_{d}}}{d_{y}} = \frac{109.8}{p_{d}}$ $\frac{d_{y}}{p_{d}} = \frac{109.6}{p_{d}}}$ $\frac{d_{y}}{p_{d}} = \frac{109.6}{p_{d}}$ $\frac{d_{y}}{p_{d}} = \frac{109.6}{p_{d}}$ $\frac{d_{y}}{p_{d}} = \frac{109.6}{p_{d}}}$ $\frac{d_{y}}{p_{d}} = \frac{109.6}{p_{d}}$ $\frac{d_{y}}{p_{d}} = \frac{109.6}{p_{d}}}$ $\frac{d_{y}}{p_{d}} = \frac{100.6}{p_{d}}}$ $\frac{d_{y}}{p_{d}} = \frac{100.6}{p_{d}} = \frac{100.9}{p_{d}} = \frac{100.9}{p_{d}} = \frac{100.9}{p_{d}} = \frac{100.9}{p_{d}} = \frac{100.9}{p_{d}} = \frac{100.9}{p$			• • •				ng the intersecti	on
$\frac{\mathbf{d}_{gd} = \frac{\mathbf{p}_{d}}{\mathbf{p}_{d}} \qquad \text{nonzero delay} \qquad \text{nonzero delay} \qquad \text{nonzero delay} \qquad \mathbf{d}_{g} = \text{average pedestrian gap delay (s)} \\ \mathbf{d}_{g} = \frac{104.6}{0.952} \qquad \mathbf{d}_{g} = \frac{109.85}{\mathbf{p}_{g}} \qquad \mathbf{d}_{g} = \frac{100.65}{\mathbf{p}_{g}} \qquad \mathbf{d}_{g} = \frac{100.65}{$	Adequate Gap			e.g., any pedestrian exp	-		alay for podestri	ns who incur
$\frac{1}{d_{g}} = \frac{104.6}{0.952} \qquad d_{g} = \frac{109.85}{p_{d}} \qquad d_{g} = \frac{109.95}{p_{d}} \qquad d_{g} = 109.$			$d_{gd} = \frac{d_g}{P_d}$		where.	0	ay tor pedestrik	ins who mean
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$			crossing 1	crossing 2		- '	rian gap delay (s)
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. 		d _g =	104.6	d _g =		0		
Step 5: Estimate Delay Reduction due to Yielding Vehicles $n = \frac{n}{p_e} \frac{1}{p_e} \frac{1}{p$		P _d =	0.952 d _{gd} = 109.85	P _d = d _{gd} =				
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, motrist yield rates actually vary considerably. Some crossing treatments and yield rates based on research are provided on the next page. Average pedestrian delay $d_{p} = \sum_{i=1}^{n} h_{i}(i - 0.5)P(Y_{i}) + (P_{d} - \sum_{i=1}^{n} P(Y_{i}))d_{gd}$ $d_{p} = \sum_{i=1}^{n} h_{i}(i - 0.5)P(Y_{i}) + (P_{d} - \sum_{i=1}^{n} P(Y_{i}))d_{gd}$ $h = average headway for each through lane = N/n.$ $P(Y_{i}) = probability that motorists yield toP(Y_{i}) = P(Y_{i}) = P_{a}(P_{a}(Y_{i}))^{1/2}P(Y_{i}) = P_{a}(P_{a}(Y_{i})) = P_{a}(P_{a}(Y_{i}) = P_{a}(P_{a}(Y_{i})) = P_{a}(P_{$		Whe	n a pedestrian arrives at a c	rossing and finds an ina	dequate g	ap, that pedestrian is	delayed until o	ne of two
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 $d_p = \sum_{i=1}^{n} h_i(i \circ 0.5) P(Y_i) + (P_d - \sum_{i=1}^{n} P(Y_i)) d_{gd}$ where: $d_i = average pedestrian delay (s)$ $i = crossing event (i = 1 to 7:)$ $h = average headway for each through lane = N/t.P(Y_i) = probability that motorists yield toP(Y_i) = probability that motorists yield topedestrian on crossing event (i = 1 to 7:)h = average headway for each through lane = N/t.P(Y_i) = probability that motorists yield toP(Y_i) = probability that motorists yield topedestrian on crossing event (i = 1 to 7:)h = average headway for each through lane = N/t.P(Y_i) = probability that motorists yield topedestrian on crossing event (i = 1 to 7:)h = average headway for each through lane = N/t.P(Y_i) = probability that motorists yield topedestrian on crossing event (i = 1 to 7:)P(Y_i) = probability that motorists yield topedestrian on crossing event (j = 1 to 7:)P(Y_i) = probability that motorists yield topedestrian on crossing event (j = 1 to 7:)P(Y_i) = probability that motorists yield topedestrian on crossing event (j = 1 to 7:)P(Y_i) = probability that motorists yield topedestrian on crossing event (j = 1 to 7:)P(Y_i) = probability that motorists yield topedestrian on crossing event (j = 1 to 7:)P(Y_i) = probability that motorists yield topedestrian on crossing event (j = 1 to 7:)P(Y_i) = probability that motorist yield rate (decimal) M_{ij} = 0P(Y_i) = P_i P_i P_i P_i P_i P_i P_i P_i P_i P_i$		I						
Some crossing treatments and yield rates based on research are provided on the next page. Average pedestrian delay $d_p = \sum_{i=1}^{n} h(i-0.5)P(Y_i) + (P_d - \sum_{i=1}^{n} P_i(Y_i))d_{gd}$ $h = \operatorname{average pedestrian delay(s)}$ $i = \operatorname{crossing event} (i = 1 \text{ on })$ $h = \operatorname{average pedestrian delay(s)}$ $i = \operatorname{crossing event} (i = 1 \text{ on })$ $h = \operatorname{average pedestrian on crossing event i$ $n = \operatorname{int} d_{eg}/h), \text{ average number of crossing}$ $P(Y_i) = \operatorname{probability} \text{ that motorists yield to}$ $P(Y_i) = \operatorname{probability} \text{ that motorist yield to}$ $P(Y_i) = \operatorname{probability} \operatorname{that motorist yield to}$ $P(Y_i) = \left[P_a - \sum_{i=1}^{i-1} P(Y_i)\right] \left[\left[\frac{(2P_b(1 - P_b)M_b)}{P_a} + \left(\frac{P_b^2M_b^2}{P_a} \right] \right]$ 3. Three-Lane Crossing $P(Y_i) = \left[P_a - \sum_{i=0}^{i-1} P(Y_i)\right] + \left[\frac{P_b^2M_b^2 + 3P_b^2(1 - P_b)M_b^2}{P_a} + \frac{P_b^2(1 - P_b)^2M_b^2}{P_a} \right]$ $P(Y_i) = \left[P_a - \sum_{i=0}^{i-1} P(Y_i)\right] + \left[\frac{P_b^2M_b^2 + 4P_b^3(1 - P_b)M_b^2}{P_a} + \frac{P_b^2(1 - P_b)^2M_b^2}{P_a} + \frac{P_b^2(1 - P_b)^2M_b^2}{P_a} \right]$ 4. Four-Lane Crossing $P(Y_i) = \left[P_a - \sum_{i=0}^{i-1} P(Y_i)\right] + \left[\frac{P_b^4M_b^4 + 4P_b^3(1 - P_b)M_b^2}{P_a} + \frac{P_b^2(1 - P_b)^2M_b^2}{P_a} + \frac{P_b^2(1 - P_b)^2M_b^2}{P_a} \right]$ 4. Four-Lane Crossing $P(Y_i) = \left[P_a - \sum_{i=0}^{i-1} P(Y_i)\right] + \left[P_b^4M_b^4 + 4P_b^$		I		• • •	•	•••		-
Average pedestrian delaywhere: $d_p = average pedestrian delay$ (s) $d_p = \sum_{i=1}^{n} h(i - 0.5) P(Y_i) + (P_q - \sum_{i=1}^{n} P(Y_i)) d_{gd}$ $i = crossing event (i = 1 to n_i)$ $h_e = crossing 1$ $h = \sum_{i=1}^{n} h_e = n_e$ $h = n_e = n_e$ <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th>ally vary conside</th> <th>erabiy.</th>							ally vary conside	erabiy.
Image: Step 5: EstimateImage: Step 5: EstimateDelay Reduction due to Yielding VehiclesCrossing 1 $h = m = n = n = n = n = n = n = n = n = n$								
Step 5: EstimateDelay Reduction due to Yielding Vehicles $d_p = \sum_{i=1}^{b} h(i-0.5)P(Y_i) + (P_d - \sum_{i=1}^{p} P(Y_i))d_{xd}$ $h = average headway for each through lane = N/2P(Y_i) = probability that motorists yield toP(Y_i) = probability that motorists yield toUsing iszero, then skipstep 5)1. One-Lane CrossingP(Y_i) = P_d M_y (1-M_y)^{i-1}P(Y_i) = P_d M_y (1-M_y)^{i-1}P_dP(Y_i) = P_d M_y (1-M_y)^{i-1}P(Y_i) = P_d M_y (1-M_y)^{i-1}P_dStep 5:2. Two-Lane CrossingP(Y_i) = (P_d - \sum_{j=0}^{i-1} P(Y_p)) + (\frac{P_b^3 M_y^3 + 3P_b^2 (1-P_b)M_y^2) + 3P_b (1-P_b)^2 M_y}{P_d}SummaryAverage 109.9LOS FAverageP(Y_i) = [P_d - \sum_{j=0}^{i-1} P(Y_p)] + (\frac{P_b^4 M_y^4 + 4P_b^3 (1-P_b)M_y^2) + 6P_b^2 (1-P_b)^2 M_y^2) + 4P_b (1-P_b^3)M_y}{P_d}SummaryAverage 109.9LOS FStep 6: CalculateAveragePedestrian DelayRO -5O ccasionally some delay due to conflicting trafficP_dAveragePedestrian DelayRO -5O ccasionally some delay due to conflicting trafficP_dD20-30E = 30-45Delay approaches tolerance level, risk-taking likely$		Average			where			
Step 5: EstimateDelay Reduction due to Yielding Vehicles $h = 1$ $n = 1$ $p = 1$			$\mathbf{d}_{\mathbf{p}} = \sum h(i - 0.5) P(Y_i)$) + (\mathbf{P}_{d} - $\sum P(Y_{i})$)d _{gd}				gh lane = N/ v
due to Yielding Vehicles h = n = h = n = n = n = n = n = n = n =	Step 5: Estimate		2=1	2=1		$P(Y_i)$ = probability	that motorists y	ield to
Vehicles $d_p =$ $d_p =$ events before an adequate gap is available, >0(If yielding is zero, then skip1. One-Lane Crossing $j = \operatorname{crossing} event (j=0 to i-1)$ $P(Y_i) = P_d M_y (1-M_y)^{i-1}$ probability that motorists yield to pedestrian on crossing event j 2. Two-Lane Crossing $M_y = \operatorname{motorist} yield rate (decimal)$ $U_y =$ $M_y =$ 3. Three-Lane Crossing $P(Y_i) = [P_d - \sum_{j=0}^{i-1} P(Y_j)] + [\frac{P_b^3 M_y^2 + 3P_b^2 (1 - P_b) M_y^2 + 3P_b (1 - P_b)^2 M_y]}{P_d}$ Summary 	Delay Reduction		crossing 1	crossing 2		pedestrian on crossi	ing event i	
(If yielding is zero, then skip step 5) 1. One-Lane Crossing $P(Y_i) = P_d M_y (1-M_y)^{i\cdot 1}$ $P(Y_j) = probability that motorists yield to pedestrian on crossing event j 2. Two-Lane Crossing M_y = motorist yield rate (decimal) M_y = \begin{bmatrix} P_{i}(Y_j) = P_{i}(Y_j) \end{bmatrix} = P_{i}(Y_j) = P_{i}(Y_j) \begin{bmatrix} (2P_{k}(1-P_{k})M_{y}) + (P_{k}^{2}M_{y}^{2}) \\ P_{i=1} \end{bmatrix}3. Three-Lane Crossing P(Y_i) = [P_d - \sum_{j=0}^{i-1} P(Y_j)] + [\frac{P_{b}^{3}M_{y}^{3} + 3P_{b}^{2}(1-P_{b})M_{y}^{2} + 3P_{b}(1-P_{b})^{2}M_{y}]4. Four-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}]5. Uos F 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}]5. Uos F 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}]5. Uos F 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}]5. Uos F 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}]5. Uos F 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}]6. Uos Control Delay (sec/ped) Comments4. O-5 Usually no conflicting trafficA O-5 Usually no conflicting trafficB 5-10 Occasionally some delay due to conflicting trafficD 20-30 Delay noticeable to pedestrians, but not inconvienencingE 30-45 Delay approaches tolerance level, risk-taking likely1. On the observed to the second tolerance level, risk-taking likely1. On the observed to the second tolerance level, risk-taking likely1. On the observed to the second tolerance $	U U	h =	n =			n = Int(d _{gd} /h), avera	age number of ci	ossing
(If yielding is zero, then skip step 5) $P(Y_i) = P_dM_y(1-M_y)^{i-1}$ $P(Y_j) = probability that motorists yield to pedestrian on crossing event j$ 2. Two-Lane Crossing $P(Y_i) = 2P_b(1-P_b)M_y + 1P_b^2M_y^2$ $P(Y_i) = \left[P_d - \sum_{j=0}^{i-1} P(Y_j)\right] \left[\frac{(2P_b(1-P_b)M_y) + (P_b^2M_y^2)}{P_d}\right]$ 3. Three-Lane Crossing $P(Y_i) = [P_d - \sum_{j=0}^{i-1} P(Y_j)] + \left[\frac{P_b^3M_y^3 + 3P_b^2(1-P_b)M_y^2 + 3P_b(1-P_b)^2M_y}{P_d}\right]$ 4. Four-Lane Crossing $P(Y_i) = \left[P_d - \sum_{j=0}^{i-1} P(Y_j)\right] + \left[\frac{P_b^4M_y^4 + 4P_b^3(1-P_b)M_y^3 + 6P_b^2(1-P_b)^2M_y}{P_d}\right]$ 5. Three-Lane Crossing $P(Y_i) = \left[P_d - \sum_{j=0}^{i-1} P(Y_j)\right] + \left[\frac{P_b^4M_y^4 + 4P_b^3(1-P_b)M_y^3 + 6P_b^2(1-P_b)^2M_y^2}{P_d}\right]$ 5. Three-Lane Crossing $P(Y_i) = \left[P_d - \sum_{j=0}^{i-1} P(Y_j)\right] + \left[\frac{P_b^4M_y^4 + 4P_b^3(1-P_b)M_y^3 + 6P_b^2(1-P_b)^2M_y^2}{P_d}\right]$ 5. Three-Lane Crossing $P(Y_i) = \left[P_d - \sum_{j=0}^{i-1} P(Y_j)\right] + \left[\frac{P_b^4M_y^4 + 4P_b^3(1-P_b)M_y^3 + 6P_b^2(1-P_b)^2M_y^2}{P_d}\right]$ 5. Three-Lane Crossing $P(Y_i) = \left[P_d - \sum_{j=0}^{i-1} P(Y_j)\right] + \left[\frac{P_b^4M_y^4 + 4P_b^3(1-P_b)M_y^3 + 6P_b^2(1-P_b)^2M_y^2}{P_d}\right]$ 5. Three-Lane Crossing $P(Y_i) = \left[P_d - \sum_{j=0}^{i-1} P(Y_j)\right] + \left[\frac{P_b^4M_y^4 + 4P_b^3(1-P_b)M_y^3 + 6P_b^2(1-P_b)^2M_y^2}{P_d}\right]$ 5. Three-Lane Crossing $P(Y_i) = \left[P_d - \sum_{j=0}^{i-1} P(Y_j)\right] + \left[\frac{P_b^4M_y^4 + 4P_b^3(1-P_b)M_y^3 + 6P_b^2(1-P_b)^2M_y^2}{P_d}\right]$ 5. Three-Lane Crossing $P(Y_i) = \left[\frac{P_d - \sum_{j=0}^{i-1} P(Y_j)}{P_d}\right]$ 5. Three-Lane Crossing $P(Y_i$	Vehicles		F I	d _p =	:			ailable, >0
$P\{Y_i\} = P_d M_y (1-M_y)^{CL}$ pedestrian on crossing event j pedestrian event j pedete	(If violding io	1. One-La	ane Crossing					old to
step 5) 2. Two-Lane Crossing M_{y} = motorist yield rate (decimal) $M_{y} = \begin{bmatrix} P_{1}(Y_{1}) \\ P_{2}(Y_{1}) \\ P_{3}(Y_{1}) \end{bmatrix} = \begin{bmatrix} P_{1}(Y_{1}) \\ P_{3}(Y_{1}) \\ P_{4}(Y_{1}) \end{bmatrix} \begin{bmatrix} P_{1}(Y_{1}) \\ P_{4}(Y_{1}) \\ P_{4}(Y_{1}) \end{bmatrix} \begin{bmatrix} P_{1}(Y_{1}) \\ P_{4}(Y_{1}) \\ P_{4}(Y_{1}) \end{bmatrix} \begin{bmatrix} P_{1}(Y_{1}) \\ P_{2}(Y_{1}) \\ P_{4}(Y_{1}) \end{bmatrix} \begin{bmatrix} P_{1}(Y_{1}) \\ P_{2}(Y_{1}) \\ P_{4}(Y_{1}) \end{bmatrix} \begin{bmatrix} P_{2}(Y_{1}) \\ P_{2}(Y_{1}) \\ P_{4}(Y_{1}) \end{bmatrix} \begin{bmatrix} P_{2}(Y_{1}) \\ P_{4}(Y_{1}) \\ P_{4}(Y_{1}) \\ P_{4}(Y_{1}) \end{bmatrix} \begin{bmatrix} P_{2}(Y_{1}) \\ P_{4}(Y_{1}) \\ P_{4}(Y_{1}) \\ P_{4}(Y_{1}) \end{bmatrix} \begin{bmatrix} P_{2}(Y_{1}) \\ P_{4}(Y_{1}) \\ P_{4}(Y_{1}) \\ P_{4}(Y_{1}) \end{bmatrix} \begin{bmatrix} P_{2}(Y_{1}) \\ P_{4}(Y_{1}) \\ P_{4}(Y_{1}) \\ P_{4}(Y_{1}) \\ P_{4}(Y_{1}) \end{bmatrix} \begin{bmatrix} P_{2}(Y_{1}) \\ P_{4}(Y_{1}) $. ,		$P(Y_i) = P_d M_y (1-M_y)^{i-1}$			<i>.</i>		
$Step 6: Calculate Average Pedestrian Delay & Comments \\ I OS & Delay noticeable / irritating, increased chance of risk-taking \\ I OS & Delay approaches tolerance level, risk-taking likely \\ I = 10 \\ $		2. Two-L	ane Crossing	M ₂ = motorist y	ield rate (d			
3. Three-Lane Crossing $P\{Y_{i}\} = [P_{d} - \sum_{j=0}^{i-1} P(Y_{j})] + [\frac{P_{b}^{3}M_{y}^{3} + 3P_{b}^{2}(1-P_{b})M_{y}^{2}) + 3P_{b}(1-P_{b})^{2}M_{y}}{P_{d}}]$ $\frac{Summary}{Average} 109.9$ 4. Four-Lane Crossing $P\{Y_{i}\} = [P_{d} - \sum_{j=0}^{i-1} P(Y_{j})] + [\frac{P_{b}^{4}M_{y}^{4} + 4P_{b}^{3}(1-P_{b})M_{y}^{3}) + 6P_{b}^{2}(1-P_{b})^{2}M_{y}^{2}) + 4P_{b}(1-P_{b}^{3})M_{y}}{P_{d}}$ Step 6: Calculate Average Pedestrian Delay & Determine LOS $\frac{A \qquad 0-5}{D} \qquad Usually no conflicting traffic B \qquad 5-10 \qquad Occasionally some delay due to conflicting traffic C \qquad 10-20 \qquad Delay noticeable to pedestrians, but not inconvienencing B \qquad 20-30 \qquad Delay noticeable/irritating, increased chance of risk-taking LOS \frac{P(Y_{i}) = P_{d} - \sum_{j=0}^{i-1} P(Y_{j}) + \frac{P_{b}^{4}M_{y}^{4} + 4P_{b}^{3}(1-P_{b})M_{y}^{3} + 6P_{b}^{2}(1-P_{b})^{2}M_{y}^{2} + 4P_{b}(1-P_{b}^{3})M_{y}}{P_{d}}$			*	0				
$ \begin{array}{c} P\{Y_i\} = [P_d - \sum_{j=0}^{i-1} P(Y_{jj})] + [\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}] & \begin{array}{c} \hline \\ Summary \\ \hline \\ Average & 109.9 \\ \hline \\ LOS & F \end{array} \\ \end{array} \\ \begin{array}{c} P(Y_i) = [P_d - \sum_{j=0}^{i-1} P(Y_{jj})] + [\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} \end{array} \\ \hline \\ \hline \\ Step 6: Calculate \\ Average \\ Pedestrian Delay \\ \& Determine \\ LOS & \hline \\ \hline \\ C & 10-20 & Delay noticeable to pedestrians, but not inconvienencing \\ \hline \\ D & 20-30 & Delay noticeable/irritating, increased chance of risk-taking \\ \hline \\ E & 30-45 & Delay approaches tolerance level, risk-taking likely \\ \hline \end{array} $			$P(I_{f}) = 2P_{b}(1-P_{b})W_{y} + 1P_{b}$ $i=1$	$P(I_i)$	$= \left P_d - \sum_{j=0} F \right $	$P(Y_j) \left[\frac{C - V - V - V - V}{P_d} \right]$		
A. Four-Lane CrossingLOSF $P(Y_i) = [P_d - \sum_{j=0}^{i-1} P(Y_{jj})] * [\frac{P_b^4 M_y^4 + 4P_b^3 (1 - P_b) M_y^3) + 6P_b^2 (1 - P_b)^2 M_y^2) + 4P_b (1 - P_b^3) M_y}{P_d}]$ Step 6: CalculateLOSCommentsAverageA0-5Usually no conflicting trafficPedestrian DelayB5-10Occasionally some delay due to conflicting trafficC10-20Delay noticeable to pedestrians, but not inconvienencingLOSE30-45		I						
A. Four-Lane CrossingLOSF $P(Y_i) = [P_d - \sum_{j=0}^{i-1} P(Y_{jj})] * [\frac{P_b^4 M_y^4 + 4P_b^3 (1 - P_b) M_y^3) + 6P_b^2 (1 - P_b)^2 M_y^2) + 4P_b (1 - P_b^3) M_y}{P_d}]$ Step 6: CalculateLOSCommentsAverageA0-5Usually no conflicting trafficPedestrian DelayB5-10Occasionally some delay due to conflicting trafficC10-20Delay noticeable to pedestrians, but not inconvienencingLOSE30-45			$P(Y_i) = [P_d - \sum_{j=1}^{l-1} P(Y_{ij})] * [\frac{P_b}{d_{ij}}]$	${}^{3}M_{y}{}^{3}+3P_{b}{}^{2}(1-P_{b})M_{y}{}^{2})$	+ 3P _b (1 - 1	$\left[\frac{P_b}{M_y}\right]$		
Step 6: Calculate Average Pedestrian Delay LOSLOSControl Delay (sec/ped)CommentsMathematical Average LOSA0-5Usually no conflicting traffic Delay noticeable to pedestrians, but not inconvienencing DControl Delay (sec/ped)C10-20Delay noticeable to pedestrians, but not inconvienencing E30-45Delay approaches tolerance level, risk-taking likely			7=0	P_d			-	
LOS Control Delay (sec/ped) Comments Average A 0-5 Usually no conflicting traffic Pedestrian Delay B 5-10 Occasionally some delay due to conflicting traffic & Determine C 10-20 Delay noticeable to pedestrians, but not inconvienencing LOS E 30-45 Delay approaches tolerance level, risk-taking likely			0	tu t i an 3/4 n 14/3	1 CD 2/2			r
LOS Control Delay (sec/ped) Comments Average A 0-5 Usually no conflicting traffic Pedestrian Delay B 5-10 Occasionally some delay due to conflicting traffic & Determine C 10-20 Delay noticeable to pedestrians, but not inconvienencing LOS E 30-45 Delay approaches tolerance level, risk-taking likely			$P(Y_i) = [P_d - \sum_{i=1}^{n} P(Y_{ji})] * [\frac{P_b}{P(Y_{ji})}]$	$m_y + 4P_b (1 - P_b)M_y)$	$\frac{+6P_b^{-}(1-P_d)}{P_d}$	$(P_b J^{-} M_y^{-}) + 4P_b (1 - P_b)$	<u>]</u>]	
Step 6: Calculate A 0-5 Usually no conflicting traffic Average B 5-10 Occasionally some delay due to conflicting traffic Pedestrian Delay C 10-20 Delay noticeable to pedestrians, but not inconvienencing & Determine D 20-30 Delay noticeable/irritating, increased chance of risk-taking LOS E 30-45 Delay approaches tolerance level, risk-taking likely			1-0					
Average A 0-5 Usually no conflicting traffic Pedestrian Delay B 5-10 Occasionally some delay due to conflicting traffic & Determine C 10-20 Delay noticeable to pedestrians, but not inconvienencing LOS E 30-45 Delay approaches tolerance level, risk-taking likely	Stop 6: Coloulato		Control Delay (sec/ped)			Comments		
B 5-10 Occasionally some delay due to conflicting traffic & Determine LOS C 10-20 Delay noticeable to pedestrians, but not inconvienencing E 30-45 Delay approaches tolerance level, risk-taking likely		A	0-5	Usually no conflicting t	raffic			
C 10-20 Delay noticeable to pedestrians, but not inconvienencing LOS D 20-30 Delay noticeable/irritating, increased chance of risk-taking E 30-45 Delay approaches tolerance level, risk-taking likely	-					-		
D 20-30 Delay noticeable/irritating, increased chance of risk-taking E 30-45 Delay approaches tolerance level, risk-taking likely	,			, .	,		0	
							king	
E Deleu evened-t-l l biek-b		E F		,		<u> </u>	~	
		F	>45			n chance of risk-takin	Ig	Page 4 of 5

Calculations Sheet 2

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

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:	defaults:	Input	Table:
L = crosswalk length (ft)		L =	75
S _p = average pedestrian walking speed (ft/s)	$S_p = 3.5$ t _s = 3.0	S _p =	4.7
t _s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t _s =	3
V = vehicular hourly volume (veh/hr)		V =	585
$\upsilon_{ m p}$ = pedestrian flow rate (ped/s)	$v_{p} = 0^{*}$	$v_p =$	0.00
v = vehicular flow rate (veh/s) = V/3600	υ = V/3600	υ =	0.200
W_c = crosswalk width (ft)	W _c = 8.0	$W_c =$	8.0
N = number of through lanes crossed (Integer)	N = INT(L/11)	N =	4
	*no platooning	observed	
Crossing 2:	(only used for two-stage cro	ossings)	

(only used for two-stage crossings)					
Evaluation Inputs:	defaults: Input Table:				
L = crosswalk length (ft)	L=				
S _p = average pedestrian walking speed (ft/s)	S _p = 3.5 S _p =				
t_s = pedestrian start-up and end clearance time (s)	t _s = 3.0 t _s =				
V = vehicular hourly volume (veh/hr)	V =				
$\upsilon_{ m p}$ = pedestrian flow rate (ped/s)	$v_p = 0^*$ $v_p =$				
υ = vehicular flow rate (veh/s) = V/3600	υ = V/3600 υ =				
W_c = crosswalk width (ft)	W _c = 8.0 W _c =				
N = number of through lanes crossed (Integer)	N = INT(L/11) N =				
	*no platooning observed				
Crossing Treatment Yield Rate	Input Table:				
M_y = motorist yield rate (decimal)	M ₂ , =				

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

Results:

Average Delay	202.2
LOS	F

Inputs and Results

Page 2 of 5

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Crossing Location:	: Date:	
City, State:	Scenario:	
Reviewer(s):	Agency:	
Step 1: Identify	Is there a median available for a two-stage crossing?	N
Two-Stage	If yes, does the median refuge meet ADA requirements (4' x 4' landing)?	N
Crossings	If yes, does the median refuge need to meet ADA requirements (4' x 4' landing)?	N
0.000.000	Critical headway is the time below which a pedestrian will not attempt to begin crossing the street. Pedestrians	
	judgement to determine whether the available headway is sufficent for a safe crossing.	
	For a single pedestrian: where: $t_c = critical$ headway for a single pedestrian (s)	
	Learning the second line of the	
	$t_c = \frac{L}{S_n} + t_s$ $S_n = average pedestrian walking speed (ft/s)$	
	crossing 1 crossing 2 t _s = pedestrian start-up and end clearance time (s	s)
	$L = 75$ $t_e = 3$ $L = t_e = S_o = 3.5$ ft/s	
	$S_{p} = 4.7$ $t_{c} = 19$ $S_{p} = t_{c} = t_{s} = 3 \sec t_{s}$	
	If pedestrian platooning is observed, the spatial distribution of pedestrians should be computed:	
	1. use field observations or estimate platoon size using equation:	
	$v_n e^{v_p t_c} + v e^{-v t_c}$ where: N_c = total number of pedestrians in crossing plate	oon
	$N_{c} = \frac{v_{p}e^{v_{p}t_{c}} + ve^{-vt_{c}}}{(v_{p} + v)e^{(v_{p}\cdot v)t_{c}}} $ where: N _c = total number of pedestrians in crossing plate (ped)	
Chan 2	v_{p} = pedestrian flow rate (ped/s)	
Step 2:	crossing 1 crossing 2 v = vehicular flow rate across crossing (veh/s)	
Determine	$v_p = t_c = 19$ $v_p = t_c = t_c = single pedestrian critical headway (s)$	
Critical Headway	$v = 0.2$ N _e = $v = N_e =$	
	2. compute spatial distribution:	
	$N_{p} = \inf \left[\frac{8.0(N_{c}-1)}{W_{c}} \right] + 1$ where: N_{p} = spatial distributions of pedestrians (ped) N_{c} = total number of pedestrians in crossing plate	
	$N_p = Int \begin{bmatrix} W_c \end{bmatrix} + 1$ N _c = total number of pedestrians in crossing plate	oon
	(ped)	
	crossing 1 crossing 2 W _c = crosswalk width (ft)	
	N _c = 8.0 = default clear width used by a single pedestr	rian
	$W_c = 8$ $N_p = W_c = N_p = $ to avoid interference with other pedestrians (ft)	
	3. compute group critical headway: clear width, if other than 8:	
	$t_{c,G} = t_c + 2(N_p-1)$ where: $t_{c,G} = \text{group critical headway (s)}$	
	t _c = single pedestrian critical headway (s)	
	crossing 1 crossing 2 N _p = spatial distributions of pedestrians (ped)	
	N _p = N _p =	
	$t_{c} = 19$ $t_{c,G} = t_{c} = t_{c,G} =$	
	Probability that a pedestrian will not incur any crossing delay is equal to the likelihood that a pedestrian will	I
	encounter a gap greater than or equal to the critical headway immediately upon arrival at the intersection.	
	$P_b = 1 - e^{-t_{c,c}v/N}$ where: $P_b = probability of blocked lane$	
Step 3: Estimate	P_d = probability of delayed crossing	
Probability of a	$P_d = 1 - (1 - P_b)^N$ N = number of lanes crossed	
Delayed	$t_{c,G}$ = group critical headway (s) = t_c , if no platoon	ning
Crossing	crossing 1 crossing 2 v = vehicular flow rate across crossing(veh/s)	
	$\mathbf{t}_{\mathbf{c},\mathbf{G}} = 19 \qquad \mathbf{t}_{\mathbf{c},\mathbf{G}} = 19$	
	$v = 0.2$ $P_b = 0.61$ $v = P_b = 0.61$ $P_b = 0.98$ $N = P_d = 0.98$	

Calculations Sheet 1

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



	Ave	rage delay assumes that no	motor vehicles yield ar	nd the ped	estrian is forced to w	ait for an adequ	ate gap.	
		1 vt.c	0	where:	d _g = average pedest	rian gap delay (s)	
		$d_{g} = \frac{1}{v} (e^{v t_{c,G}} - v t_{c,G})$	- 1)		$t_{c,G}$ = group critical l	headway (s)		
		crossing 1	crossing 2		v = vehicular flow ra	ate across crossi	ng (veh/s)	
Step 4: Calculate	t _{c,G} =	18.96	$t_{c,G} = d_g = d_g$		_			
Average Delay	v =	0.2 d _g = 197.65]			
to Wait for Adequate Gap		Average delay for a pedestrian who is unable to cross immediately upon reaching the intersection (e.g., any pedestrian experiencing nonzero delay.)						
Adequate Gap			e.g., any pedesthan exp	where:	d _{gd} = average gap de	alay for nedestria	ans who incur	
		$d_{gd} = \frac{d_g}{P_d}$			nonzero delay	ing for peaceting	ins the mean	
		crossing 1	crossing 2		d _g = average pedest	rian gap delay (s)	
	d _g =	197.7	d _g =		P_d = probability of a	delayed crossing	g	
	P _d =	197.7 0.977 d _{gd} = 202.22	P _d = d _{gd} =	-				
		n a pedestrian arrives at a c		dequate g	ap, that pedestrian is	delayed until o	ne of two	
		ions occurs: (a) a gap great			, , ,			
		an to cross. While motorist nd either marked or unmarl		•	•••		-	
		ossing treatments and yield					crabiy.	
		pedestrian delay	ates based on research			rian delav (s)		
	Average							
		$d_{p} = \sum_{i=1}^{n} h(i - 0.5) P(Y_{i})$	$(P_d - \sum P(Y_i))d_{gd}$		h = average headwa		gh lane = N/ v	
Step 5: Estimate		7=7	1=1		$P(Y_i) = \text{probability}$	that motorists y	ield to	
Delay Reduction		crossing 1	crossing 2		pedestrian on crossi	ing event i		
due to Yielding	h =	n =	h = n :		$n = \ln(d_{gd}/h)$, avera		_	
Vehicles	1.0.1	d _p =	d _p =	=	events before an ad		ailable, >0	
(If yielding is		ane Crossing			j = crossing event (j) $P(Y_j) = probability$		ield to	
zero, then skip		$P(Y_i) = P_d M_y (1-M_y)^{i-1}$			pedestrian on crossi			
step 5)	2. Two-La	ane Crossing	M_y = motorist y	vield rate (e				
		$P(Y_1) = 2P_b(1-P_b)M_y+1P_b$	0			$(P_b^2 M_y^2)$]		
		<i>i=1 i=1 i=1</i>	i v y $i > 1$	$-\left[P_d - \sum_{j=0}^{p_d}\right]$	P_d			
		Lane Crossing						
		$P(Y_i) = [P_d - \sum_{i=0}^{t-1} P(Y_i)] * [\frac{P_i}{2}]$	$\frac{{}_{y}^{3}M_{y}^{3}+3P_{b}^{2}(1-P_{b})M_{y}^{2})}{P_{z}}$	$+3P_{b}(1-1)$	$\left[P_b\right]^2 M_y$	Summ		
		ine Crossing	r d			Average LOS	202.2 F	
		0	^{4}M $^{4} \pm AD$ $^{3}(1 - D)M$ $^{3})$	$\pm 6P.^{2}(1 -$	$(P_{1})^{2}M^{2} + AP_{1}(1 - P_{2})$		- F	
		$P(Y_i) = [P_d - \sum_{i=0}^{i-1} P(Y_{i})] * [-1]$	$5 m_y + 4r_b (1 - r_b)m_y$	$\frac{P_d}{P_d}$	$(r_b) m_y + r_b (1 - r_b)$	<u>[]</u>]		
	LOS	1-1			Comments			
Step 6: Calculate	LUS	Control Delay (sec/ped)			comments			
Average	Α	0-5	Usually no conflicting t					
Pedestrian Delay	B	5-10	Occasionally some dela	,	-			
& Determine	С	10-20	Delay noticeable to per	,		0		
LOS	D E	20-30	Delay noticeable/irrita Delay approaches toler			king		
	F	30-45	Delay approaches toler Delay exceeds tolerand		<u> </u>	σ		
	r	240	Calculations Sh		gir chance of risk-takin	5	Page 4 of 5	

Calculations Sheet 2

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Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations

Intersection and Mid-Block Crossings

Crossing Location:	Example 8	Date:	
City, State:		Scenario:	AM Peak Hour, Staged, RRFB
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				
Evaluation Inputs:	defaults:	Input Table:		
L = crosswalk length (ft)		L = 50		
S _p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p = 4.7		
t _s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t _s = 3		
V = vehicular hourly volume (veh/hr)		V = 201		
$\upsilon_{\rm p}$ = pedestrian flow rate (ped/s)	υ _p = 0*	υ _p = 0.00		
υ = vehicular flow rate (veh/s) = V/3600	υ = V/3600	v = 0.060		
W_c = crosswalk width (ft)	W _c = 8.0	W _c = 8.0		
N = number of lanes crossed (Integer)	N = INT(L/11)	N = 2		
	*no platooning	observed		
Crossing 2: north	(only used for two-stage cro	ossings)		
Evaluation Inputs:	defaults:	Input Table:		
L = crosswalk length (ft)		L= 25		
${\sf S}_{\sf p}$ = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p = 5		
t_s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t, = 3		
V = vehicular hourly volume (veh/hr)		V = 201		
$\upsilon_{\rm p}$ = pedestrian flow rate (ped/s)	υ _p = 0*	υ _p = 0.00		
υ = vehicular flow rate (veh/s) = V/3600	υ = V/3600	υ = 0.060		
W_c = crosswalk width (ft)	W _c = 8.0	W _c = 8.0		
N = number of lanes crossed (Integer)	N = INT(L/11)	N = 2		
	*no platooning	ning observed		
Crossing Treatment Yield Rate		Input Table:		
M_y = motorist yield rate (decimal)		M _y = 84%		

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

Results:

Average Delay	14.8
LOS	С

Inputs and Results

Page 2 of 5

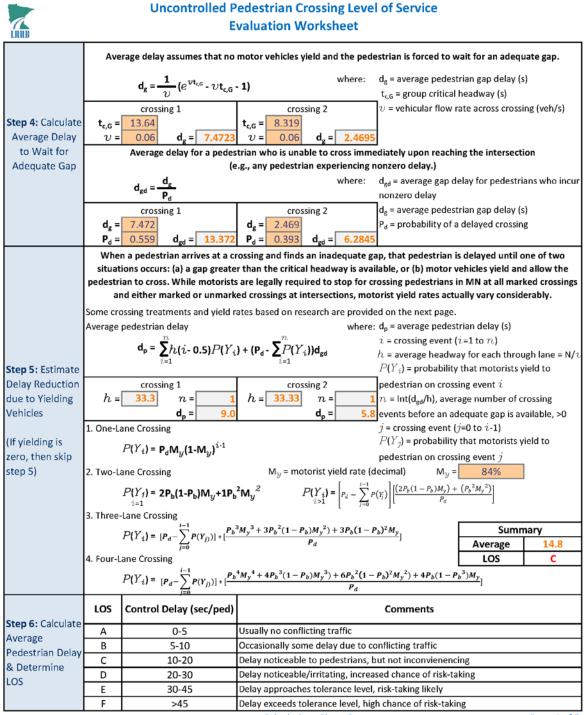
Developed by Bolton Menk, Inc. for the Local Road Research Board.



Two-StageIf yes, does the median refuge meet ADA requirements (4' x 4' landing)?YesCrossingsYesCritical headway is the median refuge meet ADA requirements (4' x 4' landing)?YesCritical headway is the median refuge meet ADA requirements (4' x 4' landing)?YesCritical headway is the median refuge meet ADA requirements (4' x 4' landing)?YesCritical headway is the median refuge meet ADA requirements (4' x 4' landing)?YesCritical headway is the median refuge meet ADA requirements (4' x 4' landing)?YesCritical headway is the median refuge meet ADA requirements (4' x 4' landing)?YesCritical headway is the median refuge meet ADA requirements (4' x 4' landing)?YesCritical headway is the median refuge meet ADA requirements (4' x 4' landing)?YesCritical headway is the median refuge meet ADA requirements (4' x 4' landing)?YesCritical headway is suffice the available headway to a single pedestrian single pedestrian valing parent to begin refuge meet to determine whether the available headway to a single pedestrian single pedestrian single pedestrian single pedestrian single pedestrian single pedestrian sin crossing platoe (ped)Super Critical HeadwayNet to a single pedestrian sin crossing platoe (ped)V = 0.06V = 0.06V = 0.06V = 0.06V = 0.	LRRB	
Reviewer(s):Agency:Step 1: Identify Two-StageIs there a median available for a two-stage crossing?If yes, does the median refuge meet ADA requirements (4' x 4' landing)?YesWo-StageIf yes, does the median refuge meet ADA requirements (4' x 4' landing)?YesIf yes, does the median refuge need to meet ADA requirements (4' x 4' landing)?YesCritical headway is the time below which a pedestrian will not atterm to begin crossing.Critical headway is the time below which a pedestrian will not atterm to a safe crossing.For a single pedestrian:where t, = critical headway for a single pedestrian (5)t = $\frac{1}{2}$, 1	-	
Step 1: IdentifyIs there a median available for a two-stage crossing?If yes, does the median refuge meet ADA requirements (4', 4' landing)?YesCrossingsIf yes, does the median refuge meet ADA requirements (4', 4' landing)?YesYesIf yes, does the median refuge meet ADA requirements (4', 4' landing)?YesYesCritical headway is the time below which a pedistrian will not attemp to begin crossing the street. Pedestrians updgement to determine whether the available headway is sufficent for a safe crossing.For a single pedestrian (s)Tor a single pedestrian:where: t, = critical headway for a single pedestrian (s)L = crossing 2t, = pedestrian start-up and end clearance time (s)Sp = average pedestrian valid stribution of pedestrians is crossing 1t, = a sect = crossing 2t, = a secIf pedestrian platooning is observed, the spatial distribution of pedestrian should be computed:t. use field observations or estimate platon size using equation:where: N, = total number of pedestrians in crossing platooRef= $\frac{2V_{e}C^{VA} + 2V_{e}^{VA} + 2$	1.	
Two-Stage CrossingsIf yes, does the median refuge meet ADA requirements (4' x 4' landing)?YesCrossingsIf yes, does the median refuge need to meet ADA requirements (4' x 4' landing)?YesCritical headway is the time below which a pedestrian will no attempt to begin crossing the street. Predestrians u judgement to determine whether the available headway is sufficent for a safe crossing.For a single pedestrian is the median refuge meet to determine whether the available headway is sufficent for a safe crossing.For a single pedestrian:where: t, = critical headway for a single pedestrian (s) t = $\frac{1}{50}$ t, = $\frac{1}{3.6}$ t, $\frac{1}{5}$ = $\frac{25}{4.7}$ t, $\frac{1}{5}$ = $\frac{225}{2.5}$ t, $\frac{1}{4}$ = $\frac{3}{3.5}$ t, $\frac{1}{5}$ = $\frac{25}{4.7}$ t, $\frac{1}{5}$ = $\frac{225}{2.5}$ t, $\frac{1}{4}$ = $\frac{3}{3.5}$ t, $\frac{1}{5}$ = $\frac{1}{5.9}$ = $\frac{1}{4.7}$ t, $\frac{1}{2}$ = $\frac{13.6}{3.5}$ S, $\frac{1}{9.47}$ t, $\frac{1}{4}$ = $\frac{13.6}{3.5}$ U; $\frac{1}{9.6}$ end the spatial distribution of pedestrians should be computed:1. use field observations or estimate platoon size using equation: N ₆ = $\frac{10.6}{10.9}$ end the trans in crossing platoo (ped) $V_{10} = \frac{10.6}{10.9}$ end the trans the platoon size using equation: N ₆ = $\frac{10.6}{10.9}$ end the trans the platoon size using equation: N ₆ = $\frac{10.6}{10.9}$ end the trans the platoon size using equation: N ₆ = $\frac{10.6}{10.9}$ end the trans the platoon size using equation: N ₆ = $\frac{10.6}{10.9}$ end the trans the platoon size using equation: N ₆ = $\frac{10.6}{10.9}$ end the trans the platoon size using equation		
CrossingsIf yes, does the median refuge need to meet ADA requirements (4' x 4' landing)?YesCritical headway is the time below which a pedestrian will not attempt to begin crossing the treet. Pedestrians u judgement to determine whether the available headway is sufficent for a single pedestrian (s)tree as ingle pedestrian:where: $t_e = critical headway for a single pedestrian (s)t_e = \frac{1}{5_{o}} + t_sUse field beadway for a single pedestrian (s)t_e = crossing 1t_e = crossing 2t_e = \frac{1}{5_{o}} + t_sStep 2:DetermineNet = \frac{12.6}{4.7}t_e = \frac{12.6}{2.5}tree = \frac{12.6}{4.7}t_e = \frac{12.6}{2.5}tree = \frac{12.6}{4.7}t_e = \frac{12.6}{2.5}tree = \frac{12.6}{2.5}tree = \frac{12.6}{4.7}t_e = \frac{12.6}{2.5}tree = \frac{12.6}{2.5}$		
Critical headway is the time below which a pedestrian will not attempt to begin crossing the street. Pedestrians u judgement to determine whether the available headway is sufficient for a safe crossing. For a single pedestrian: $ t_{c} = \frac{1}{4s_{p}} + t_{s}$ $ t_{s} = 2 edestrian star-up and end clearance time (s)$ $ t_{s} = 2 edestrian star-up and end clearance time (s)$ $ t_{s} = 2 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 3 edestrian star-up and end clearance time (s)$ $ t_{s} = 1 edestrian star-up edestrian star-up and end clearance time (s)$ $ t_{s} = 1 edestrian star-up edestrian star-up and end clearance time (s)$ $ t_{s} = 1 edestrian star-up edestrian star-up and e$	-	
$ \begin{array}{c} \text{Judgement to determine whether the available headway is sufficent for a safe crossing. \\ \text{For a single pedestrian: } & \text{where: } t_{e} = \text{critical headway for a single pedestrian (s)} \\ \text{for a single pedestrian: } & \text{where: } t_{e} = \text{critical headway for a single pedestrian (s)} \\ \text{for a single pedestrian: } & \text{where: } t_{e} = \text{crosswalk length (f)} \\ \text{S}_{p} = \text{average pedestrian walking speed (fi/s)} \\ \text{S}_{p} = \frac{13.6}{4.2} t_{e} = \frac{3}{13.6} t_{p} = \frac{25}{4.2} t_{e} = \frac{3}{3.32} \\ \text{t}_{e} = \frac{3}{3.32} t_{e} = 3.51 \text{ t/s} \\ \text{s}_{p} = 3.5 \text{ t/s} \\ \text{t}_{e} = 3.822 \\ \text{t}_{e} = \frac{13.6} U_{p} = \frac{U_{e}U^{2/k}}{(U_{p} + U)e^{(U_{p}/W)t_{e}}} & \text{where: } N_{e} = \text{total number of pedestrians in crossing platoo (ped) \\ \text{v}_{p} = \frac{U_{e}U^{2/k}}{0.06} \frac{V_{e}}{N_{e}} = \frac{13.6}{0} U_{p} = \frac{Crossing 2}{U_{p} = 0.06} \frac{V_{e}}{N_{e}} = \frac{8.322}{U_{e}} & \text{v}_{e} = \text{ingle pedestrian critical headway (s) } \\ \text{t}_{e} = \text{ingle pedestrian critical headway (s) } \\ \text{t}_{e} = \text{ingle pedestrian critical headway (s) } \\ \text{v}_{e} = \frac{Crossing 1}{W_{e}} = \frac{N_{e}}{0.06} \frac{N_{e}}{N_{e}} = \frac{N_{e}}{0.06} \frac{N_{e}}{N_{e}} = \frac{N_{e}}{0.06} \frac{N_{e}}{N_{e}} = \frac{N_{e}}{0.006} N_$	Crossings	
encounter a gap greater than or equal to the critical headway immediately upon arrival at the intersection.Step 3: EstimateProbability of aProbability of aPolayedCrossing $t_{c,G} = \begin{bmatrix} 13.6 \\ \upsilon = 0.06 \end{bmatrix} P_b = \begin{bmatrix} 0.34 \\ \upsilon = 0.06 \end{bmatrix} P_b = \begin{bmatrix} 0.34 \\ \upsilon = 0.06 \end{bmatrix} P_b = \begin{bmatrix} 0.22 \\ \upsilon = 0.06 \end{bmatrix} V = vehicular flow rate across crossing(veh/s)$	Determine	For a single pedestrian: $t_{c} = \frac{L}{S_{p}} + t_{s}$ $L = crosswalk length (ft)$ $S_{p} = acrossing 1$ $L = \frac{crossing 1}{L} = \frac{crossing 2}{L} = \frac{25}{L} = \frac{3}{L} = \frac{25}{L} = \frac{13.6}{L} = \frac{25}{L} = \frac{13.6}{L} = \frac{25}{L} = \frac{13.6}{L} = \frac{25}{L} = \frac{13.6}{L} = 1$
Step 3: Estimate Probability of a Delayed Crossing $P_b = 1 - e^{-q_c to /N}$ $P_d = \text{probability of delayed crossing}$ $P_d = 1 - (1-P_b)^N$ $N = \text{number of lanes crossed}$ 		
Step 3: Estimate P_d = probability of delayed crossingProbability of a $P_d = 1 - (1 - P_b)^N$ Delayed $P_d = 1 - (1 - P_b)^N$ Crossing $r_{c,G} = 13.6$ $v = 0.06$ $P_b = 0.34$ $v = 0.06$ $P_b = 0.22$		$P_{L} = 1 - e^{-\frac{1}{2}} e^{-\frac{1}{2}} e^{-\frac{1}{2}}$
Delayed Crossing $\mathbf{P}_{d} = 1 - (1 - \mathbf{P}_{b})^{T}$ $\mathbf{t}_{c,G} = \operatorname{group critical headway (s)} = \mathbf{t}_{c}, \text{ if no platoonir}$ $\mathbf{t}_{c,G} = \operatorname{group critical headway (s)} = \mathbf{t}_{c}, \text{ if no platoonir}$ $\upsilon = \upsilon + v = v = v = v = v = v = v = v = v = v$	Step 3: Estimate	P_d = probability of delayed crossing
Crossing $\begin{aligned} \mathbf{t}_{c,G} = \text{group critical headway (s)} = \mathbf{t}_{c} \text{ if no platoning} \\ \boldsymbol{v} = 0.06 \mathbf{P}_{b} = 0.34 \boldsymbol{v} = 0.06 \mathbf{P}_{b} = 0.22 \boldsymbol{v} = \text{vehicular flow rate across crossing(veh/s)} \\ \boldsymbol{v} = 0.06 \mathbf{P}_{b} = 0.34 \boldsymbol{v} = 0.06 \mathbf{P}_{b} = 0.22 \boldsymbol{v} = 0.22 $	Probability of a	$P_{\nu} = 1 - (1 - P_{\nu})^{N}$ N = number of lanes crossed
$t_{c,G} = 13.6$ $v = 0.06$ $P_b = 0.34$ $v = 0.06$ $P_b = 0.22$	Delayed	$t_{c,G}$ = group critical headway (s) = t_{c} if no platooning
	Crossing	$ \begin{array}{c} \text{crossing 1} \\ \textbf{t}_{c,G} = \begin{array}{c} 13.6 \\ \upsilon = 0.06 \end{array} \\ \textbf{P}_{b} = \begin{array}{c} 0.34 \end{array} \\ \textbf{P}_{b} = \begin{array}{c} 0.34 \end{array} \\ \textbf{P}_{b} = \begin{array}{c} 0.22 \end{array} \\ \textbf{P}_{b} = \begin{array}{c} 0.22 \end{array} \\ \upsilon = 0.22 \end{array} \\ \upsilon = 0.22 \end{array} \\ \upsilon = 0.22 \end{array} $
Calculations Sheet 1 Page 3 o		

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HCM Evaluation Worksheet



Calculations Sheet 2

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Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations

Intersection and Mid-Block Crossings

Crossing Location:	Example 8	Date:	
City, State:		Scenario:	PM, Staged, RRFB
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		
Evaluation Inputs:	defaults:	Input Table:
L = crosswalk length (ft)		L= 50
S _p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p = 4.7
t _s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t _s = 3
V = vehicular hourly volume (veh/hr)		V = 292
$\upsilon_{ m p}$ = pedestrian flow rate (ped/s)	υ _p = 0*	U _p = 0.00
υ = vehicular flow rate (veh/s) = V/3600	υ = V/3600	U = 0.080
W_c = crosswalk width (ft)	W _c = 8.0	W _c = 8.0
N = number of lanes crossed (Integer)	N = INT(L/11)	N = 2
	*no platooning of	bserved
Crossing 2: north	(only used for two-stage cross	sings)
Evaluation Inputs:	defaults:	Input Table:
L = crosswalk length (ft)		L= 25
S _p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p = 5
t_s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t, = 3
V = vehicular hourly volume (veh/hr)		V = 293
$\upsilon_{\rm p}$ = pedestrian flow rate (ped/s)	υ _p = 0*	U _p = 0.00
υ = vehicular flow rate (veh/s) = V/3600	υ = V/3600	υ = 0.080
W_c = crosswalk width (ft)	W _c = 8.0	W _c = 8.0
N = number of lanes crossed (Integer)	N = INT(L/11)	N = 2
	*no platooning of	bserved
Crossing Treatment Yield Rate		Input Table:
M_y = motorist yield rate (decimal)		M _y = 84%

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

Results:

Average Delay	14.5
LOS	С

Inputs and Results

Page 2 of 5

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Crossing Location:	Date:
City, State:	Scenario:
Reviewer(s):	Agency:
Step 1: Identify	Is there a median available for a two-stage crossing?
Two-Stage	If yes, does the median refuge meet ADA requirements (4' x 4' landing)?
Crossings	If yes, does the median refuge need to meet ADA requirements (4' x 4' landing)? \Box Yes \Box N
0.000.000	Critical headway is the time below which a pedestrian will not attempt to begin crossing the street. Pedestrians us
	judgement to determine whether the available headway is sufficent for a safe crossing.
	For a single pedestrian: where: t _c = critical headway for a single pedestrian (s)
	L = executelly longth (6)
	$\mathbf{t}_c = \frac{\mathbf{L}}{\mathbf{S}_p} + \mathbf{t}_s$ $\mathbf{S}_p = \text{average pedestrian walking speed (ft/s)}$
	crossing 1 crossing 2 t _s = pedestrian start-up and end clearance time (s)
	$L = 50$ $t_s = 3$ $L = 25$ $t_s = 3$ $S_p = 3.5$ ft/s
	$S_p = 4.7$ $t_c = 13.6$ $S_p = 4.7$ $t_c = 8.32$ $t_s = 3 \text{ sec}$
	If pedestrian platooning is observed, the spatial distribution of pedestrians should be computed:
	1. use field observations or estimate platoon size using equation:
	$N_{c} = \frac{v_{p}e^{v_{p}t_{c}} + ve^{-vt_{c}}}{(v_{p} + v)e^{(v_{p} \cdot v)t_{c}}}$ where: N _c = total number of pedestrians in crossing platoor (ped)
Ch	v_p = pedestrian flow rate (ped/s)
Step 2:	crossing 1 crossing 2 v = vehicular flow rate across crossing (veh/s)
Determine	$v_p = t_c = 13.6$ $v_p = t_c = 8.32$ $t_c = single pedestrian critical headway (s)$
Critical Headway	v = 0.08 N _c = $v = 0.08$ N _c =
	2. compute spatial distribution:
	$N_{p} = Int \left[\frac{8.0(N_{c}-1)}{W_{c}} \right] + 1$ where: N _p = spatial distributions of pedestrians (ped) N_{c} = total number of pedestrians in crossing platoor
	$N_p = Int \begin{bmatrix} W_c \end{bmatrix} + 1$ N _c = total number of pedestrians in crossing platoor
	(ped)
	crossing 1 crossing 2 W _c = crosswalk width (ft)
	N _c = 8.0 = default clear width used by a single pedestriar
	$W_c = 8$ $N_p = W_c = 8$ $N_p = 10$ to avoid interference with other pedestrians (ft)
	3. compute group critical headway: clear width, if other than 8: ft.
	$t_{c,G} = t_c + 2(N_p-1)$ where: $t_{c,G} = \text{group critical headway (s)}$
	$t_c = single pedestrian critical headway (s)$
	crossing 1 crossing 2 N _p = spatial distributions of pedestrians (ped)
	N _p = N _p =
	$t_c = 13.6$ $t_{c,G} = t_c = 8.32$ $t_{c,G} =$
	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.
	$P_b = 1 \cdot e^{-t_{c,c}v/N}$ where: $P_b = probability of blocked lane$
Step 3: Estimate	P _d = probability of delayed crossing
Probability of a	$P_d = 1 - (1 - P_b)^N$ N = number of lanes crossed
Delayed	t _{c,G} = group critical headway (s) = t _c , if no platooning
Crossing	crossing 1 crossing 2 v = vehicular flow rate across crossing(veh/s)
	$t_{c,G} = 13.6$ $t_{c,G} = 8.32$
	$v = 0.08$ $P_b = 0.42$ $v = 0.08$ $P_b = 0.28$
	$N = 2$ $P_d = 0.66$ $N = 2$ $P_d = 0.49$
	Calculations Sheet 1 Page 3 of

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	Ave	rage delay assumes that no	motor vehicles yield an	d the pede	estrian is forced to w	ait for an adequ	iate gap.
		1 . vt.		where:	d _g = average pedesti	rian gap delay (s)
		$d_{g} = \frac{1}{v} (e^{v t_{c,G}} - v t_{c,G})$	- 1)		$t_{c,G}$ = group critical h	headway (s)	
		crossing 1	crossing 2		v = vehicular flow ra	ate across crossi	ng (veh/s)
Step 4: Calculate	t _{c,G} =	13.64	t _{c,G} = 8.319				
Average Delay	υ=	0.08 d _g = 11.08		3.4999]		
to Wait for Adequate Gap		Average delay for a pedes	strian who is unable to e e.g., any pedestrian exp			ng the intersecti	on
Adequate Gap			e.g., any pedesthan exp	where:	d _{gd} = average gap de	alay for nedestria	ans who incur
		$d_{gd} = \frac{d_g}{P_d}$		erer	nonzero delay	and the pedestri	sins time incur
		crossing 1	crossing 2		d _g = average pedesti	rian gap delay (s)
	d _g =	11.08	$d_{g} = \frac{3.5}{0.486}$ $P_{d} = \frac{0.486}{0.486}$		$P_d = probability of a$		
	P _d =	0.664 d _{gd} = 16.683	$P_{d} = 0.486 d_{gd} =$	7.2015			
		n a pedestrian arrives at a ci	-			•	
		ions occurs: (a) a gap greate			, ,,		
		an to cross. While motorists nd either marked or unmark	• • •	•	•••		-
		ossing treatments and yield r				any vary conside	crabiy.
		pedestrian delay	ates based on research			rian delav (s)	
		$d_{p} = \sum_{i=1}^{n} h(i - 0.5) P(Y_{i})$) + ($\mathbf{P}_{d} - \sum P(Y_{i})$)d _{gd}		h = average headwa		igh lane = N/ v
Step 5: Estimate		2=1	2=1		$P(Y_i)$ = probability	that motorists y	ield to
Delay Reduction		crossing 1	crossing 2		pedestrian on crossi		
due to Yielding	<i>h</i> =	25.0 <i>n</i> = 1			n = Int(d _{gd} /h), avera		
Vehicles		d _p = 8.8	d _p =	5.6	events before an ad		ailable, >0
(If yielding is		ane Crossing			$j = crossing event (j P(Y_j) = probability)$		ield to
zero, then skip		$P(Y_i) = P_d M_y (1-M_y)^{i-1}$			pedestrian on crossi		
step 5)	2. Two-L	ane Crossing	M_y = motorist y	ield rate (d		84%	
		-	0		U .		
		$P(Y_1) = 2P_b(1-P_b)M_y+1P_b$	$P(I_i) = i > 1$	$= \left P_d - \sum_{j=0}^{p} P_j \right $	$(Y_j) \begin{bmatrix} \frac{1}{P_d} \\ P_d \end{bmatrix}$		
		Lane Crossing					
		$P(Y_i) = [P_d - \sum_{i=0}^{t-1} P(Y_{i})] * [\frac{P_b}{2}]$	${}^{3}M_{y}{}^{3}+3P_{b}{}^{2}(1-P_{b})M_{y}{}^{2})$	$+ 3P_b(1 - F_b)$	$(b)^2 M_y$	Summ	
		<i>j=</i> 0	P_d		-	Average	14.5
		ane Crossing i-1	4	24		LOS	С
		$P(Y_i) = [P_d - \sum_{i=0}^{i-1} P(Y_i)] * [\frac{P_b}{2}]$	M_y + 4 P_b (1 - P_b) M_y)	$\frac{+6P_b^{-}(1-P_d)}{P_d}$	$P_b(1 - P_b)$	$\frac{b^{\circ}}{M_y}$]	
		1=1		- u			
Share C. Calavilata	LOS	Control Delay (sec/ped)			Comments		
Step 6: Calculate	Α	0-5	Usually no conflicting t	raffic			
Average Pedestrian Delay	В	5-10	Occasionally some dela	y due to co	onflicting traffic		
& Determine	С	10-20	Delay noticeable to peo	,		<u> </u>	
LOS	D	20-30	Delay noticeable/irritat	-		king	
	E	30-45	Delay approaches toler		<u> </u>		
	F	>45	Delay exceeds toleranc		h chance of risk-takin	lg	Dage 4 -67
			Calculations Sh	PPT /			Page 4 of 5

Calculations Sheet 2

Page 4 of 5

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

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
 - o 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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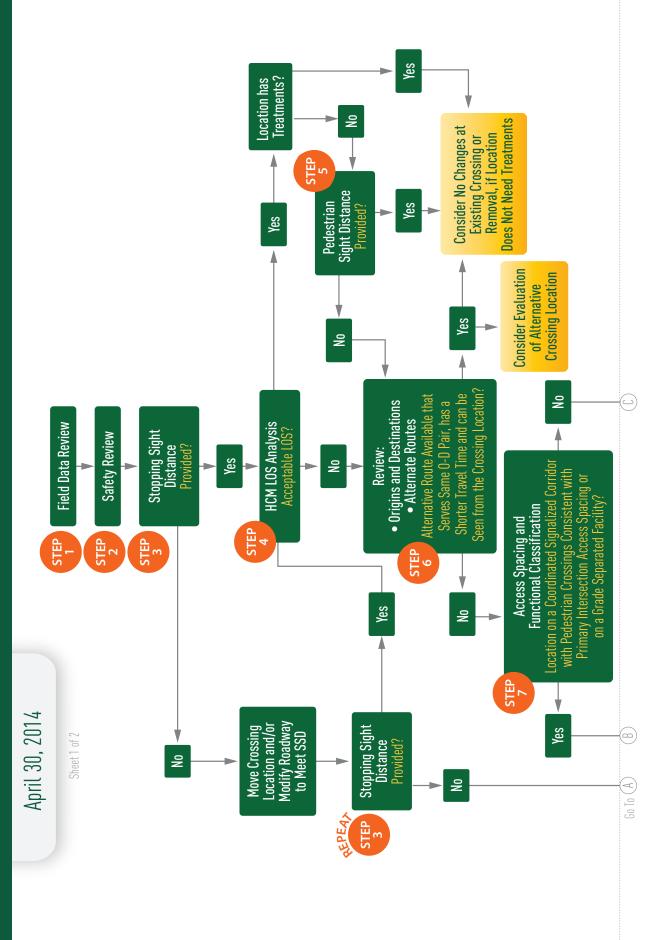
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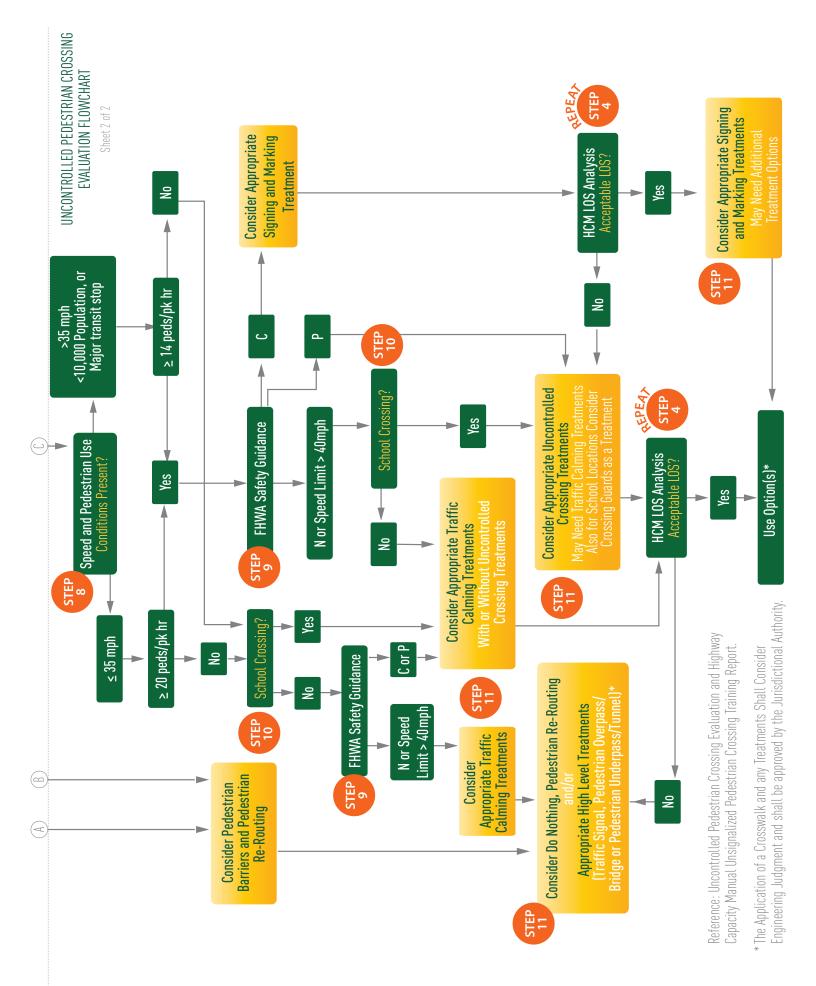
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Appendix A Evaluation Flowchart

<u>UNCONTROLLED PEDESTRIAN CROSSING EVALUATION FLOWCHART</u>





Appendix B Field Review Worksheet



Uncontrolled Pedestrian Crossing Data Collection Worksheet

Location:					Date:						
City, State:					Scenario:						
Reviewer(s):					Agency:						
Project #:	The first ste	p in understan	ding the ne	doctrian nor	ID #:	antial crossi	na location is (comple	ting		
				the location				Joinple	ling		
	Crossing Len	gth: Measure t			5		Crossing 1		f	ft.	
		ng 1 distance if	-	-			-			ft.	
		ition, fill in Cros				.ulan at the	CIOSSING Z			ι.	
	-	lth of median a	-						f	ft.	
		dth: effective c	-							ft.	
	-	dian Available?							Yes		No
		DA Compliant N		ailable (minir	num 4' x 4' '	landing)?			Yes		No
rics		os Available?	viculari / (va			ianiani6/:			Yes		No
neti		DA Compliant (Curb Ramp	Available (w	idth.grades	s truncated	domes)?		Yes		No
Geometrics	Speed:		sans namp.			85 th percent				mph	
Ŭ	· ·	rvature and Si	ght Distanc	es:		alking speed	•			ft/s	
		sing location wi	-		•	0 1	~		Yes	, <u>-</u>	No
		o calculate the fo									
	-	Stopping Sigh	_			ft.	provided?		Yes		No
		Stopping Sigh	-			ft.	provided?		Yes		No
		Pedestrian Sig	-			ft.	provided?		Yes		No
		Pedestrian Sig	-			ft.	provided?		Yes		No
T ffter and		ffic and pedest	-		te incremer	nts on the re		crossec		<u> </u>	
Traffic and	Attach Counts	vehicl	les:	Daily		ped	lestrians:	ľ	Daily		
Pedestrian	AM Peak	Hourly		Pk 15-min		Hourly	,	Pk 15	-min		
Data	PM Peak	Hourly		Pk 15-min		Hourly		Pk 15	-min		
	Lighting:										
	Is street lig	hting present a	and does it	light the cro	sswalk locat	tion?			Yes		No
	Crosswalk Pa	avement Mark	ings:	Is the pede	estrian cross	sing current	ly marked?		Yes		No
	What is the	e condition of t	the marking	ls;	Γ	Excellent	: 🗌 Good		Fair		Poor
ics		Are the marki	ings easily d	Jefined?					Yes		No
rist		Do they need	-			·			Yes		No
cte		What is the cr			rn?						
ara	Signing:	Currently sign							Yes		No
ch L		Currently sign				•			Yes		No
Additional Site Characteristics		Distances?		direction 1		ft.	direction 2		f	ft.	
Jal	Enhancemen			ements are c	urrently at						
tior			e crossing lo							-	
ddi	Adjacent Fac			earest marke	d crosswalk	?			f	ft.	
A		estrian control o		•							
		est adjacent m									
		o nearest all-wa			-					ft.	
		her location se		•	-				Yes		No
	Could anot	her location se	erve the the	movement	more effect	tively?			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 orgins and destinations .

draw or insert map of location being studied

Notes:

Sight Distance Calculations:

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

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

where:

S = design speed, mph L = length of crossing, ft

where:

defaults:

t = brake reaction time, s	2.5
a = deceleration rate, ft/s^2	11.2
${\rm S}_{\rm p}$ = average pedestrian walking speed, ft/s	3.5
t _s = pedestrian start-up and end clearance time, s	3.0

Appendix C HCM Evaluation Worksheets

2010 Highway Capacity Manual (HCM) Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations Intersection and Mid-Block Crossings

Introduction:

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

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

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

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

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

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

2010 Highway Capacity Manual (HCM)

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

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

The following is the base information needed to complete the analysis.

If this is a one-stage crossing, use only Crossing 1.

If this is a two-stage crossing, each stage must be evaluated separately using Crossing 1 and Crossing 2.

Crossing 1:

Evaluation Inputs:	defaults:	Input Table:
L = crosswalk length (ft)		L =
S _p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p =
t_s = pedestrian start-up and end clearance time (s)	$t_{s} = 3.0$	t _s =
V = vehicular hourly volume (veh/hr)		V =
$\upsilon_{\sf p}$ = pedestrian flow rate (ped/s)	υ _p = 0*	υ _p =
v = vehicular flow rate (veh/s) = V/3600	υ = V/3600	v =
W_c = crosswalk width (ft)	W _c = 8.0	W _c =
N = number of through lanes crossed (Integer)	N = INT(L/11)	N =

*no platooning observed

Crossing 2:	(only used for two-stage cro	ossings)
Evaluation Inputs:	defaults:	Input Table:
L = crosswalk length (ft)		L=
S _p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p =
t_s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t _s =
V = vehicular hourly volume (veh/hr)		V =
$\upsilon_{ m p}$ = pedestrian flow rate (ped/s)	v_{p} = 0*	U _p =
υ = vehicular flow rate (veh/s) = V/3600	υ = V/3600	υ =
W_c = crosswalk width (ft)	W _c = 8.0	W _c =
N = number of through lanes crossed (Integer)	N = INT(L/11)	N =
	*no platooning	gobserved

Crossing Treatment Yield Rate

 M_{u} = motorist yield rate (decimal)

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

Results:



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Input Table:

 $M_{ii} =$



Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

Crossing Location		Date:	
City, State:		Scenario:	
Reviewer(s):		Agency:	
Step 1: Identify	Is there a median available for a two-stage		Yes No
Two-Stage	•	et ADA requirements (4' x 4' landing)?	☐ Yes ☐ No
Crossings	If yes, do pedestrians treat this as a		☐ Yes ☐ No
		h a pedestrian will not attempt to begin crossing th	
	-	whether the available headway is sufficent for a saf	
	For a single pedestrian:	where: $t_c = critical$ headway for a single	-
	- · ·	L = crosswalk length (ft)	,
	$t_c = \frac{L}{S_n} + t_s$	S _p = average pedestrian walking	g speed (ft/s)
	S_p	$t_s = pedestrian start-up and end$	
	crossing 1 crossing 1	crossing 2 $S_p = 3.5 \text{ ft/s}$	
	$L = \begin{bmatrix} t_s \\ t_s \end{bmatrix} = \begin{bmatrix} L \\ t_s \end{bmatrix}$	$\mathbf{t}_{s} = \mathbf{t}_{s} = 3 \text{ sec}$	
	$S_p = t_c = S_p = t_c$	t _c =	
		patial distribution of pedestrians should be compute	eq.
	1. use field observations or estimate plato		
		where: N_c = total number of pedestrian	ns in crossing platoon
	$N_c = rac{v_p e^{v_p t_c} + v e^{-v t_c}}{(v_p + v) e^{(v_p - v) t_c}}$	(ped)	01
	$(v_p + v)e^{(v_p - v)t_c}$	v_p = pedestrian flow rate (ped/	's)
Step 2:	crossing 1 crossing 1	crossing 2 v = vehicular flow rate across c	
Determine	$v_{\rm p} = \mathbf{t}_{\rm c} = \mathbf{v}_{\rm p} =$	$t_c = t_c = t_c$ t t is the single pedestrian critical he	eadway (s)
Critical Headway	$v = \mathbf{N}_{c} = v =$	N _c =	
	2. compute spatial distribution:		
	[80(N - 1)]	where: N_p = spatial distributions of peo	destrians (ped)
	$N_p = INT \left[\frac{8.0(N_c - 1)}{W_c} \right]$	N _c = total number of pedestrian	ns in crossing platoon
		(ped)	
	crossing 1	crossing 2 W _c = crosswalk width (ft)	
	N _c = N _c =	8.0 = default clear width used b	
	$W_c = N_p = W_c =$	$N_p =$ to avoid interference with othe	r pedestrians (ft)
	3. compute group critical headway:	clear width, if other than 8:	ft.
	$t_{c,G} = t_c + 2(N_p - 1)$	where: $t_{c,G}$ = group critical headway (s)	
		t_c = single pedestrian critical he	
		crossing 2 N _p = spatial distributions of peo	destrians (ped)
	N _p = N _p =	<u> </u>	
	$t_c = t_{c,G} = t_c =$	t _{c,G} =	
		ncur any crossing delay is equal to the likelihood th	-
		I to the critical headway immediately upon arrival a	
Step 3: Estimate	$P_b = 1 - e^{\frac{-t_{c,G}v}{L}}$	where: P_b = probability of blocked lane	
Probability of a	$P_d = 1 - (1 - P_b)^L$	P_d = probability of delayed cross	
Delayed		N = number of through lanes cr	
Crossing		crossing 2 $t_{c,G}$ = group critical headway (s)	
	$t_{c,G} = t_{c,G} = t_{c,G}$	v = vehicular flow rate across c	rossing(ven/s)
	$v = P_b = v =$	P _b =	
Developed by Bolton	N = P _d = N = & Menk, Inc. for the LRRB.	P _d = HCM Calculations Sheet 1	Page 3 of 5



Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

TKKR		
		that no motor vehicles yield and the pedestrian is forced to wait for an adequate gap.
	$d_g = \frac{1}{\nu} (e^{\nu t_{c,G}})$	$- yt_{ac} - 1$ where: $d_g = average pedestrian gap delay (s)$
	U U	
	crossing 1	crossing 2 v = vehicular flow rate across crossing (veh/s)
Step 4: Calculate	t _{c,G} =	t _{c,G} =
Average Delay	$v = d_g =$	$v = \mathbf{d}_{g} =$
to Wait for	Average delay for	a pedestrian who is unable to cross immediately upon reaching the intersection
Adequate Gap		(e.g., any pedestrian experiencing nonzero delay.)
Adequate Cap	$d_{gd} = rac{d_g}{P_d}$	where: d _{gd} = average gap delay for pedestrians who incu
	u	nonzero delay
	crossing 1	crossing 2 d _g = average pedestrian gap delay (s)
	d _g =	$d_{g} = P_{d} = probability of a delayed crossing$ $P_{d} = d_{gd} = probability of a delayed crossing$
	$P_d = d_{gd} =$	$P_d = d_{gd} =$
		s at a crossing and finds an inadequate gap, that pedestrian is delayed until one of two
		greater than the critical headway is available, or (b) motor vehicles yield and allow the
	•	motorists are legally required to stop for crossing pedestrians in MN at all intersections
		all marked crossings, motorist yield rates actually vary considerably.
		nd yield rates based on research are provided on the next page.
	Average pedestrian delay	where: d_p = average pedestrian delay (s)
	$\sum_{n=1}^{n} I(x_{n} - x_{n}) P$	$(\mathbf{u}) \mapsto \begin{pmatrix} n & n \\ n & n \end{pmatrix}$ $i = \text{crossing event} (i=1 \text{ to } n)$
	$a_p = \sum_{i=1}^{n} h(i - 0.5) P$	$(Y_i) + \left(P_d - \sum_{i=1}^n P(Y_i)\right) d_{gd} \qquad \begin{array}{l} i = \text{crossing event } (i=1 \text{ to } n) \\ h = \text{average headway for each through lane} = N/n \\ D(V_i) = \text{arebability that restariits widd to } \end{array}$
Step 5: Estimate	<i>i</i> =1	$r(I_i)$ = probability that motorists yield to
Delay Reduction	crossing 1	crossing 2 pedestrian on crossing event <i>i</i>
due to Yielding	h = n =	$h = n = n = n = n = nt(d_{gd}/h)$, average number of crossing
Vehicles	d _p =	d _p = events before an adequate gap is available, >0
	1. One-Lane Crossing	j = crossing event (j=0 to i-1)
(If yielding is	$P(Y_i) = P_d M_v (1 -$	$P(Y_j) = \text{probability that motorists yield to}$
zero, then skip		pedestrian on crossing event <i>j</i>
step 5)	2. Two-Lane Crossing	M_y = motorist yield rate (decimal) M_y =
	$P(Y_i) = \left P_d - \sum P(Y_i) \right $	$) \left[\frac{(2P_b(1-P_b)M_y) + (P_b^2M_y^2)}{P_d} \right]$
		$\begin{bmatrix} P_d \end{bmatrix}$
	3. Three-Lane Crossing	
	$P(Y_i) = \left P_d - \sum P(Y_i) \right $	$\left[\frac{P_b^{3}M_y^{3} + 3P_b^{2}(1 - P_b)M_y^{2} + 3P_b(1 - P_b)^{2}M_y}{P_d}\right]$ Summary Average
	L J=0	
	4. Four-Lane Crossing	
	$P(Y_i) = \left[P_d - \sum_{j=0}^{i-1} P(x_j) \right]$	$(Y_j) \Big] \mathbf{x} \left[\frac{P_b {}^4 M_y {}^4 + 4P_b {}^3 (1 - P_b) M_y {}^3 + 6P_b {}^2 (1 - P_b) {}^2 M_y {}^2 + 4P_b (1 - P_b {}^3) M_y}{P_d} \right]$
	LOS Control Delay (sec	/ped) Comments
Step 6: Calculate	A 0-5	Usually no conflicting traffic
Average	B 5-10	Occasionally some delay due to conflicting traffic
Pedestrian Delay	C 10-20	Delay noticeable to pedestrians, but not inconvienencing
& Determine	D 20-30	Delay noticeable/irritating, increased chance of risk-taking
LOS	E 30-45	Delay approaches tolerance level, risk-taking likely
	F >45	Delay exceeds tolerance level, high chance of risk-taking
Developed by Bolton	& Menk, Inc. for the LRRB.	HCM Calculations Sheet 2 Page 4 of 5



Motorist Yield Rate = ${\sf M}_y$

Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

Crossing Treatment	Staged Pedestrian Yield Rate	Unstaged Pedestrian Yield Rate
Crosswalk Markings and Signs Only ⁽¹⁾	7%	7%
Median Refuge Islands ⁽¹⁾	34%	29%
Pedestal Mounted Flashing Beacon (2-Lane, 35 mph) ⁽³⁾	N/A	57%
Overhead Flashing Beacon (push-button activation) ⁽¹⁾	47%	49%
Overhead Flashing Beacon (passive activation) ⁽¹⁾	31%	67%
Pedestrian Crossing Flags ⁽¹⁾	65%	74%
School Crossing Guards ⁽⁵⁾	N/A	86%
In-street Crossing Signs (25-30 mph) ⁽¹⁾	87%	90%
Warning Sign with Edge Mounted LEDs ⁽⁶⁾	N/A	28%
In-road warning lights ⁽¹⁾	N/A	66%
High-visibility Signs and Markings (35 mph) ⁽¹⁾	17%	20%
High-visibility Signs and Markings (25 mph) ⁽¹⁾	61%	91%
Rectangular Rapid-Flash Beacon (RRFB) ⁽²⁾⁽⁴⁾	84%	81%
School Crossing Guards with RRFB ⁽⁵⁾	N/A	91%
Pedestrian Hybrid Beacon		99%

Sources: (1) Fitzpatrick, K., S.M. Turner, M. Brewer, P.J. Carlson, B. Ullman, N.D. Trout, E.S. Park, J. Whitacre, N. Lalani, and D. Lord. NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings. Transportation Research Board of the National Academies, Washington D.C., 2006.

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Appendix D FHWA Safety Guidance Table

E	Ve	Vehicle ADT	DT	Ň	Vehicle ADT	DT		Vehicle ADT	DT	>	Vehicle AD7	DT
Koadway Lype		<u>< 9,000</u>		>,<<	>9,000 to 12,000	2,000	>I<	>12,000-12,000	,000		<u>> 10,000 <</u>	
(Number of Travel Lanes						Speed]	Speed Limit**					
and Median Type)	<u><</u> 48.3	56.4	64.4	<u><</u> 48.3	56.4	64.4	<u><</u> 48.3	56.4	64.4	<u><</u> 48.3	56.4	64.4
	km/h (30	km/h (35	km/h (40	km/h (30	km/h (35	km/h (40	km/h (30	km/h (35	km/h (40	km/h (30	km/h (35	km/h (40
	(h/im	mi/h)	mi/h)	(h/im	mi/h)	mi/h)	(h/im	mi/h)	mi/h)	mi/h)	mi/h)	mi/h)
Two lanes	C	С	Р	С	С	Ρ	C	C	z	C	Ь	Z
Three lanes	C	C	Р	C	Ь	Ь	Р	Ь	Z	Р	Z	Z
Multilane (four or more lanes)	С	С	Р	С	Р	Z	Р	Р	Z	Z	z	Z
with raised median***												
Multilane (four or more lanes)	C	Р	Z	Р	Р	Z	Z	z	z	Z	Z	z
without raised median												
* 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	dblock locati n. Crosswall	ions with n cs should n	to traffic si tot be insta	ignals or st illed at loci	op signs o ations that	n the appro could pres	ach to the cent an incre	crossing.	They do nc v risk to p	ot apply to edestrians.	school cro such as w	ssings. A
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	gns, a substa	ntial volun	ne of heav	y trucks, o	r other dan	igers, withc	out first pro	viding ade	squate desi	gn features	s and/or tra	ffic cont
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	ke crossings	safer, nor	will they n	ecessarily	result in n adian troff	iore vehicle	es stopping	for pedest	rians. Wh	ether or no	ot marked o	rosswall
mstarted, it is important to consuct outer perestrian facinity emiancements (e.g., taised incutant, tained and a martowing, emianced overhead ingitting, uarnic-cammig measures, curb extensions), as needed, to improve the safety of the crossing. These are general recommendations: good engineering indement should be used in individual cases	ove the safet	v of the cro	ucuus (c.g. ossing. Th	, taiscu ille lese are gei	ruiall, uall neral recor	nc signal, i nmendatio:	uauway na. ns: good en	nowing, ci ngineering	iudement	should be t	used in ind	ividual c
for deciding where to install crosswalks.			ò				0	0	0			
** Where the speed limit exceeds 64.4 km/h (40 mi/h), marked crosswalks alone should not be used at unsignalized locations.	0 mi/h), mar	ked crossv-	valks aloné	e should ne	ot be used	at unsignal	ized locatic	ons.				
*** 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	be at least 1.	.2 m (4 ft)	wide and i	1.8 m (6 ft)) long to se	erve adequi	ately as a re	efuge area	for pedestr	ians, in ac	cordance v	rith MU
and American Association of State Highway and Transportation Officials (AASHTO) guidelines	nd Transport	ation Uthic	als (AAS	HTO) gun	delines.							
C = Candidate sites for marked crosswalks. Marked crosswalks must be installed carefully and selectively. Before installing new marked crosswalks, an engineering study is	Marked cros	sswalks m	ust be inst	alled carefi	ully and se	lectively.	Before insta	alling new	marked cr	osswalks,	an enginee	ring stud
needed to determine whether the location is unitable for a matter crosswalk. For an entimetring that every action is unitable for a matter crosswalk. For an entimetring that with a sufficient at some locations, while a more indentity	table for a m	arked cros	swalk Fo	ur an enoin	eering stud	tv a site re	view may 1	he sufficie	nt at some	locations	n o o lidur	

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.

Appendix E Treatment Tables

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Treatment Advantages Disadvantages Recommanded locations Monomisticate locations Exercitation			Signing and Marking Treatments (Treatments Should be Justified Through an Engineering Study)	Treatments ough an Engineering Study)			
Tradement Advantages Disadontages					Motorist	Yield Rate	
Inequencione Very little effect at right Mot usually recommended afone NR NR Inclusions to divorse that a crossing locations Speeds increase over time Low volume and low speed roadways NR NR Inclusions to divorse that a crossing locations Rote en spoet and avoid by pedestrians multiple NM NR NR Repensive Tend to be grooted unless pedestrians NM or without a marked NR NR Repensive Repensive Repensive NM NR NR Repensive Repensive Repensive NM or without a marked NR NR Repensive Repensive Repensive Repensive NM NR NR Repensive Repensive Repensive NM or without a marked NR NR Repensive Repensive Repensive Repensive NM NR NR Repensive Repensive Repensive NR NR NR Repensive Repensive Repensive NR NR NR Repensive	Treatment	Advantages	Disadvantages	Recommended Locations	Staged Pedestrian	Unstaged Pedestrian	Cost
Image: Notice of the a crossing bloction Specific increase over time Low volume and low specific and ways Image: Notice of the a crossing bloction Nm Nm Indicates to divers that a crossing bloction Indicates to divers that a crossing bloction Image: Notice of the a crossing bloction Nm end to be growed undist spectations Nm Nm Nm Signs Present Provent to be growed undist spectations End to be growed undist spectations Mm end to be growed undist spectations Nm Nm Nm Nm Signs satist" Present Present Present Downershift and the mutupid lanes Nm		Inexpensive	Very little effect at night	Not usually recommended alone			
Indicates to drivers that a crossing location is peter arreading. Moree justrified Moree justrified More instruction Reservation Tend to be growed unless peterstrans Where unexpected entries into the instructions in each actions in a count of a drivers that a crossing location More instructions More instructinsting More instructions	Crosswalk Markings Only	Helps define a crossing location	Speeds increase over time	Low volume and low speed roadways	NR	NR	\$500 to \$2,000
Begensive Immediate Linespected entrins: into the liptored unless pedestrians: may occur use the crossing consistently to evaluate the termosting consistently in advary by pedestrians: may occur. NR NR & SBins Heps define a crossing location exerts at uncontrolled intersections in advary by pedestrians: may occur. NR NR Warning to drivers that a crossing location Proven to be inerffective at reducing there at or before the crossing location Returns not exercised NR NR Warning to drivers that a crossing location Returns not exercised Multi-line readwars Multi-line readwars NR NR Sign essient to see when have multiple lands Requires northead structure Nulti-line readwars NR NR NR Groncrete/Brick May decrease which speed Cost NR Usually coupled with other measures NR NR May decrease which speed Constraint Usually coupled with other measures NR NR May decrease which speed Cost NR Usually coupled with other measures NR NR May decrease which speed Cost NR Usually coupled with other measures NR NR May decrease whiche speed Cost		Indicates to drivers that a crossing location is present		Where justified			
B3Bns Helps define a crossing location Proven to be ineffactive at reducing transfers at uncontrolled intersections. Ether at or before the crossing location NR NR Warning to drivers that a crossing location is present. Maning to drivers that a crossing location is present. Ether at or before the crossing location is present. Hend distance increased NR NR NR ad Warning signs Requires outher ad structure Kubil distance increased Null-lane coadways NR NR NR ad Warning signs Present. Ether at or before the crossing location is di approach Level to be givened unless pedestrans Mulbi-lane coadways NR NR Additional Variance state to crossing location is for approach Mathinas and averning some which speed Corrospective crossing locations NR NR Markings and for approach Markings and avernings and different at night. Downtownty havement markings NR NR Markings and for approach Markings and averning signs Markings and because which speed such as RFBs to beacons NR NR Markings and for approach Markings and averning signs Marking artified Markings NR NR NR		Inexpensive	Tend to be ignored unless pedestrians use the crossing consistently	Where unexpected entries into the roadway by pedestrians may occur			
Warning to drivers that a crossing location isEffer with or with out a markedEffer marke	Warning Signs	Helps define a crossing location	Proven to be ineffective at reducing crashes at uncontrolled intersections	Either at or before the crossing location	NR	NR	\$300 to \$1,200
Visual distance increasedRequires overhead structureMulti-lane roadwaysMulti-lane roadwaysNinad Warning SignsWarning to drivers that a crossing location is terentTend to be ignored unless pedestrians by evolved with other measuresMulti-lane crossing locationsNinSigns easier to see when have multiple lanesEach be expensiveLous lay coupled with other measuresNinSigns easier to see when have multiple lanesCan be expensiveDowntown/urban conditionsNinMay decrease whicle speedCan be expensiveDowntown/urban conditionsNinMay decrease whicle speedConcrete/BrickDowntown/urban conditionsNinMay decrease whicle speedNot been shown to reduce crashesTraffic signal locationsNinMarkings and Warkings andMore downes that a crossing locationNinNinMarkings andMarkings andNot been shown to reduce crashesTraffic signal locationsNinMarkings and Markings and dirional Warning to drivers that a crossing locationNorteen shown to reduce crashesDowntown/Urban conditionsNinMarkings andMarkings andNorteen shown to reduce crashesDowntown/Urban conditionsNinNinMarkings andMarkings andNorteen shown to reduce crashesDowntown/Urban conditionsNinNinMarkings andMarkings at highSinNinNinNinMarkings andMarking drivers that a crossingNam here shown to reduce crashesDowntown/Urban conditionsNinMarkings andM		Warning to drivers that a crossing location is present		Either with or without a marked crosswalk			
Warning to drivers that a crossing location is be the crossing consistently Figne easter to see when have multiple lanes of approachTend to be ignored unless pedestrians busulty coupled with other measures such as RRFBs or beaconsMRNRSigne sesier to see when have multiple lanes of approachEigne to see with other measures such as RRFBs or beaconsUsually coupled with other measures such as RRFBs or beaconsNRNRMay decrease whicle speedCan be expensive to approachDowntown/Urban conditionsNRNRMarkings and Warning to drivers that a crossing location is presentVery little effect at might Where justifiedWhere justifiedT%T%May decrease whicle speedNer with pavement markingsT%T%T%T%Markings and presentMarkings or drivers that a crossing location is presentNere justifiedT%T%T%Markings and presentMarkings or drivers that a crossingMay make snow removal more difficultDowntown/Urban conditionsT%T%Markings are inghMarkings or drivers that a crossingMay make snow removal more difficultDowntown/Urban conditionsT%T%May decrease whicle speedMay make snow removal more difficultDowntown/Urban conditionsT%T%T%Markings are inghMarkings are inghMarkings are inghB7%T%T%May decrease ower timeMay mere instringDowntown/Urban conditionsT%T%Markings are inghMarkings are inghMarkings are inghT%T% <td></td> <td>Visual distance increased</td> <td>Requires overhead structure</td> <td>Multi-lane roadways</td> <td></td> <td></td> <td></td>		Visual distance increased	Requires overhead structure	Multi-lane roadways			
Signe sasier to see when have multiple lanes Signe sasier to see when have multiple lanes Usually coupled with other measures Image Usually coupled with other measures Image Image <th< td=""><td>Overhead Warning Signs</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>NR</td><td>NR</td><td>\$60,000 to \$75,000</td></th<>	Overhead Warning Signs	Warning to drivers that a crossing location is present	Tend to be ignored unless pedestrians use the crossing consistently	Midblock crossing locations	NR	NR	\$60,000 to \$75,000
May decrease vehicle speed Can be expensive Downtown/Urban conditions NR NR Concrete/Brick Not been shown to reduce crashes Traffic signal locations NR NR In conjunction with pavement markings Not been shown to reduce crashes In conjunction with pavement markings NR NR In Repensive Very little effect at night Nhere justified 7% 7% 7% In Repensive Very little effect at night Nhere justified 7% 7% 7% In Repensive Network that a crossing location is present Not been shown to reduce crashes Nhere justified 7% 7% In expensive Network that a crossing location is present May make snow removal more difficult Downtown/Urban conditions 7% 90% In expensive Network that a crossing location is present Network that acrossing location is present Not obtain whith pavement markings 7% 90% In provincition with pavement markings Not obtain whith pavement markings 87% 90% 90% In provincition with pavement markings Not obtain whith pavement markings 87% 90%<		Signs easier to see when have multiple lanes of approach		Usually coupled with other measures such as RRFBs or beacons			
Concrete/BrickNot been shown to reduce crashesTraffic signal locationsNRNRI concrete/BrickSpeeds increase over timeIn conjunction with pavement markingsNRNRalk Markings and ming to drivers that a crossing location is meaning to drivers that a crossing location is meaning to drivers that a crossing locationVery little effect at nightWhere justified7%7%Na Addresse eventNa Addresse over timeNot been shown to reduce crashesMere justified7%7%7%I crossing SignsInexpensiveMay decrease over timeDown/Urban conditions7%7%90%I crossing SignsAdditional Warning to drivers that a crossingNew encoula more difficutDown/Urban conditions90%I crossing SignsAdditional Warning to drivers that a crossingNeed consistent maintenance and pedestrian volume locationsStopplement warning signs at high pedestrian volume locations90%I crossing SignsMay decrease eventNet eluction with pavement markings17% (35 mph)90% (35 mph)I crossing SignsMay decrease event timeUrban conditions17% (35 mph)20% (35 mph)		May decrease vehicle speed		Downtown/Urban conditions			
Image Image <th< td=""><td>Colored Concrete/Brick Pavers</td><td></td><td>Not been shown to reduce crashes</td><td>Traffic signal locations</td><td>NR</td><td>NR</td><td>\$10,000 to \$75,000</td></th<>	Colored Concrete/Brick Pavers		Not been shown to reduce crashes	Traffic signal locations	NR	NR	\$10,000 to \$75,000
Where institued Mere justified 7% 7% walk Markings and bresent Worning to drivers that a crossing location is present Very little effect at night present Very little effect at night present 7% 7% May decrease vehicle speed Speeds increase over time Downtown/Urban conditions 7% 7% Inexpensive May make snow removal more difficult Downtown/Urban conditions 87% 90% 130 mph) Inexpensive Need consistent maintenance and replacement due to vehicle hits Supplement warning signs at high predestrian volume locations 87% 90% 130 mph) Incation is present Not been shown to reduce crashes Neer justified 61% (25mph) 91% (25mph) Visibility Crosswalk May decrease vehicle speed Not been shown to reduce crashes Where justified 61% (25mph) 20% (35 mph) Visibility Crosswalk May decrease vehicle speed Not been shown to reduce crashes Urban conditions 61% (25mph) 20% (35 mph)			Speeds increase over time	In conjunction with pavement markings			
InexpensiveMay make snow removal more difficultDowntown/Urban conditionsMay <th< td=""><td>Crosswalk Markings and Signs</td><td>Inexpensive Warning to drivers that a crossing location is present May decrease vehicle speed</td><td></td><td>Where justified</td><td>7%</td><td>7%</td><td>\$800 to \$3,200</td></th<>	Crosswalk Markings and Signs	Inexpensive Warning to drivers that a crossing location is present May decrease vehicle speed		Where justified	7%	7%	\$800 to \$3,200
Additional Warning to drivers that a crossing location is presentNeed consistent maintenance and pedestrian volume locationsSupplement warning signs at high gow 87% 90% location is presentreplacement due to vehicle hitspedestrian volume locations 90% 90% May decrease vehicle speedNot been shown to reduce crashesWhere justified 61% ($35 $ mph) 91% ($35 $ mph)Speeds increase over timeUrban conditions 17% ($35 $ mph) 20% ($35 $ mph)		Inexpensive	May make snow removal more difficult	Downtown/Urban conditions			
May decrease vehicle speed Not been shown to reduce crashes Where justified 61% (25mph) 91% (25 mph) Speeds increase over time Urban conditions 17% (35 mph) 20% (35 mph)	In-Street Crossing Signs (25 to 30 mph)	Additional Warning to drivers that a crossing location is present	Need consistent maintenance and replacement due to vehicle hits	Supplement warning signs at high pedestrian volume locations	87%	%06	\$500 to \$1,000
May decrease vehicle speed Not been shown to reduce crashes Where justified 61% (25 mph) 91% (25 mph) Speeds increase over time Urban conditions 17% (35 mph) 20% (35 mph)				In conjunction with pavement markings			
Speeds increase over time Urban conditions 17% (35 mpn) 20% (35 mpn)	High Visibility Crosswalk		Not been shown to reduce crashes	Where justified	61% (25mph)	91% (25 mph)	\$5,000 to \$50,000
	Markings		Speeds increase over time	Urban conditions	17% (35 mpn)	(ndm <£) %02	

	5	Uncontrolled Crossing Treatments (in conjunction with markings and signs) (Treatments Should be Justified Through an Engineering Study)	ijunction with markings and signs) rough an Engineering Studv)			
				Motorist)	Motorist Yield Rate	
Treatment	Advantages	Disadvantages	Recommended Locations	Staged Pedestrian	Unstaged Pedestrian	Cost
Center Median with Refuge Island	Decreases pedestrian crossing distance Provides higher pedestrian visibility Reduces vehicle Speeds approaching the island Reduces conflicts Increases usable gaps Reduces pedestrian exposure time	May make snow removal more difficult May be a hazard for motorists Small islands not recommended on high speed (>40 mph) roadways	Wide two-lane roads and multi-lane roads with sufficient right-of-way	34%	29%	Variable depending on length
School Crossing Guards	Inexpensive Provides higher pedestrian visibility to drivers Highlights when a pedestrian crossing is being used	May require trained staff or local law enforcement, especially on high speed and high volume roadways	At school locations	NR	86%	Variable
Pedestrian Crossing Flags		No effect at night Requires pedestrian to actively use a flag Can be easily removed/stolen Shorter crossings are preferred	Downtown/Urban locations High pedestrian volume locations Across low speed (<45 mph) roadways	65%	74%	<\$500
Warning Sign with Edge Mounted LEDs	Highlights a crossing both at night and during Requires pedestrian activation the day	Requires pedestrian activation Minimal to no effect on speed	In conjunction with In-Road Warning Lights Downtown/Urban conditions	NR	28%	\$3,000 to \$8,000
In-Road Warning Lights	Highlights a crossing both at night and during Snow plows can cause maintenance the day issues Provides higher driver awareness when a No effect when road surface is cover pedestrian is present In snow Requires pedestrian activation	Snow plows can cause maintenance issues No effect when road surface is covered In snow Requires pedestrian activation	Downtown/Urban conditions	NR	%99	\$20,000 to \$40,000
Pedestal Mounted Pedestrian Flashing Signal Beacons	Provides higher driver awareness when a pedestrian is present	Requires pedestrian activation Not advisable on multi-lane streets Not been shown to reduce crashes	Low speed school crossings Two lane roadways Midblock crossing locations	NR	57% (2-Lane, 35 mph)	\$12,000 to \$18,000
Pedestrian Overhead Flashing Signal Beacons	Provides higher driver awareness when a pedestrian is present	Requires pedestrian activation	Multi-lane roadways Midblock crossing locations Lower speed roadways	active 47% passive 31%	active 49% passive 67%	\$75,000 to \$150,000
Rectangular Rapid Flash Beacons (RRFBs)	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	Supplement existing pedestrian crossing warning signs School Crossings Midblock crossing locations Low and high speed roadways	84%	81%	\$12,000 to \$18,000
		NR = No Research Found on Effect to Yielding Rate	Effect to Yielding Rate			

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

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		High Level Treatments (Treatments Should be Justified Through an Engineering Studv)	tments ough an Engineering Studv)			
				Motorist	Motorist Yield Rate	
Treatment	Advantages	Disadvantages	Recommended Locations	Staged	Unstaged	Cost
				Pedestrian	Pedestrian	
Pedestrian Hvbrid	Provides higher driver awareness when a pedestrian is present	Potential increase in vehicle crashes	Justified locations			
Beacon	Has been shown to decrease pedestrian crashes	Can have spotty compliance rates due to Midblock crossing locations a lack of driver understanding	Midblock crossing locations	%16	%66	\$150,000 to \$300,000
Tffic Cianol	Provides higher driver awareness when a pedestrian is present	May increase crashes due to the driver	High pedestrian volume crossings	V IV	412	
	Easily understandable	expectation of a green signal indication	Justified locations, meets signal warrants	ΨN	ΕN.	הההיההבל הו הההיההול
	Removes pedestrian/vehicle conflicts	Potential of the crossing not being used Location with compatible grades	Location with compatible grades			
Underpass Grade		Very location specific	High pedestrian volume crossings	:	:	
Separation		Very expensive Drainage within an underpass can be problematic Underpass would require lighting	High volume roadways High speed roadways	NA	NA	\$800,000+
	Removes pedestrian/vehicle conflicts	Potential of the crossing not being used Location with compatible grades	Location with compatible grades			
Overpass Grade		Very location specific	High pedestrian volume crossings	NA	NA	\$1,200,000+
Separation		Very expensive Snow removal on overpass may be difficult	High volume roadways High speed roadways			
		NA = Not Applicable or No Research Found on Effect to Yielding Rates	und on Effect to Yielding Rates			

Appendix F Guidebook

Pedestrian Crossings: Uncontrolled Locations



















MINNESOTA LTAP center for transportation studies



Pedestrian Crossings: Uncontrolled Locations	June 2014	Published By Minnesota Local Road Research Board (LRRB) Web: www.lrrb.org	MnDOT Office of Maintenance MnDOT Research Services Section MS 330, 395 John Ireland Blvd. St. Paul, Minnesota 55155 Phone: 651-366-3780 Fax: 651-366-3789 E-mail: research@dot.state.mn.us

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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.

It is the responsibility of agencies to determine if the procedure presented source to in this guide is appropriate and consistent with their needs. In cross-	in pro- • This guidebook does not set requirements or mandates.	This guidebook contains no warrants or standards and does not supersede other publications that do.	al transpor- • This guidebook is not a standard and is neither intended to be, nor conflicting does it establish, a legal standard of care for users or professionals.	and can be • This guidebook does not supersede the information in publications lestrian such as:	sign, - Minnesota Manual on Uniform Traffic Control Devices	- AASHTO Guide for the Planning, Design, and Opera- tion of Pedestrian Facilities	Capacity - Minnesota's Best Practices for Pedestrian/Bicycle Safety	- Best Practices Synthesis and Guidance in At-Grade		nent of - 2010 Highway Capacity Manual Trans-	ard, and onsistent	locations	or any of debook re- that agen- nat actual
The information presented in this guidebook is provided as a resource to assist agencies in their efforts to evaluate uncontrolled pedestrian cross-	ings and determine appropriate treatment options. The evaluation pro- cedure provided in this guidebook takes into account accepted practice.	safety, and operations.	Pedestrian crossings are an important feature of the multimodal transpor- tation system. They enable pedestrians and bicyclists to cross conflicting traffic so they can access locations on either side of streats and high-	ways. 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 midebook is a summary of the evoluation moredured mesented 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 Trans-	portation Officials (AASHTO), the Transportation Research Board, and other research. The information is intended to offer agencies a consistent	methodology for evaluating uncontrolled pedestrian crossing loo 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 re- sides with the agency. There is no expectation or requirement that agen- distribution strategy, and it is understood that actual

Document Information and Disclaimer

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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 cross-

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.

State of Minnesota, "2013 Minnesota Statutes 169.21 Pedestrian," 2013. Available: https://www.revisor.mn.gov/statutes. [Accessed January 2014]. Sources:

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

Pedestrian Crossing Evaluation Methodology

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

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

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



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:

<u>GEOMETRICS</u>

Crossing Length

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

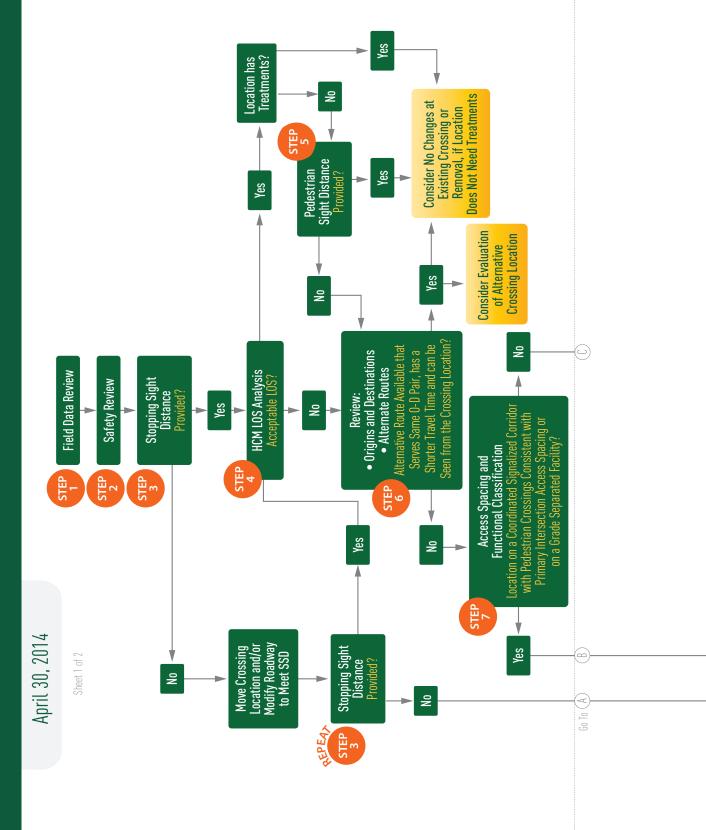


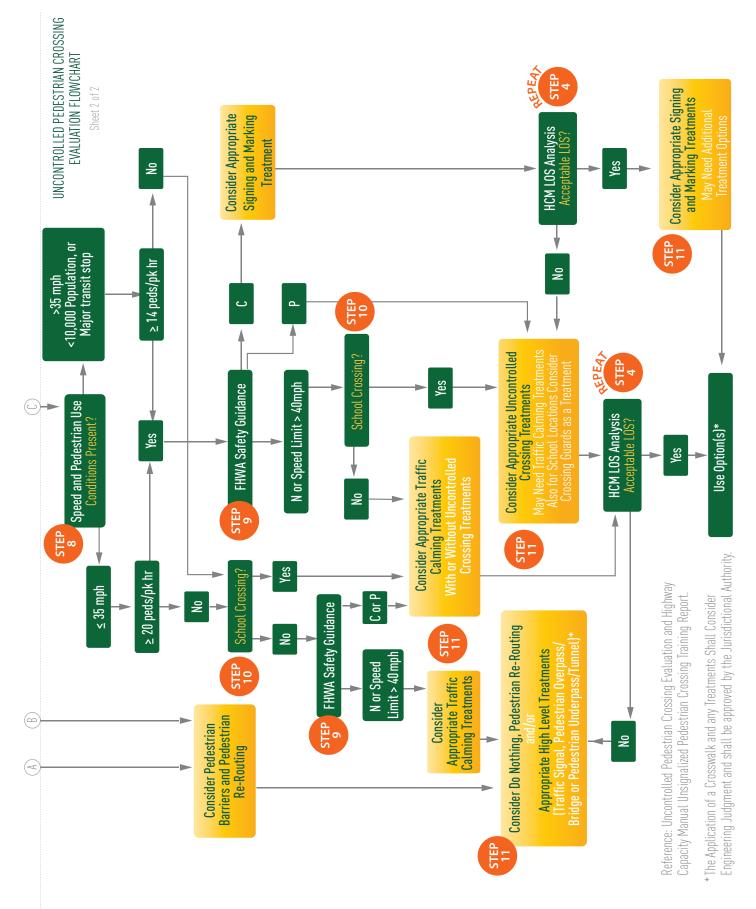




MEASURING CROSSING LENGTH

UNCONTROLLED PEDESTRIAN CROSSING EVALUATION FLOWCHART

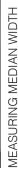




Median Width

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

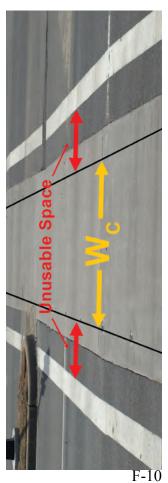




MEASURING MEDIAN WIDTH

Crosswalk Width

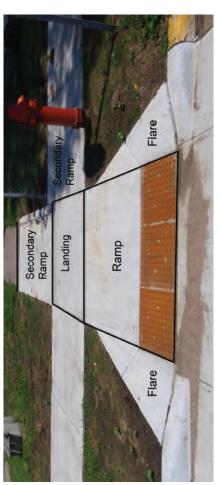
- Crosswalk width provide a defined area in which to cross.
- Effective crosswalk width is measured at the narrowest point of the crossing, be it in the ramp or the crosswalk.
- Crosswalk width (W_c) is the width measurement of at the narrowest point of the crossing (as shown at right), unless other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



MEASURING CROSSWALK WIDTH

Curb Ramps

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



CURB RAMP DIAGRAM

Americans with Disabilities Act (ADA) Requirements

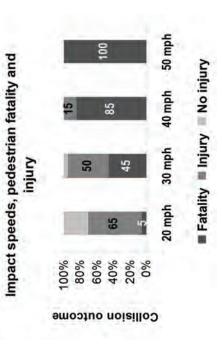
- ADA requirements for pedestrian crossings include grades, tactile surfaces/truncated domes, ramp width, and landing areas.
- The requirements are expansive and are beyond the scope of this guidebook.
- sibility Design Guidance, http:///www.dot.state.mn.us/ada/design Please see the Minnesota Department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

Sources:

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

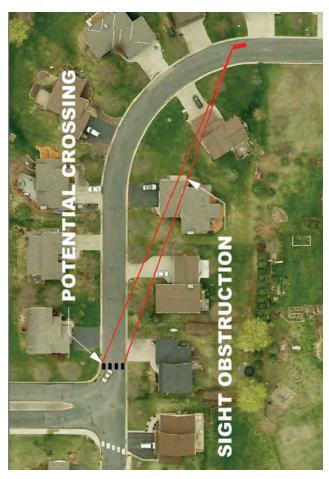
Roadway Speed

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



Roadway Curvature

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



SIGHT OBSTRUCTION CAUSED BY ROADWAY CURVATURE

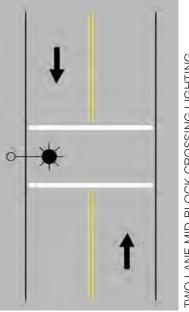
Sources: A. V. Moudon, L. Lin and P. Hurvitz, "Managing Pedestrian Safety I: Injury Severity," Washington State Department of Transportation, Olympia, WA, February 2007.

 Pedestrian Sight Distance While Minnesota State Statute requires that motorists stop for pedestrians legally crossing, many pedestrians wait for an adequate gap in traffic before crossing. Pedestrian sight distance (PedSD) is a term to describe the distance covered by a motorist during the time it takes a pedestrian to recognize an adequate gap in traffic and cross the roadway. 	$PedSD = 1.47S\left(\frac{L}{S_p} + t_s\right)$	Where: <i>PedSD</i> = pedestrian crossing sight distance	S = design speed (mph) L = crossing distance (ft) $S_p =$ average pedestrian walking speed (ft/s), default = 3.5 ft/s	$t_s = \text{pedestrian start-up and end clearance time (s)}, default = 3.0 s$	 Traffic and Pedestrian Data The volume of vehicles on the roadway directly affects the number of gaps available for pedestrians to cross a roadway. 	• The volume of pedestrians using the crossing affects how motor- ists view the crossing. A highly used crossing may be more recog- nizable to a motorist, resulting in a safer crossing.
 Stopping Sight Distance Stopping sight distance (SSD) is the distance covered by a vehicle during a stopping procedure. SSD should be provided at all pedestrian crossings. The SSD considers both brake reaction distance and braking distance. 	$SSD = 1.47St$ $= 1.47St$ $+ 1.075 \frac{S^2}{30 \left[\left(\frac{a}{32.2} \right) \pm G \right]}$	Where: SSD = stopping sight distance	S = speed (mph) t = brake reaction distance, 2.5 s a = deceleration rate, ft/s^2 , default = 11.2 ft/s^2 G = grade, rise/run, ft/ft	For more information on SSD, please see the AASHTO Green Book.		F-12

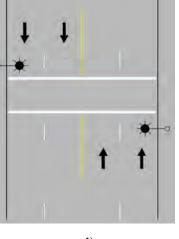
ADDITIONAL SITE CHARACTERISTICS

Lighting

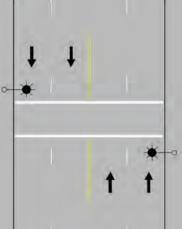
- Lighting should be provided at intersection crossings and marked crossings that are used at night.
- Intersection or pedestrian scale lighting may be appropriate to light the pedestrian crossing location.
- of pedestrian facilities but may need to be supplemented at Continuous street lighting can provide adequate lighting 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.



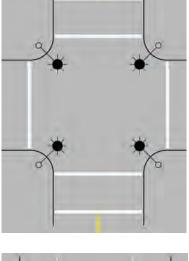




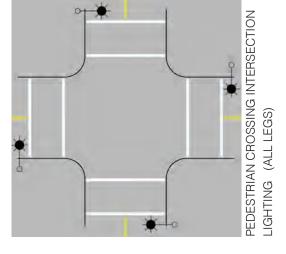
CROSSING LIGHTING

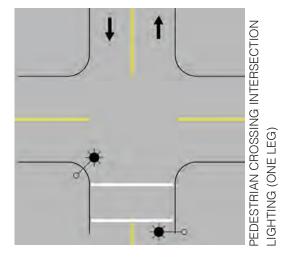


MULTI-LANE OR LONG MID-BLOCK



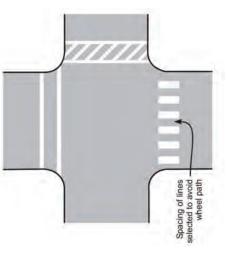
TRADITIONAL INTERSECTION LIGHTING (ALL LEGS)



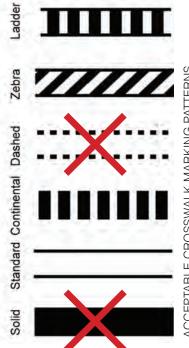


Crosswalk Pavement Markings

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



CROSSWALK MARKING EXAMPLES







STANDARD/TRANSVERSE CROSSWALK PAVEMENT MARKINGS



CONTINENTAL CROSSWALK PAVEMENT MARKINGS

Signing

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



PEDESTRIAN CROSSING WARNING SIGN PLUS IN-ROAD SIGNS



SCHOOL CROSSING WARNING SIGN

Sources:

C. V. Zeeger, J. R. Stewart, H. H. Huang, P. A. Lagerwey, J. Feaganes and B. Campbell, "Safety Effects of Marked Minnesota Department of Transportation, Minnesota Manual on Uniform Traffic Control Devices, Roseville, MN: Minnesota Department of Transportation, January 2014.

versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines," Federal Highway Administration, McLean, VA, September 2005.

 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 	- Remement communities to bus stops and commercial retain - 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 		
 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. 	F 15



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.

STEP HCM Level of Service Analysis

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



STEP Review: Origins and Destinations, STEP 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 effec- tively while providing less delay. This includes the time to traverse to the alternative crossing cross, and complete the movement to the desting-	tion. 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 effec- tively at another crossing without much backtracking, consider making no changes at the existing crossing or adding pedestrian channelization	and/or wayfinding. Also consider evaluating the alternate crossing location.			 Sources: American Association of State Highway and Transportation Officials, A Policy on Geometric Design of Highways and Streets, 6th Edition, Washington DC: American Association of State Highway and Transportation Officials, 2011. C. V. Zeeger, J. R. Stewart, H. H. Huang, P. A. Lagerwey, J. Feaganes and B. Campbell, "Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines," Federal Highway Administration, McLean, VA, September 2005. Transportation Research Board, HCM 2010 Highway Capacity Manual, Washington, DC: National Academy of Sciences, 2010.
This six-step procedure to determine LOS for pedestrians at uncontrolled		The input information for use in the equations is provided in the input table on the second worksheet. An explanation of measuring crosswalk length (L) and crosswalk width (W_c) can be found on page 4 of this guidebook.	LOS is generally deemed acceptable between A and D and deemed unacceptable at E or F. Local agency direction on acceptable service levels should be verified. If the LOS is acceptable and the location already has	treatments such as signing and/or striping, consider making no changes at the existing crossing.	If LOS is unacceptable, skip to Step 6. If this procedure is completed after Step 11, consider applying appropriate treatment option(s) if LOS is accentable. If LOS is deemed accentable, 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.	F-17

STEP Access Spacing and Functional Classification	STEP 8 Speed and Pedestrian Use
The functional classification of the roadway and the current access con- trol of the roadway being crossed should be considered.	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
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.	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 high- est 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 high- est vehicle volume hour separately.
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.	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.
Due to the limited access along grade-separated roadway facilities, marked and unmarked pedestrian crossings on those facilities are lim-	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.
ited 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.	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.
 Sources: C. V. Zeeger, J. R. Stewart, H. H. Huang, P. A. Lagerwey, J. Feaganes and B. Campbell, "Safety Effects of C. V. Zeeger, J. R. Stewart, H. H. Huang, P. A. Lagerwey, J. Feaganes and B. Campbell, "Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guide lines," Federal Highway Administration, McLean, VA, September 2005. K. Fitzpatrick, S. Turner, M. Brewer, P. Carlson, B. Ullman, N. Trout, E. S. Park and J. Whitcare, "Improving Pedestrian Safety at Unsignalized Crossings," Transportation Research Board of the National Academies, Washington, DC, 2006. 	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.

16

This research provides the basis for the guidance in Table 1 on page 18. Guidelines provided in the table include intersections and midblock loca- tions with no traffic signals or stop signs on the approach to the crossing.	()	Q	measures, curb extensions, etc.) as needed to improve the safety of the crossing.	Guidelines outlined in the table are general recommendations; good engineering judgment should be used in individual cases when deciding	where to install crosswalks.					 Sources: C. V. Zeeger, J. R. Stewart, H. H. Huang, P. A. Lagerwey, J. Feaganes and B. Campbell, "Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guide lines," Federal Highway Administration, McLean, VA, September 2005. K. Fitzpatrick, S. Turner, M. Brewer, P. Carlson, B. Ullman, N. Trout, E. S. Park and J. Whitcare, "Improving Pedestrian Safety at Unsignalized Crossings," Transportation Research Board of the National Academies, Washington, DC, 2006.
STEP FHWA Safety Guidance	Federal Highway Administration (FHWA) guidance in the Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations should be determined based on the traffic volume, speed, and roadway type. The study indicates the types of treatments recommended for installing marked crosswalks at uncontrolled locations.	Research indicates that there is a statistically significant difference in the safety between a marked and unmarked crossing when traffic volume is over 15,000, or over 12,000 without a median, under most speeds, as shown in the table below.	16	1.2 N.S. = No Significant Difference	Privan Creative Privan Creative Privation (Privation Creative Privation Creative Privative Privative Privative Privatio	Tan Cra (g=0.62)	N.S. 0.25	M U M U M U M U M U M U M U M U M U M U	Type of Crossing	F-19

Table 1: FHWA Safety Guidance Table

	Vehic	Vehicle ADT \leq 9,000	9,000	> 6 ^	Vehicle ADT > 9,000–12,000	T 00	> 12 <	Vehicle ADT > 12,000–15,000	D00	>	Vehicle ADT > 15,000	F
						Speed	Speed Limit*					
Number of Travel Lanes and Median Type)	≤ 48.3 km/h (30 mph)	56.4 km/h (35 mph)	64.4 km/h (40 mph)	≤ 48.3 km/h (30 mph)	56.4 km/h (35 mph)	64.4 km/h (40 mph)	≤ 48.3 km/h (30 mph)	56.4 km/h (35 mph)	64.4 km/h (40 mph)	≤ 48.3 km/h (30 mph)	56.4 km/h (35 mph)	64.4 km/h (40 mph)
Two lanes	U	υ	٩	υ	C	Ч	υ	υ	z	U	٩	z
Three lanes	U	U	ط	U	Ъ	Ч	ط	ط	z	ط	z	z
Multilane (four or more lanes) with raised median**	U	υ	ط	υ	Ъ	z	٩	ط	z	z	z	z
Multilane (four or more lanes) without raised me- dian	U	٩	z	٩	ط	z	z	z	z	z	z	z

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

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

may be sufficient at some locations, while a more in-depth study of pedestrian volume, vehicle speed, sight distance, vehicle mix, and other factors walks, an engineering study is needed to determine whether the location is suitable for a marked crosswalk. For an engineering study, a site review C = Candidate sites for marked crosswalks. Marked crosswalks must be installed carefully and selectively. Before installing new marked crossmay 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 $^{
m ON}$ = 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.



School Crossings

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



ADULT SCHOOL CROSSING GUARD





Consider Appropriate Treatment Options

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

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

SIGNING AND MARKING TREATMENTS

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

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

Sources:

"Minnesota's Best Practices for Pedestrian/Bicycle Safety," MnDOT Office of Traffic, Safety and Technology, September 2013.

Best Practices Synthesis and Guidance in At-Grade Trail-Crossing Treatments," Minnesota Department of Transportation, St. Paul, MN, September 2013.

NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings. Transportation Research Board of the National Academies, Washington D.C., 2006.

Assessment of Driver Yield Rates Pre- and Post-RRFB Installation, Bend, Oregon. Oregon Department of Transportation, Washington D.C., 2011. E. Bolton & Menk, Inc.

Transportation Research Board, HCM 2010 Highway Capacity Manual, Washington D.C.: National Academy of Sciences, 2010.

Before-and-After Study of the Effectiveness of Rectangular Rapid-Flashing Beacons Used with School Sign in Garland, Texas. Texas Transportation Institute, College Station, TX, April 2012.



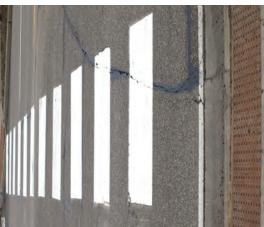


CROSSWALK MARKINGS AND SIGN



IN-STREET CROSSING SIGN

HIGH-VISIBILITY CROSSWALK MARKINGS



Treatment	Advantages	Disadvantages	Recommended Locations	Staged Pedestrian Yield Rate	Unstaged Pedestrian Yield Rate	Cost
Crosswalk Markings Only	 Inexpensive Helps define a crossing location Indicates to drivers that crossing location is present 	 Very little effect at night Speeds increase over time Not shown to reduce crashes 	 Not usually recommended alone Low-volume and low-speed road- ways • Where justified 	NR	NR	\$500-\$2,000
Warning Signs	 Inexpensive Helps define a crossing location Warning to drivers that crossing location is present 	 Tend to be ignored unless pedestrians use the crossing consistently Proven to be ineffective at reducing crashes at uncontrolled intersections 	 Where unexpected entries into the road by pedestrians may occur At or before the crossing loca- tion • With or without a marked crosswalk 	NR	NR	\$300-\$1,200
Overhead Warning Signs	 May decrease vehicle speed 	 Requires overhead structure Tend to be ignored unless pedestrians use the crossing consistently 	 Multilane roadways • Mid- block crossing locations • Usually coupled with other measures such as RRFBs or beacons 	NR	NR	\$60,000- \$75,000
Colored Concrete/Brick Pavers	 Inexpensive • Warning to drivers that crossing location is present • May decrease vehicle speed 	 Can be expensive Not shown to reduce crashes 	 Downtown/urban conditions Traffic signal locations • In conjunction with pavement markings 	NR	NR	\$10,000- \$75,000
Crosswalk Markings and Signs	 Inexpensive • Warning to drivers that crossing location is present • May decrease vehicle speed 	 Make snow removal more difficult • Need consistent main- tenance and replacement due to vehicle hits 	 Where justified 	7%	7%	\$800-\$3,200
In-Street Crossing Signs (25–30 mph)	 Inexpensive • Additional warning to drivers that crossing location is present 	 Not shown to reduce crashes Speeds increase over time 	 Downtown/urban conditions Supplement warning signs at high pedestrian volume locations In conjunction with pavement markings 	87%	%06	\$500-\$1,000
High-Visibility Crosswalk Markings	 May decrease vehicle speed 	 Not shown to reduce crashes Speeds increase over time 	 Where justified • Urban condi- tions 	61% (25mph) 17% (35mph)	91% (25mph) 20% (35mph)	\$5,000- \$50,000
		NR = No research found on effect to yielding rate	n effect to yielding rate			

Table 2: Signing and Marking Treatments

21

UNCONTROLLED CROSSING TREATMENTS

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

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



OVERHEAD FLASHING SIGNAL BEACONS



CENTER MEDIAN WITH REFUGE ISLAND







PEDESTAL-MOUNTED FLASHING SIGNAL BEACONS

IN-ROAD WARNING LIGHTS

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Table 3

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

23

TRAFFIC CALMING TREATMENTS

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

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

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

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



CURB BUMP-OUTS



CHANNELIZED TURN LANE WITH RAISED CROSSING



ROAD DIET/4-LANE TO 3-LANE CONVERSION



'Minnesota's Best Practices for Pedestrian/Bicycle Safety," MnDOT Office of Traffic, Safety and Technology, September 2013.

NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings. Transportation Research Board of the National Academies, Washington D.C., 2006. 'Best Practices Synthesis and Guidance in At-Grade Trail-Crossing Treatments," Minnesota Department of Transportation, St. Paul, MN, September 2013.

Assessment of Driver Yield Rates Pre- and Post-RRFB Installation, Bend, Oregon. Oregon Department of Transportation, Washington D.C., 2011. Bolton & Menk, Inc. F-26

Before-and-After Study of the Effectiveness of Rectangular Rapid-Flashing Beacons Used with School Sign in Garland, Texas. Texas Transportation Institute, Transportation Research Board, HCM 2010 Highway Capacity Manual, Washington D.C.: National Academy of Sciences, 2010. College Station, TX, April 2012.



CENTER MEDIAN WITH REFUGE ISLAND

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

Table 4: Traffic Calming Treatments

High-level treatments are high cost and are generally implemented on high-volume and high-speed roadways. They are much more difficult to implement unless they are justified based on traffic and pedestrian volume. Possible high-level treatments are outlined in Table 5 on page 27, and examples of selected treatment options are shown below. For additional information on Treatment Options, please see the sources listed below.



PEDESTRIAN HYBRID BEACON



TRAFFIC SIGNAL



OVERPASS



Evaluate LOS for Treatment Options

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

If acceptable service levels cannot be met:

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

Sources:

- "Minnesota's Best Practices for Pedestrian/Bicycle Safety," MnDOT Office of Traffic, Safety and Technology, September 2013.
- Best Practices Synthesis and Guidance in At-Grade Trail-Crossing Treatments," Minnesota Department of Transportation, St.Paul, MN, September 2013.
- VCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings. Transportation Research Board of the National Academies, Washington D.C., 2006.
- Assessment of Driver Yield Rates Pre- and Post-RRFB Installation, Bend, Oregon. Oregon Department of Transportation, Washington D.C., 2011.
 - 3olton & Menk, Inc.
- Transportation Research Board, HCM 2010 Highway Capacity Manual, Washington D.C.: National Academy of Sciences, 2010.
- Before-and-After Study of the Effectiveness of Rectangular Rapid-Flashing Beacons Used with School Sign in Garland, Texas. Texas Transportation Institute, College Station, TX, April 2012.

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10

 Provides higher driver awareness when a pedestrian is present • Has been shown to decrease pedestrian crashes 	 Potential increase in vehicle crashes Can have spotty com- pliance rates due to a lack of driver understanding 	 Justified locations • Mid- block crossing locations 	97%	%66	\$150,000- \$300,000
 Provides higher driver awareness when a pedestrian is present Easily understandable 	 May increase crashes due to the driver expectation of a green signal indication 	 High pedestrian volume crossings Justified loca- tions, meets signal warrants 	NA	NA	\$150,000- \$300,000
 Removes pedestrian/vehicle conflicts 	 Potential of the crossing not being used • Very location specific Very expensive • Drainage within an underpass can be problematic • Underpass would require lighting 	 Location with compatible grades • High pedestrian volume crossings • High-vol- ume roadways • High-speed roadways 	NA	NA	\$800,000+
 Removes pedestrian/vehicle conflicts 	 Potential of the crossing not being used • Very location specific • Very expensive • Snow removal on overpass may be difficult 	 Location with compatible grades High pedestrian volume crossings High-vol- ume roadways High-speed roadways 	NA	NA	\$1,200,000+
NA = Not	NA = Not applicable or no research found on effect to yielding rates	effect to yielding rates			

F-29



Uncontrolled Pedestrian Crossing Data Collection Worksheet

Location:					Date:						
City, State:	C				Scenario:	_					
Reviewer(s):					Agency:						
Project #:	2				ID #:						
	The first ste	p in unders					sing location is	comple	eting		
				of the location							
				sing distance fr			Crossing 1	_		ft.	
				no median. If t		edian at th	ne Crossing 2			ft.	
			and the second	nd 2 distances				_			
	Median: wid									ft.	-
	Crossing Wid			k width						ft.	
	Raised Med								Yes		No
S				Available (mini	mum 4' x 4'	landing)?			Yes		No
trie	Curb Ramp								Yes		No
ů.)A Complia	nt Curb Rar	np Available (w					Yes		No
Geometrics	Speed:						ntile speed			mph	
	Roadway Cu				Average w		ed			ft/s	
		1. 1 . 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.		orizontal or ve					Yes		No
				ire located on th	e next page			_		_	
	Direction 1:					ft.	provided?		Yes		No
	Direction 2:					ft.	provided?		Yes	Ц	No
	Direction 1:		이 영화 영상 이야지 않다.			ft.	provided?	Ц	Yes	Ц	No
	Direction 2:					ft.	provided?		Yes		No
Traffic and						1	roadway to be			_	
Pedestrian	Attach Counts		hicles:	Daily			edestrians:	-	Daily	-	
Data	AM Peak	Hourly		Pk 15-mir		Hour	-	-	5-min		_
-	PM Peak	Hourly		Pk 15-mir		Hour	ΊΥ	PK 15	5-min		-
	Lighting:		بريار أرور فر	te Itulia els suss							
		And The second		it light the cro			Chevineeu vite		Yes		No
	Crosswalk Pa		of the mark		estrian cros: F	Excelle	ntly marked? nt		Yes Fair	H	No Poor
v				ly defined?	L					H	No
stic	1		eed replace						Yes Yes	H	No
eri				marking patte	rn?	-			Tes		NU
act	Signing:		signed at cr		1116				Yes		No
hai	Jighing.			vance of cross	walk?				Yes	Ē	No
e O		Distances		direction 1		ft.	direction 2			ft.	NO
I Si	Enhancemen			ncements are o	Currently at	10.	uncedon 2				
ona	Ennoncenter		the crossin		currently ac	1					
Additional Site Characteristics	Adjacent Fac			nearest marke	ed crosswalk	2		-		ft.	
Ade			rol devices a								
	and the state of the state of the		nt marked ci								
	and the second se			roundabout or	signalized in	ntersectio	n			ft.	
	the second second second second			same pedestria					Yes		No
				the movement					Yes		No

Developed by Bolton & Menk, Inc. in coordination with the Local Road Research Board. Worksheets made without charge and under no circumstances shall be sold by third parties for profit.



Uncontrolled Pedestrian Crossing Data Collection Worksheet

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

draw or insert map of location being studied

Notes:

Sight Distance Calculations:

where:

 $\label{eq:stopping} \begin{array}{l} \mbox{Stopping sight distance (SSD), ft = 1.47St + 1.075S^2/a} \\ \mbox{Pedestrian sight distance (PedSD), ft = 1.47S(L / S_p + t_s)} \end{array}$

S = design speed, mph L = length of crossing, ft where:

defaults:

2.5
11.2
3.5
3.0

2010 Highway Capacity Manual (HCM) Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations Intersection and Mid-Block Crossings

Introduction:

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

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

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

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

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

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

Introduction

HCM Evaluation Worksheet

2010 Highway Capacity Manual (HCM)

Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations

Intersection and Mid-Block Crossings

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

The following is the base information needed to complete the analysis.

If this is a one-stage crossing, use only Crossing 1.

If this is a two-stage crossing, each stage must be evaluated separately using Crossing 1 and Crossing 2.

Product after the second	de Coultar	Increase Tables
Evaluation Inputs:	defaults:	Input Table:
L = crosswalk length (ft)	1111001	L=
S_p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p =
t_s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t _s =
V = vehicular hourly volume (veh/hr)		V =
υ_{p} = pedestrian flow rate (ped/s)	υ _p = 0*	$v_p =$
υ = vehicular flow rate (veh/s) = V/3600	υ = V/3600	U =
W_c = crosswalk width (ft)	W _c = 8.0	W _c =
N = number of through lanes crossed (Integer)	N = INT(L/11)	N =
	*no platooni	ng observed
Crossing 2:	(only used for two-stage c	rossings)
Evaluation Inputs:	defaults:	Input Table:
L = crosswalk length (ft)		L=
S_p = average pedestrian walking speed (ft/s)	S _p = 3.5	S _p =
t _s = pedestrian start-up and end clearance time (s)	t _s = 3.0	t _s =

- t_s = pedestrian start-up and end clearance time (s) V = vehicular hourly volume (veh/hr)
- $v_{\rm p}$ = 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)

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:

	Average Delay	sec/ped
	LOS	
Developed by Bolton & Menk, Inc.		
for the Local Road Research Board		Inputs and Results

Page 2 of 5

V =

 $v_p =$

v =

 $W_c =$

N =

 $M_{v} =$

Input Table:

*no platooning observed

0*

V/3600

8.0

INT(L/11)

 $v_p =$

v =

W. =

N =

HCM Evaluation Worksheet



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

LRRB		Worksheet	
Crossing Location:		Date:	
City, State:		Scenario:	
Reviewer(s):		Agency:	
Step 1: Identify	Is there a median available for a two-stage cross	ing?	🗌 Yes 🗌 No
Two-Stage	If yes, does the median refuge meet ADA	requirements (4' x 4' landing)?	🗌 Yes 🗌 No
Crossings	If yes, do pedestrians treat this as a two-	stage crossing location?	🗌 Yes 🗌 No
Step 2: Determine Critical Headway	For a single pedestrian: $t_{c} = \frac{L}{S_{p}} + t_{s}$ $\boxed{t_{c} = \frac{L}{S_{p}} + t_{s}}$ $\boxed{t_{c} = \frac{t_{s}}{t_{c}} = \frac{t_{s}}{S_{p}} = \frac{t_{c}}{S_{p}} = \frac$	er the available headway is sufficent for where: $t_c = critical headway for a L = crosswalk length (ft) Sp = average pedestrian v ts = pedestrian start-up a Sp = 3.5 ft/s ts = 3 sec tc = sec tc = v_c = total number of pede(ped)v_p = pedestrian flow rate avtc = single pedestrian critNc = total number of pede(ped)v_p = spatial distributionsNc = total number of pede(ped)w_e = crosswalk width (ft)8.0 = default clear widthto avoid interference withclear width, if other thatwhere: tc,G = group critical headwtc = single pedestrian critv_p = spatial distributionsNc = total number of pede(ped)w_c = crosswalk width (ft)8.0 = default clear widthto avoid interference withclear width, if other thatwhere: tc,G = group critical headwtc = single pedestrian critv_p = spatial distributionsv_c = single pedestrian crit$	a single pedestrian (s) valking speed (ft/s) and end clearance time (s) omputed: estrians in crossing platoon (ped/s) cross crossing (veh/s) cical headway (s) of pedestrians (ped) estrians in crossing platoon used by a single pedestrian h other pedestrians (ft) an 8: ft. vay (s) cical headway (s) of pedestrians (ped)
	encounter a gap greater than or equal to the $-t - av$		
Step 3: Estimate	$P_b = 1 - e^{\frac{-t_{c,G}v}{L}}$	where: P_b = probability of blocke	
Probability of a	$P_d = 1 - (1 - P_b)^L$	P_d = probability of delaye	1.0.00000000000000000000000000000000000
Delayed		N = number of through la	the second se
Crossing	crossing 1 crossin		way (s) = t _c , if no platooning
	t _{c,G} = t _{c,G} =	v = vehicular flow rate a	cross crossing(veh/s)
	$v = P_b = v =$	P _b =	
	$N = P_d = N =$	P _d =	
Developed by Bolton 8	Menk, Inc. for the LRRB.	HCM Calculations Sheet 1	Page 3 of 5



Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

LRRB						
		nes that no motor v $t_{c,G} - \ v t_{c,G} - 1 ig)$	ehicles yield and the wher	e pedestrian is forced re: d _g = average pec t _{c,G} = group criti	lestrian gap delay (s	
ton A. Calquiata	crossing 1	t _{c,G} =	crossing 2		w rate across crossi	ng (veh/s)
Step 4: Calculate	$v = d_g =$		d _g =			
Average Delay to Wait for	Average delay	for a pedestrian wi	no is unable to cross	immediately upon re	aching the intersect	tion
Adequate Gap		(e.g., any	pedestrian experien	cing nonzero delay.)		
Adequate Gap	$d_{gd} = rac{d_g}{P_d}$		wher	e: d _{gd} = average ga nonzero delay	p delay for pedestria	ins who incui
	crossing 1		crossing 2	d _g = average peo	lestrian gap delay (s	1
	d _g =	d _g = P _d =		P _d = probability	of a delayed crossing	5
	P _d = d _{gd} =	P _d =	d _{gd} =			
Step 5: Estimate Delay Reduction due to Yielding Vehicles	situations occurs: (a) a pedestrian to cross. W and Some crossing treatmen Average pedestrian dela $d_p = \sum_{i=1}^n h(i-0.5)$ crossing 1 $h = \boxed{n} = d_p =$ 1. One-Lane Crossing	hile motorists are le d at all marked cros ts and yield rates ba y b) $P(Y_i) + \left(P_d - \frac{1}{2}\right)$	egally required to sto sings, motorist yield used on research are wh	op for crossing pedes rates actually vary con- provided on the next here: d_p = average peo- i = crossing even h = average head $P(Y_i)$ = probabil pedestrian on cr n = lnt(d_{gd} /h), a events before ar j = crossing even	trians in MN at all in page. lestrian delay (s) nt (i =1 to n) dway for each throu lity that motorists yi ossing event i verage number of cr n adequate gap is avent of (j =0 to i -1)	ntersections gh lane = N/2 ield to ossing ailable, >0
(If yielding is zero, then skip step 5)	$P(Y_i) = P_d M_y (1$ 2. Two-Lane Crossing	M	I_v = motorist yield ra	pedestrian on cr	lity that motorists yi ossing event j	eld to
	$P(Y_i) = \left[P_d - \sum_{j=0}^{i-1} P_{j} \right]$ 3. Three-Lane Crossing	$P(Y_j)\left[\frac{(2P_b(1-P_b))}{2}\right]$	$\frac{\left(P_b^2 M_y^2\right) + \left(P_b^2 M_y^2\right)}{P_d}$			
	$p(\mathbf{y}) \begin{bmatrix} \mathbf{p} & \frac{i-1}{\sum} \end{bmatrix}$	$\left[P_{b}^{3}M_{y}^{3}+3P_{b}\right]$	$\frac{P_{d}^{2}(1-P_{b})M_{y}^{2}+3P_{b}(1-P_{d})}{P_{d}}$	$(1-P_b)^2 M_y$	Summ	ary
	$P(Y_i) = P_d - \sum_{i=0}^{n} P_i $		P_d		Average	
	4. Four-Lane Crossing	1.			LOS	
	$P(Y_i) = \left[P_d - \sum_{j=1}^{i-1} \right]$	$\frac{1}{20} P(Y_j) \mathbf{x} \left[\frac{P_b^4 M_y^4 + 4}{2} \right]$	$\frac{P_b^3(1-P_b)M_y^3+6P_b^2(1)}{P_d}$	$(-P_b)^2 M_y^2 + 4P_b (1-P_b^3) M_b$		
	LOS Control Delay (sec/ped)		Comments		
step 6: Calculate		the second				
	A 0-5	Usually r	no conflicting traffic			
Average	A 0-5 B 5-10	10 A 10 A 200	0	to conflicting traffic		
Average Pedestrian Delay		Occasior	ally some delay due	to conflicting traffic ans, but not inconvien	encing	
Average Pedestrian Delay & Determine	B 5-10	Occasion Delay no	ally some delay due ticeable to pedestria			
Average Pedestrian Delay	B 5-10 C 10-20	Occasion Delay no Delay no	nally some delay due nticeable to pedestria nticeable/irritating, ir	ans, but not inconvien	k-taking	



Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

	a possible reduction in delay.	Lucia de la composición de
Crossing Treatment	Staged Pedestrian Yield Rate	Unstaged Pedestrian Yield Rate
Crosswalk Markings and Signs Only ⁽¹⁾	7%	7%
Median Refuge Islands ⁽¹⁾	34%	29%
Pedestal Mounted Flashing Beacon (2-Lane, 35 mph) ⁽³⁾	N/A	57%
Overhead Flashing Beacon (push-button activation) ⁽¹⁾	47%	49%
Overhead Flashing Beacon (passive activation) ⁽¹⁾	31%	67%
Pedestrian Crossing Flags ⁽¹⁾	65%	74%
School Crossing Guards ⁽⁵⁾	N/A	86%
In-street Crossing Signs (25-30 mph) ⁽¹⁾	87%	90%
Warning Sign with Edge Mounted LEDs ⁽⁶⁾	N/A	28%
In-road warning lights ⁽¹⁾	N/A	66%
High-visibility Signs and Markings (35 mph) ⁽¹⁾	17%	20%
High-visibility Signs and Markings (25 mph) ⁽¹⁾	61%	91%
Rectangular Rapid-Flash Beacon (RRFB) ⁽²⁾⁽⁴⁾	84%	81%
School Crossing Guards with RRFB ⁽⁵⁾	N/A	91%
Pedestrian Hybrid Beacon (HAWK) ⁽¹⁾	97%	99%

Sources: (1) Fitzpatrick, K., S.M. Turner, M. Brewer, P.J. Carlson, B. Ullman, N.D. Trout, E.S. Park, J. Whitacre, N. Lalani, and D. Lord. NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings. Transportation Research Board of the National Academies, Washington D.C., 2006.

(2) Lewis, R., J.R. Ross, D.S. Serpico : Assessment of Driver Yield Rates Pre- and Post-RRFB Installation, Bend, Oregon. Oregon Department of Transportation, Washington D.C., 2011.

(3) Bolton & Menk Field Data Collection

(4) Transportation Research Board, HCM 2010 Highway Capacity Manual, Washington D.C.: National Academy of Sciences, 2010.

(5) Brewer, Marcus A., Kay Fitzpatrick. Before-and-After Study of the Effectiveness of Rectangular Rapid-Flashing Beacons Used with School Sign in Garland, Texas. Texas Transportation Institute, College Station, TX, April 2012.

(6) Kipp, Wendy M.E., Jennifer M. V. Fitch. Evaluation of SmartStud In-Pavement Crosswalk Lighting System and BlinkerSign Interim Report. Vermont Agency of Transportation, Report 2011-3, Montpelier, VT, February 2011. (Rate Normalized to High Visibility Markings and Signs at 35 mph)