Application of Highway Capacity Manual Methodology into Unsignalized Pedestrian Crossing Evaluation

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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 Statutes

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

<table>
<thead>
<tr>
<th>Roadway Type (Number of Travel Lanes and Median Type)</th>
<th>Vehicle ADT</th>
<th>Speed Limit**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤ 9,000</td>
<td>≤ 48.3 km/h (30 mi/h)</td>
</tr>
<tr>
<td>Two lanes</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Three lanes</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Multiline (four or more lanes) with raised median***</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Multiline (four or more lanes) without raised median</td>
<td>C</td>
<td>P</td>
</tr>
</tbody>
</table>

* These guidelines include intersections and midblock locations with no traffic signals or stop signs on the approach to the crossing. They do not apply to school crossings. A two-way center turn lane is not considered a median. Crosswalks should not be installed at locations that could present an increased safety risk to pedestrians, such as where there is poor sight distance, complex or confusing designs, a substantial volume of heavy trucks, or other 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 1.0 m (3.3 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 unlighted crossing point nearby). While a series 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.
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 Route Example

Example:
- Traffic signals at ¼ mile spacing
- Pedestrian at mid-point between signals
- Estimate 30 seconds delay at signal crossing

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

- This is unacceptable to pedestrians
- Possibility that crossing at mid-point will 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.

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

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

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

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

• Safety
• Operations/delay
• 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?
“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

Step 1: Field Data Review

Step 2: Safety Review

Step 3: Stopping Sight Distance Provided?

Step 4: HCM LOS Analysis
   - Acceptable LOS?

Step 5: Pedestrian Sight Distance Provided?
   - Yes
     - Location has Treatments?
     - Yes
       - Consider no changes at existing crossing or removal, if location does not need treatments
     - No
     - Consider no changes at existing crossing or removal, if location does not need treatments
   - No

Step 6: Review:
   - Origins and Destinations
   - Alternate Routes
     - Alternative Route Available that Serves Same O-D Pair, has a Shorter Travel Time and can be Seen from the Crossing Location?

Step 7: Access Spacing and Functional Classification
   - Location on a Coordinated Signalized Corridor with Pedestrian Crossings Consistent with Primary Intersection Access Spacing or on a Grade Separated Facility?

Go to A, B, or C.
Example: Four-Lane Urban Crossing
Example: Video
Example: Field Data Review
Example: Evaluation

- **Safety Review**
  - Two pedestrian crashes in last ten years, one fatality.
  - 14 crashes at the location
  - Large intersection and long crossing distance

- **SSD, PedSD**
  - Acceptable SSD
  - Unacceptable PedSD

- **HCM Analysis (AM Peak)**
  - No yielding: Delay = 7,118 sec. per pedestrian, LOS F
  - Crossing is marked and signed, 20% yielding rate
  - Delay = 44.5 sec. per pedestrian, LOS E
  - Still unacceptable
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 verification of equations are directed to the 2010 HCM.

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

Submitted for Approval: May 12, 2014

Crossing 1:

Evaluation inputs:

- \( L = \) crosswalk length (ft)
- \( S_p = \) average pedestrian walking speed (ft/s)
- \( t_s = \) pedestrian start-up and end clearance time (s)
- \( V = \) vehicular hourly volume (veh/hr)
- \( \tau_p = \) pedestrian flow rate (ped/h)
- \( \gamma = \) vehicular flow rate (veh/s) \(= V/3600\)
- \( W_c = \) crosswalk width (ft)
- \( N = \) number of lanes crossed (integer)

\[ N = \text{INT}(11) \]

Crossing 2:

Evaluation inputs:

- \( L = \) crosswalk length (ft)
- \( S_p = \) average pedestrian walking speed (ft/s)
- \( t_s = \) pedestrian start-up and end clearance time (s)
- \( V = \) vehicular hourly volume (veh/hr)
- \( \tau_p = \) pedestrian flow rate (ped/h)
- \( \gamma = \) vehicular flow rate (veh/s) \(= V/3600\)
- \( W_c = \) crosswalk width (ft)
- \( N = \) number of lanes crossed (integer)

Crossing Treatment Yield Rate

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

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

Results:

<table>
<thead>
<tr>
<th>Average Delay</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>85.5</td>
<td>E</td>
</tr>
</tbody>
</table>

Developed by Bolton & Menk, Inc. in coordination with the LRBC for the Local Road Research Board.
HCM LOS Worksheets

Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

Step 1: Identify Two-Stage Crossing

Is there a median available for a two-stage crossing? [ ] Yes [ ] No
If yes, does the median refuge meet AASHTO requirements (4' x 8' opening)? [ ] Yes [ ] No
If yes, does the median refuge meet AASHTO requirements (4' x 6' opening)? [ ] Yes [ ] No

Critical headway is the time below which a pedestrian will not attempt to begin crossing the street. Pedestrians use judgment to determine if the available headway is sufficient for a safe crossing.

For a single pedestrian:
- $t_c = \frac{L}{V}$ (critical headway for a single pedestrian)
- $V = 5.0 \text{ ft/s}$ (average pedestrian walking speed)
- $L = 12 \text{ ft}$

If pedestrian platooning is occurring, the spatial distribution of pedestrians should be computed:
1. Use field observations or estimate pedestrian nearside distribution equation:
   - $N_p = \text{total number of pedestrians crossing}
   - t_c = \text{critical headway for a single pedestrian}
   - V = \text{average pedestrian walking speed}
   - L = \text{crosswalk length}

Step 2: Determine Critical Headway

Crossing 1:
- Critical headway:
  - $t_c = 3 \text{ sec}$

Crossing 2:
- Critical headway:
  - $t_c = 4 \text{ sec}$

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.

$P_0 = 1 - \exp(-t_c/V)$

Probability of delayed crossing:

$P_d = 1 - (1-P_0)$

Step 4: Calculate Average Delay

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

$\tau_d = \frac{1}{N_p} \sum_{i=1}^{N_p} \left[ \frac{t_i}{V} - t_c \right]$ (where: $t_i = \text{arrival time}$ of pedestrian $i$, $V = \text{average walking speed}$)

Step 5: Estimate Delay Reduction Due to Yielding Vehicles

If yielding is zero, then yield step is not included.

Step 6: Calculate LOS

$LOS = \frac{\sum_{i=1}^{N_p} \left( \frac{t_i}{V} - t_c \right)}{N_p}$

Summary

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<tr>
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<td>Crosswinds some delay due to conflicting traffic</td>
</tr>
<tr>
<td>C</td>
<td>10-20</td>
<td>Delay noticeable to pedestrians, but not economically significant</td>
</tr>
<tr>
<td>D</td>
<td>20-30</td>
<td>Delay noticeable to pedestrians, but economic impact minimal</td>
</tr>
<tr>
<td>E</td>
<td>30-45</td>
<td>Delay approaches tolerance level, risk-taking likely</td>
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<tr>
<td>F</td>
<td>&gt;45</td>
<td>Delay exceeds tolerance level, high chance of risk-taking</td>
</tr>
</tbody>
</table>
# 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.

<table>
<thead>
<tr>
<th>Crossing Treatment</th>
<th>Staged Pedestrian Yield Rate</th>
<th>Unstaged Pedestrian Yield Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crosswalk Marking Only</td>
<td>7%</td>
<td>7%</td>
</tr>
<tr>
<td>Median Refuge Islands</td>
<td>3.0%</td>
<td>29%</td>
</tr>
<tr>
<td>Pedestrian Mounted Flashing Beacon (2-Lane, 35 mph)</td>
<td>N/A</td>
<td>5%</td>
</tr>
<tr>
<td>Overhead Flashing Beacon (push-button activation)</td>
<td>4.7%</td>
<td>49%</td>
</tr>
<tr>
<td>Overhead Flashing Beacon (one-push activation)</td>
<td>3.1%</td>
<td>67%</td>
</tr>
<tr>
<td>Pedestrian Crossing Flags</td>
<td>6.5%</td>
<td>74%</td>
</tr>
<tr>
<td>School Crossing Guards</td>
<td>N/A</td>
<td>88%</td>
</tr>
<tr>
<td>In-street Crossing Signs (25-30 mph)</td>
<td>8.7%</td>
<td>90%</td>
</tr>
<tr>
<td>Warning Sign with Edge-Mounted LEDs</td>
<td>N/A</td>
<td>28%</td>
</tr>
<tr>
<td>In-road warning Sign</td>
<td>N/A</td>
<td>66%</td>
</tr>
<tr>
<td>High-visibility Signs and Markings (35 mph)</td>
<td>17%</td>
<td>20%</td>
</tr>
<tr>
<td>High-visibility Signs and Markings (25 mph)</td>
<td>81%</td>
<td>91%</td>
</tr>
<tr>
<td>Rectangular Rapid-Fast Beacon (225°)</td>
<td>84%</td>
<td>81%</td>
</tr>
<tr>
<td>School Crossing Guards with RRFB</td>
<td>N/A</td>
<td>91%</td>
</tr>
<tr>
<td>Pedestrian Hybrid Beacon (HAWK)</td>
<td>97%</td>
<td>96%</td>
</tr>
</tbody>
</table>

**Motorist Yield Rate**

<table>
<thead>
<tr>
<th>Motorist Yield Rate</th>
<th>M_p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Sources:**
3. Bletch & Menlo Final Study Collection.
5. Brewer, Marcus A., Kay Fitzpatrick, Before and After Study of the Effectiveness of Rectangular Rapid Flashing Beacon Used with School Sign in Garland, Texas, Texas Transportation Institute, College Station, TX, April 2012.
6. Roes, Rodney M., & Stoller, M. V. Roes, Evaluation of SmartPedestrian Crosswalk Lighting System and Rectangular Rapid Flashing Beac...
Example: Four-Lane Urban Crossing
Example: Evaluation

• Origins and Destination, Alternate Routes
  • Serves direct need, no acceptable alternative routes

• Access Spacing and Functional Classification
  • Along a signalized corridor but adequately spaced from signals

• Speed and Pedestrian Use
  • 35 mph, >10,000 population, major transit stop
  • Only 6 peds/hour

• School Crossing?
  • No
Consider Pedestrian Barriers and Pedestrian Re-Routing

STEP 8
Speed and Pedestrian Use Conditions Present?

≤ 35 mph

≥ 20 peds/pk hr

No

≥ 20 peds/pk hr

Yes

≥ 14 peds/pk hr

No

Consider Appropriate Traffic Calming Treatments With or Without Uncontrolled Crossing Treatments

STEP 9
FHWA Safety Guidance

N or Speed Limit > 40 mph

No

C or P

Yes

School Crossing?

STEP 10

FHWA Safety Guidance

N or Speed Limit > 40 mph

C or P

Consider Appropriate Traffic Calming Treatments

Consider Do Nothing, Pedestrian Re-Routing and/or Appropriate High Level Treatments (Traffic Signal, Pedestrian Overpass/Bridge or Pedestrian Underpass/Tunnel)*

STEP 11

Consider Appropriate Uncontrolled Crossing Treatments May Need Traffic Calming Treatments Also for School Locations Consider Crossing Guards as a Treatment

HCM LOS Analysis Acceptable LOS?

No

Yes

Yes

HCM LOS Analysis Acceptable LOS?

No

Consider Appropriate Signign and Marking Treatments May Need Additional Treatment Options

Use Option(s)*

Repeat

REPEAT

Repeat


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

• FHWA Safety Guidance
  • Multi-lane with raised median, speed limit 35 mph, ADT = 15,000
  • P, Location should be closely monitored and enhanced with pedestrian crossing improvements.

• Consider Appropriate Traffic Calming Treatments
  • Extend median
  • Delay = 41 sec/ped (LOS E) in AM, 23 sec/ped (LOS D) in PM
  • With low pedestrian volume, no other changes recommended
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.

• Treatment options:
  • Signing and Marking Treatments
  • Uncontrolled Crossing Treatments
  • Traffic Calming Treatments
  • High Level Treatments
Important points

• Safety is important
• Serving the needs of pedestrians is important
• HCM provides a methodology to determine delay to a pedestrian
• Evaluation of where to place a crossing should follow a process that takes into account safety, delay, and other considerations including pedestrian use.
Next Steps

• Finalize Report
• Finalize Guidebook
• Training: First training June 5th
Thank you!

For more information contact:

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