Safety Considerations at Uncontrolled Pedestrian Crossings

November 20, 2014

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Made possible by the
Local Road Research Board

This presentation does not make any legal standings and is based on the understanding of the law by a Professional Engineer. No guarantees of the law are provided.

Background

- Pedestrian Crossings are an important feature of the multi-modal transportation system.
- Difficulty:
  - Where should pedestrian crossings be considered?
  - When to consider no changes?
  - When to consider marking pedestrian crossings?
  - When to consider other treatment options?

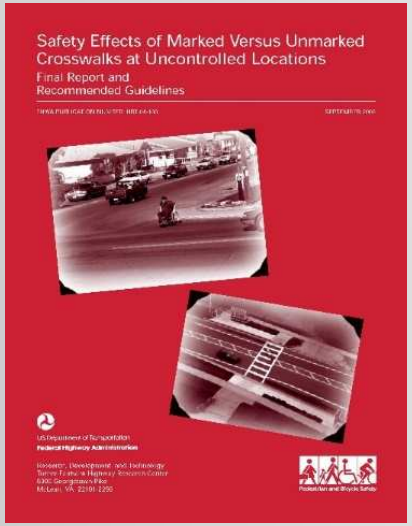
State Statute Important Points

- All intersections include legal pedestrian crossings whether marked or unmarked
- All marked crossings are legal pedestrian crossings, intersection or mid-block
- Drivers shall stop to pedestrians in legal crossings
  - Pedestrians shall yield the right-of-way to vehicles at all other locations
- A bicycle is considered a pedestrian when using a crosswalk

But….motorists may not always stop for pedestrians

Safety Considerations

- Safety Effects of Marked Versus Unmarked Crossings at Uncontrolled Locations



- "Pedestrians have a right to cross the road safely and without unreasonable delay."

Safety Evaluation

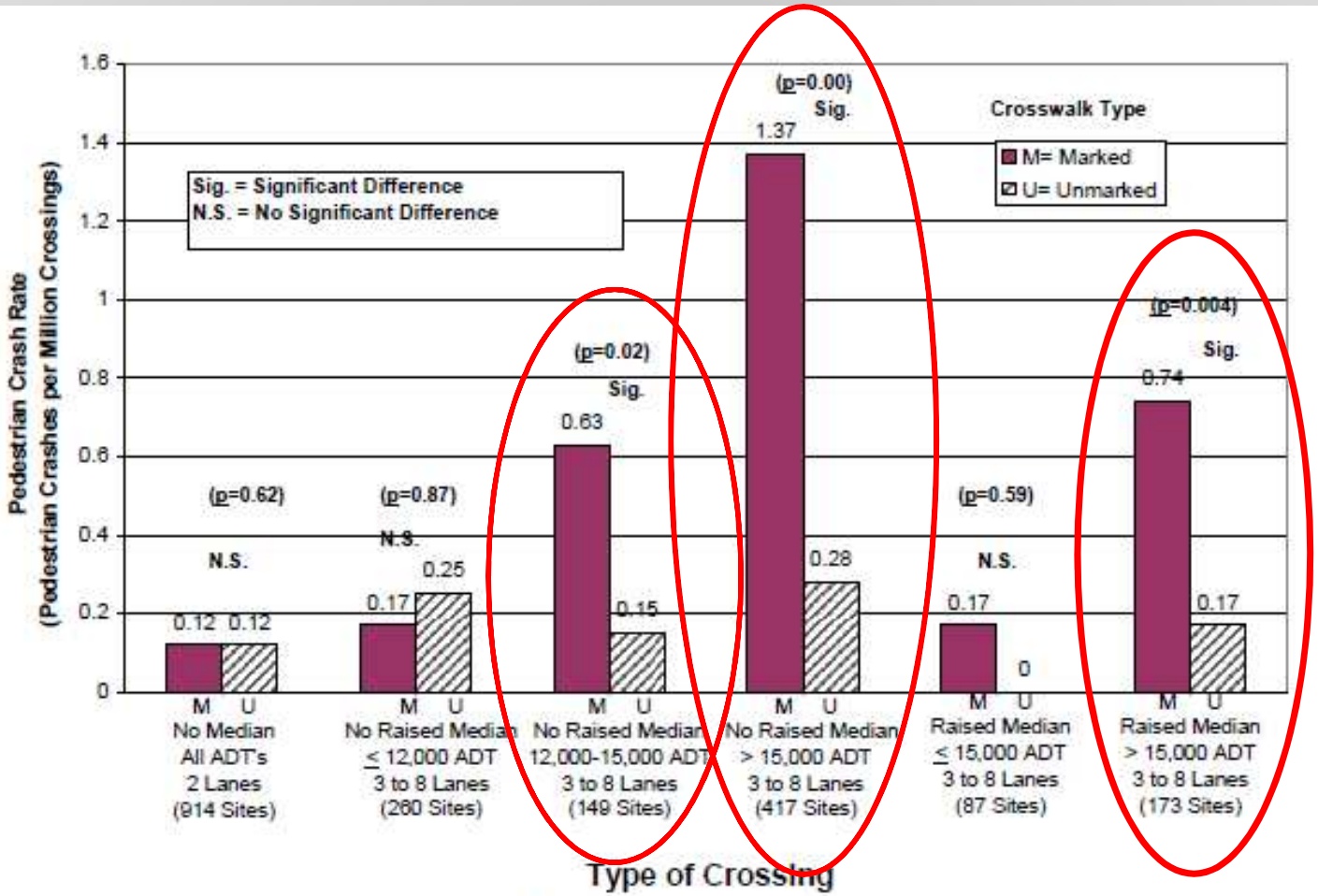
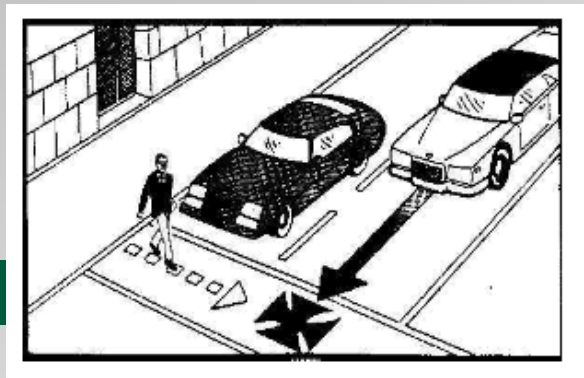


Figure 18. Pedestrian crash rate versus type of crossing.

Marked vs Unmarked Crosswalks

- Why are there more crashes that occur at marked crosswalks at high traffic volumes?
  - False sense of security?
  - More pedestrians?
  - More vulnerable populations use them?
- Higher volume typically leads to more lanes of traffic
  - Multiple-Threat?



Multiple Threat Video

FHWA Recommendations

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

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

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

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

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

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

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

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

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

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

Safety Effects of Marked Versus Unmarked Crossings at Uncontrolled Locations

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

Minnesota MUTCD

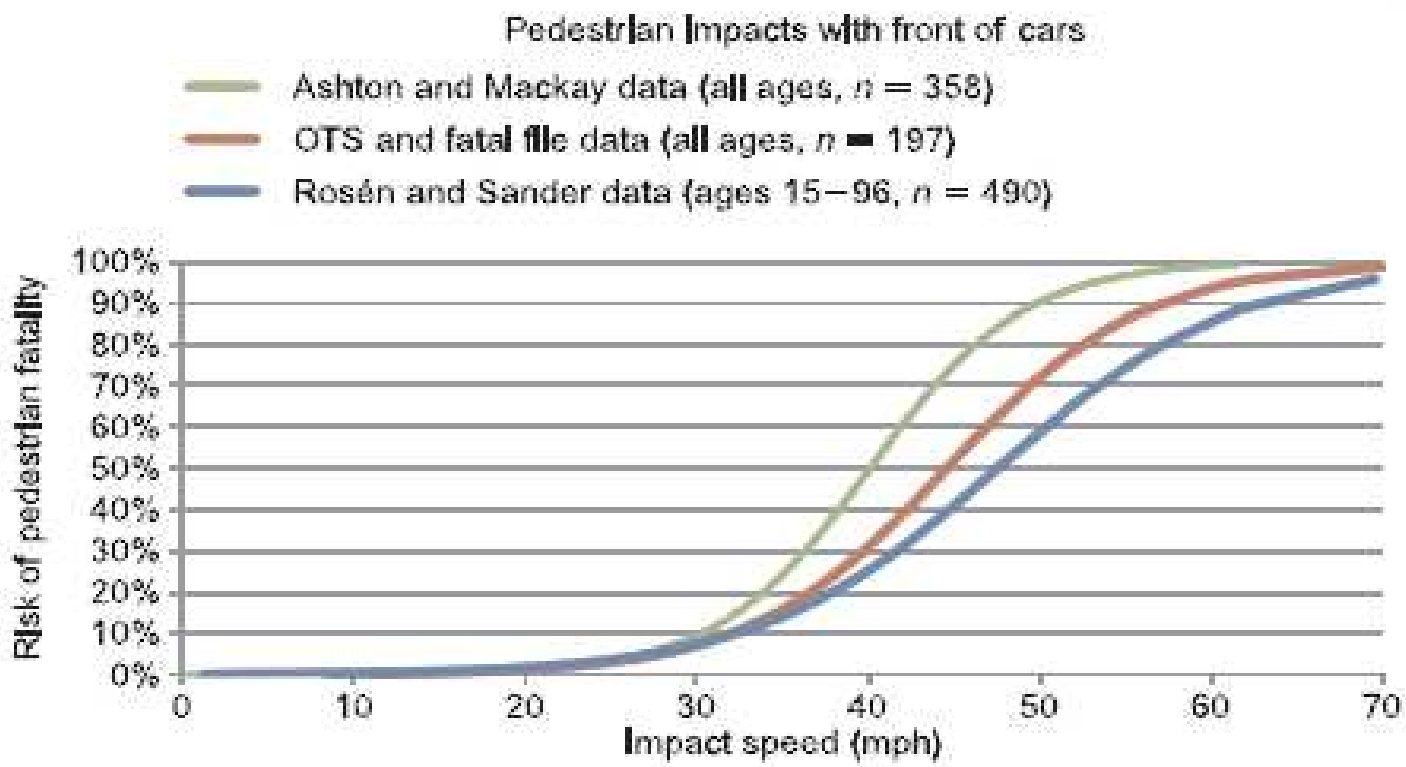
- "New marked crosswalks alone, without other measures designed to reduce traffic speeds, shorten crossing distances, enhance driver awareness of the crossing, and/or provide active warning of pedestrian presence, should not be installed across uncontrolled roadways where the speed limit exceeds 40 mph 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."

Relationship between Speed and Risk of Fatal Injury

Figure 4.1: Risk of pedestrian fatality calculated using logistic regression from the Ashton and Mackay, OTS and police fatal file, and Rosen and Sander datasets

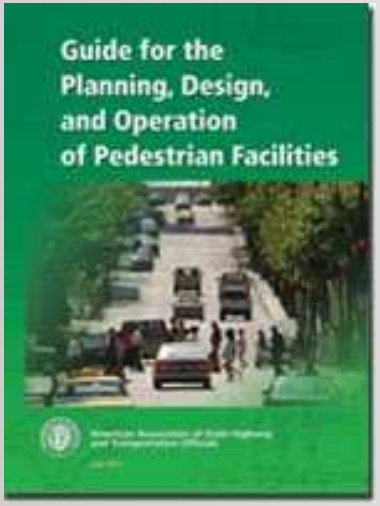


Could safety be the only consideration?

- What about a heavily used pedestrian crossing?
- What about a crossing that directly connects an origin and destination?
- What if the alternative crossing location is one block away, ¼ mile away, ½ mile away?

Guide for the Planning, Design, and Operation of Pedestrian Facilities

- Walk decisions are primarily based upon three factors:
  - travel distance,
  - personal safety and security,
  - and personal comfort and attractiveness



Alternative Routes

- Check to see if an alternate route can serve the same movements effectively while providing less delay
  - This includes the entire travel time to traverse the route
  - Example:
    - Traffic signals at ¼ mile spacing
    - Pedestrian at mid-point between signalized intersections
    - Estimate 30 seconds of delay at signal

$$\frac{660\ ft}{3.5\ ft/s} + 30\ \text{sec} + \frac{660\ ft}{3.5\ ft/s} = 407\ \text{seconds (6.8 minutes) of delay (LOS F)}$$

    - This is unacceptable to pedestrians
    - Mid-point crossing, even with the wait, could be faster

Guide for the Planning, Design, and Operation of Pedestrian Facilities

- 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 underpass or overpass crossing is generally more than the crossing time at ground level, there is a high probability that pedestrians will not use the underpass or overpass 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%

Percent of Pedestrians Using the Grade Separated Route vs. the At-Grade Route

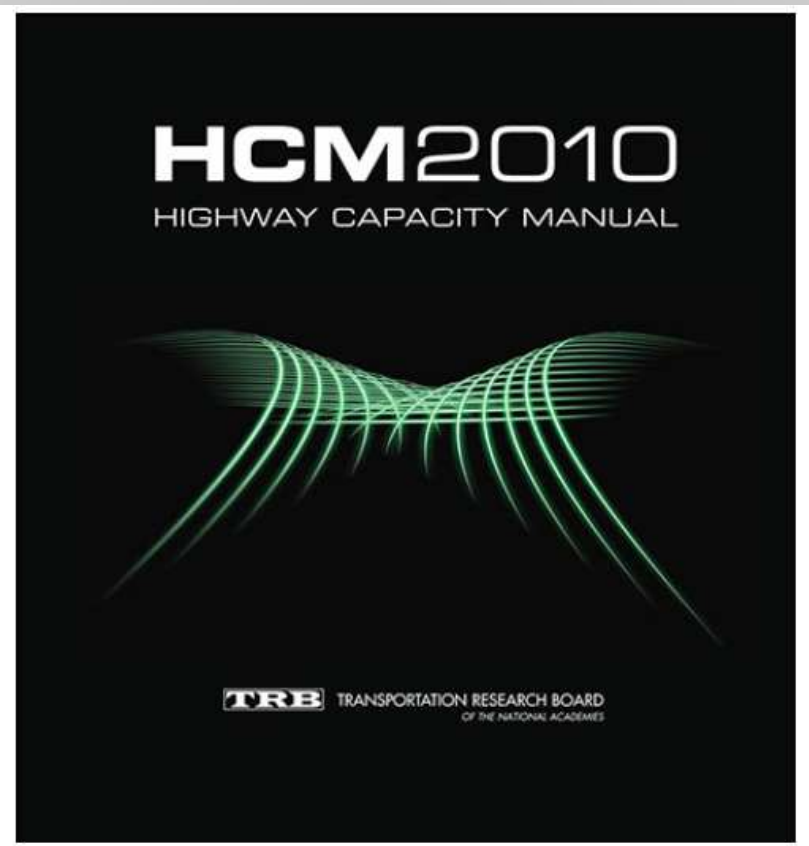
Operational Consideration

Pedestrian Level of Service (LOS) can affect pedestrian judgment and risk-taking behaviors.

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

HCM 2010

- Pedestrian delay and service levels at pedestrian crossings



Level-of-Service Methodology

Step 1: Identify Two-Stage Crossings

Step 2: Determine Critical Headway

Step 3: Estimate Probability of a Delayed Crossing

Step 4: Calculate Average Delay to Wait for Adequate Gap

Step 5: Estimate Delay Reduction due to Yielding Vehicles

Step 6: Calculate Average Pedestrian Delay and Determine LOS

Motorist Yield Rates

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

Collected Pedestrian Walking Speed

Crossing	City, State	Existing Crossing Treatment	Average Collected Walking Speed (ft/s)	15th %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
CSAH 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

Bring different evaluation methodologies together

- What to do when delay is unacceptable?
  - Add a treatment to provide acceptable service?
  - Ignore, just consider safety?
- Should we account for both?
- How do we account for both?
- Are there other factors that should be considered?
  - Pedestrian volume
  - Origins and destinations
- How do we consider all of the factors?

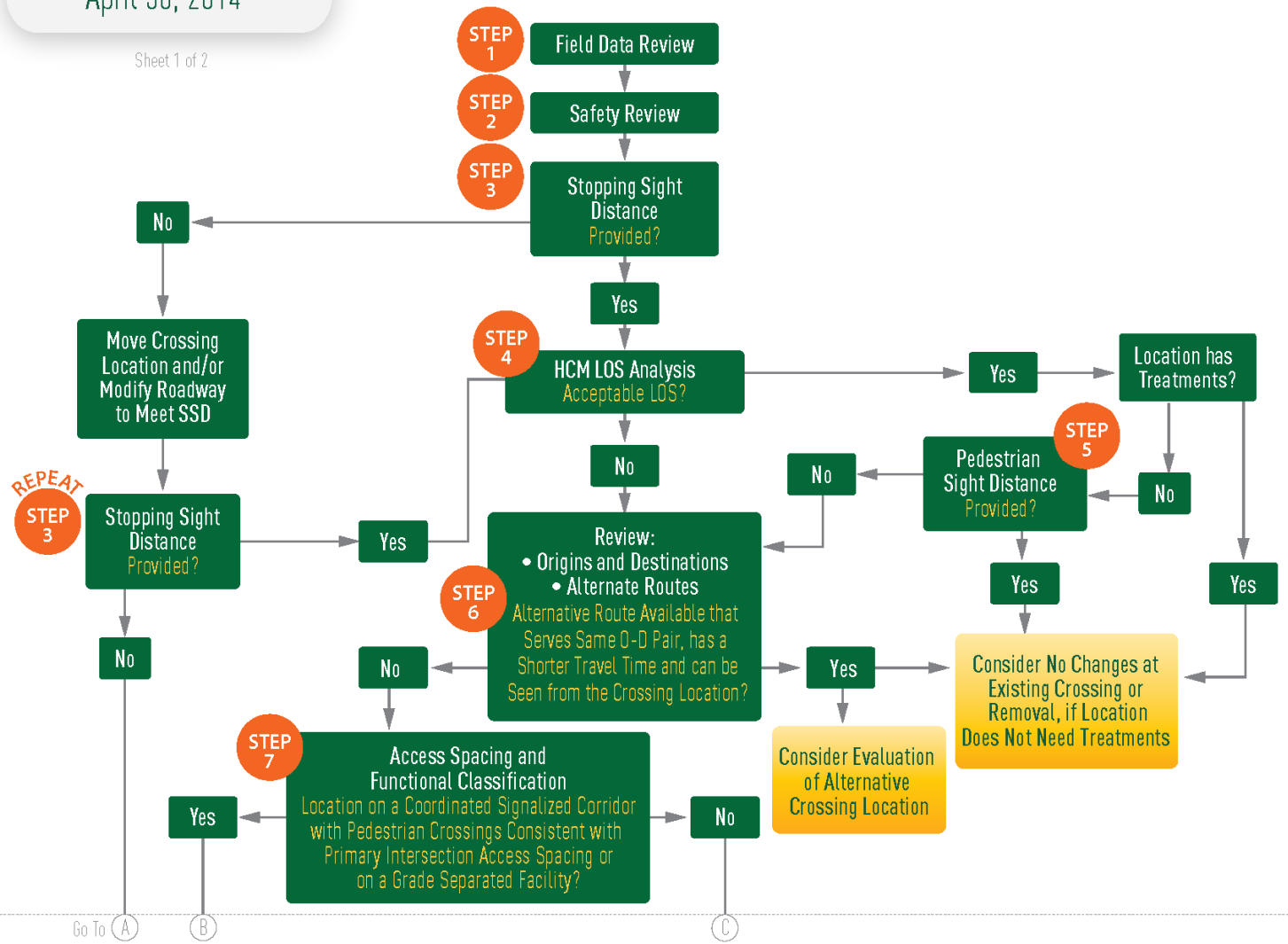
Minnesota MUTCD

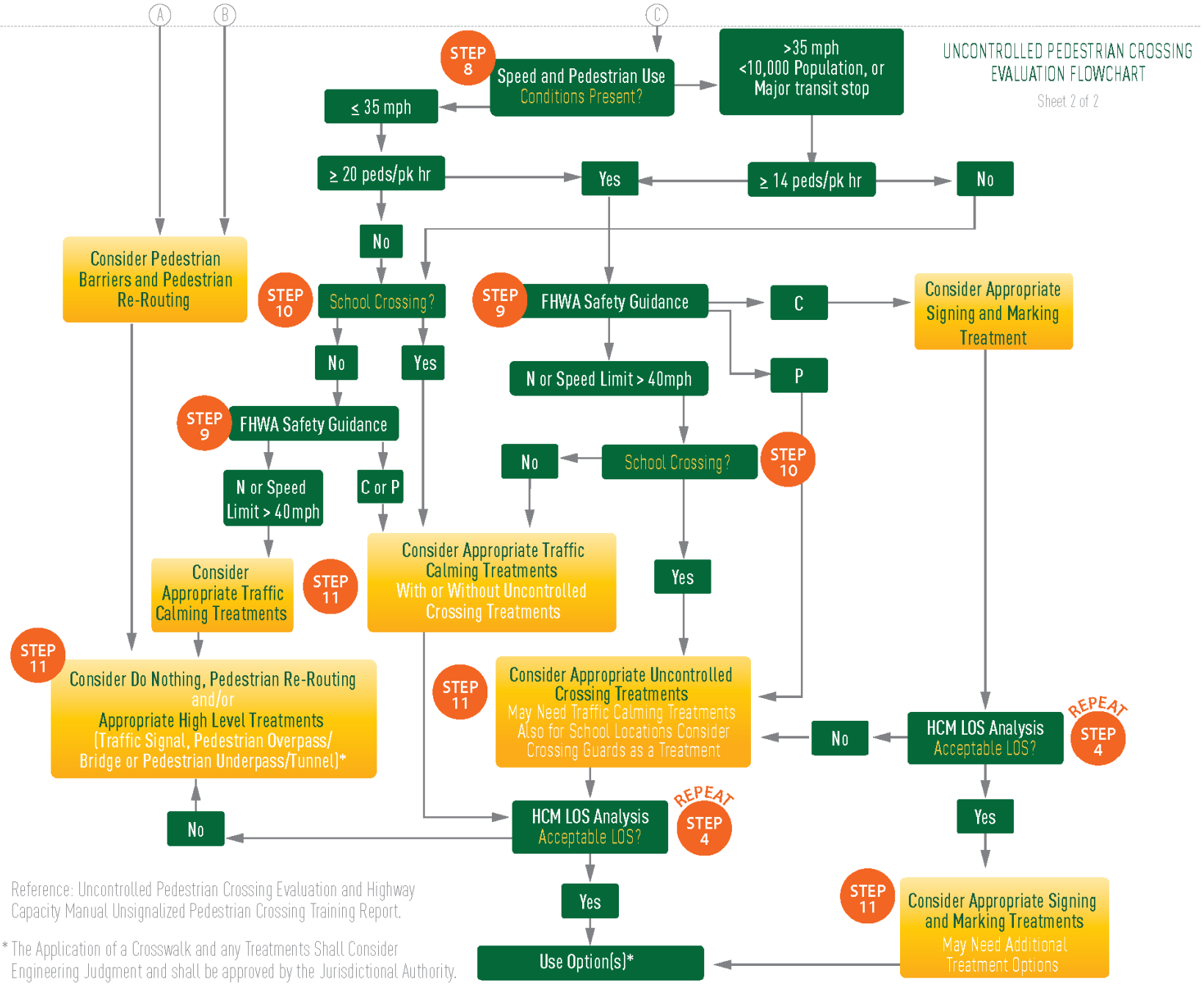
- "Crosswalk lines should not be used indiscriminately. An engineering study should be performed before a marked crosswalk is installed at a location away from a traffic control signal or an approach controlled by a STOP or YIELD sign. The engineering study should consider the number of lanes, the presence 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."

UNCONTROLLED PEDESTRIAN CROSSING EVALUATION FLOWCHART

April 30, 2014

Sheet 1 of 2





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

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

Field Data Review

Uncontrolled Pedestrian Crossing
Data Collection Worksheet

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

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

Geometrics

Crossing Length: Measure the crossing distance from curb to curb. Crossing 1 ____ ft.
Fill in Crossing 1 distance if there is no median. If there is a median at the crossing location, fill in Crossing 1 and 2 distances. Crossing 2 ____ ft.
Median: width of median at crossing location ____ ft.
Crossing Width: effective crosswalk width ____ ft.
Raised Median Available? ☐ Yes ☐ No
ADA Compliant Median Available (minimum 4' x 4' landing)? ☐ Yes ☐ No
Curb Ramps Available? ☐ Yes ☐ No
ADA Compliant Curb Ramp Available (width, grades, truncated domes)? ☐ Yes ☐ No
Speed: Posted or 85th percentile speed ____ mph
Roadway Curvature and Sight Distances: Average walking speed ____ ft/s
Is the crossing location within a horizontal or vertical curve? ☐ Yes ☐ No
Equations to calculate the following are located on the next page
Direction 1: Stopping Sight Distance (SSD) ____ ft. provided? ☐ Yes ☐ No
Direction 2: Stopping Sight Distance (SSD) ____ ft. provided? ☐ Yes ☐ No
Direction 1: Pedestrian Sight Distance (PedSD) ____ ft. provided? ☐ Yes ☐ No
Direction 2: Pedestrian Sight Distance (PedSD) ____ ft. provided? ☐ Yes ☐ No

Traffic and Pedestrian Data

Measure traffic and pedestrian volume in 15-minute increments on the roadway to be crossed.
Attach Counts **vehicles:** Daily ____ **pedestrians:** Daily ____
AM Peak Hourly ____ Pk 15-min ____ Hourly ____ Pk 15-min ____
PM Peak Hourly ____ Pk 15-min ____ Hourly ____ Pk 15-min ____

Additional Site Characteristics

Lighting:
Is street lighting present and does it light the crosswalk location? ☐ Yes ☐ No
Crosswalk Pavement Markings: Is the pedestrian crossing currently marked? ☐ Yes ☐ No
What is the condition of the markings? ☐ Excellent ☐ Good ☐ Fair ☐ Poor
Are the markings easily defined? ☐ Yes ☐ No
Do they need replacement? ☐ Yes ☐ No
What is the crosswalk marking pattern? ____
Signing: Currently signed at crosswalk? ☐ Yes ☐ No
Currently signed in advance of crosswalk? ☐ Yes ☐ No
Distances? direction 1 ____ ft. direction 2 ____ ft.
Enhancements: What enhancements are currently at the crossing location? ____
Adjacent Facilities: Distance to nearest marked crosswalk? ____ ft.
What pedestrian control devices are present at the nearest adjacent marked crosswalk? ____
Distance to nearest all-way stop, roundabout or signalized intersection ____ ft.
Could another location serve the same pedestrian crossing movement? ☐ Yes ☐ No
Could another location serve the the movement more effectively? ☐ Yes ☐ No

Uncontrolled Pedestrian Crossing
Data Collection Worksheet

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

draw or insert map of location being studied

Notes: _____

Sight Distance Calculations:

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

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

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

HCM LOS 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

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 =	
v_p = pedestrian flow rate (ped/s)	v_p =	0*	v_p =	
v = vehicular flow rate (veh/s) = V/3600	v =	V/3600	v =	
W_c = crosswalk width (ft)	W_c =	8.0	W_c =	
N = number of through lanes crossed (Integer)	N =	INT(L/11)	N =	

*no platooning observed

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

Evaluation Inputs:

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

*no platooning observed

Crossing Treatment Yield Rate

M_y = motorist yield rate (decimal)

Input Table:	
M_y =	

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

Results:

Average Delay		sec/ped
LOS		

HCM LOS Worksheets

Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

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

Step 1: Identify Two-Stage Crossings

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

Step 2: Determine Critical Headway

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

For a single pedestrian:

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

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

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

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

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

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

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

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

2. compute spatial distribution:

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

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

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

3. compute group critical headway:

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

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

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

Step 3: Estimate Probability of a Delayed Crossing

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

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

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

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

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

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

HCM Evaluation Worksheet

Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

Step 4: Calculate Average Delay to Wait for Adequate Gap

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

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

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

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

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

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

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

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

Step 5: Estimate Delay Reduction due to Yielding Vehicles

(If yielding is zero, then skip step 5)

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

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

Average pedestrian delay

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

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

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

1. One-Lane Crossing

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

2. Two-Lane Crossing

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

3. Three-Lane Crossing

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

4. Four-Lane Crossing

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

M_y = motorist yield rate (decimal) M_y = _____

Summary	
Average	
LOS	

Step 6: Calculate Average Pedestrian Delay & Determine LOS

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

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HCM Evaluation Worksheet

HCM LOS Worksheets

Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

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

Motorist Yield Rate = M_{ij}

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

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

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

(3) Bolton & Menk Field Data Collection

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

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

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

Consider Appropriate Treatment Options

- Appropriate treatment options should be considered for crossing locations based on a consistent approach.
  - Flowchart may be used to provide this approach

- 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.

- Treatment options:
  - Signing and Marking Treatments
  - Uncontrolled Crossing Treatments
  - Traffic Calming Treatments
  - High Level Treatments

Traffic Engineering Manual

- 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

Critical Placement and Design Elements

- Sight Distance
- Clear Sight Lines
- Link Origins and Destinations
- Curb Ramps
- Truncated Domes
- Medians/Islands
- Lighting

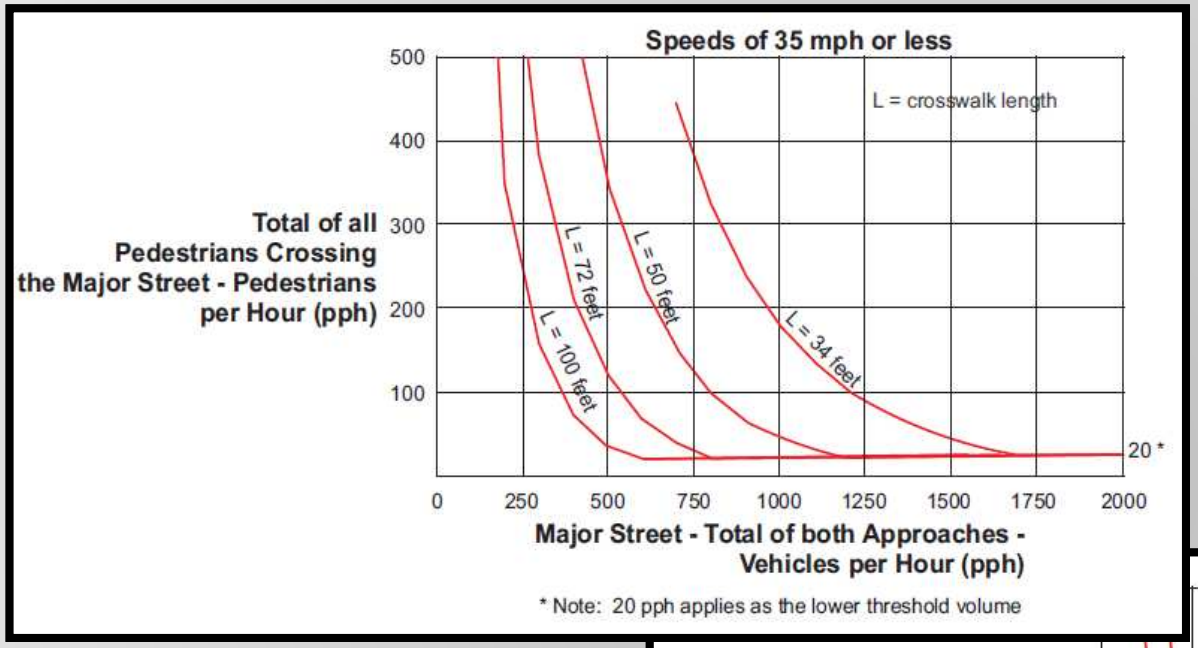
Treatments Consideration

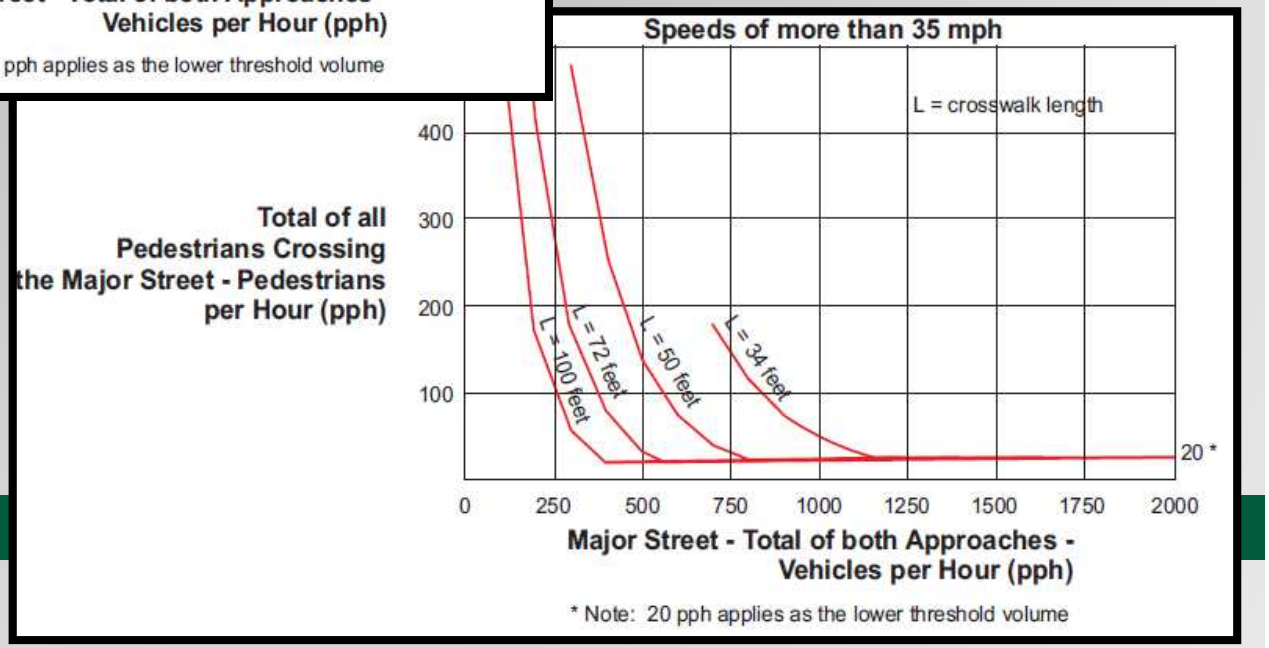
- Enhanced Treatments
  - Pedestrian Volume
  - Roadway Speed
  - Vehicle Volume
  - Level of Service for different times of day
  - School Crossing

Treatment Options

Treatment Options

Pedestrian Hybrid Beacon Warrant





Pedestrian Signal Warrants

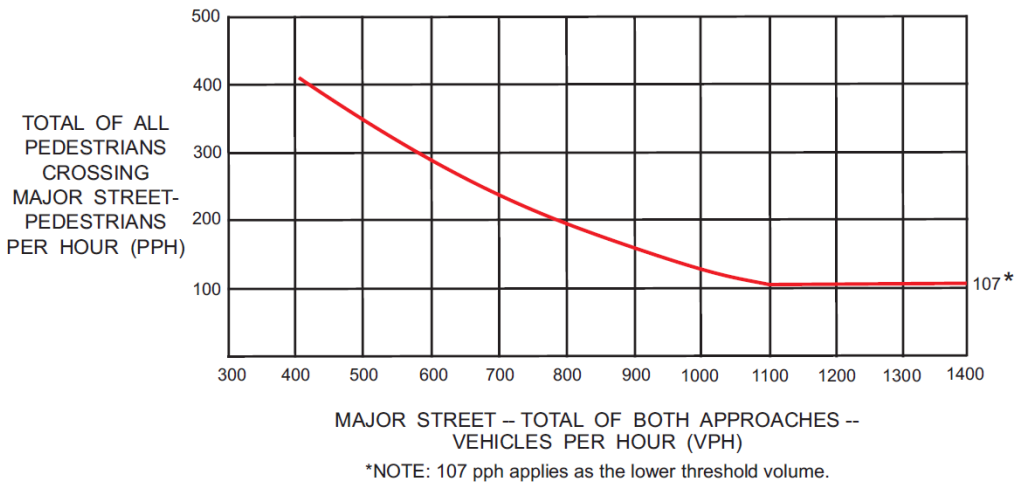


Figure 4C-5. Warrant 4 - Pedestrian Four-Hour Volume

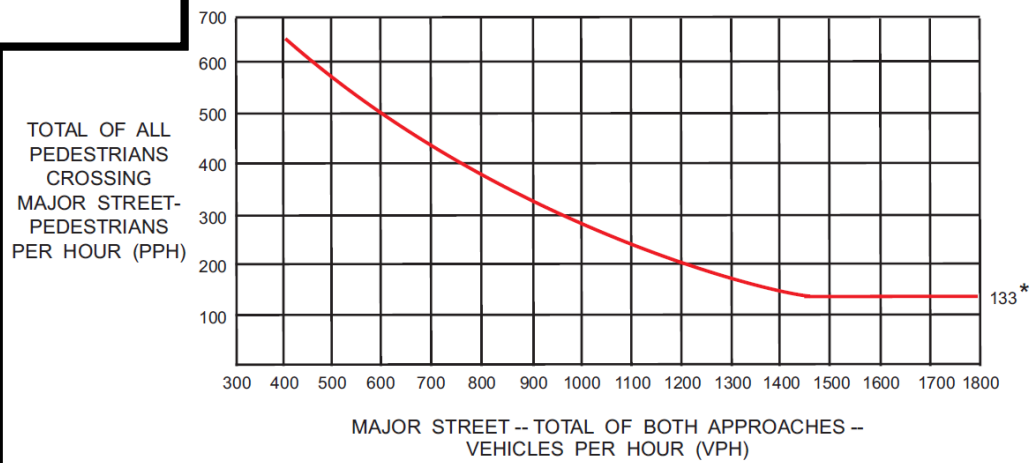


Figure 4C-7. Warrant 4 - Pedestrian Peak Hour

Report/Guidebook/Training

- Report
  - State of Practice
  - Data Collection
  - Safety
  - HCM Analysis
  - Evaluation Flowchart Procedure
  - Treatment Options
  - Examples
- Guidebook
  - Shortened version of Report

Information Available Online

- http://www.mnltap.umn.edu/publications/handbooks/
- http://www.cts.umn.edu/Publications/ResearchReports/reportdetail.html?id=2368

Thank you!

For more information and for copies of the Data Collection and LOS Spreadsheets contact:

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