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INTRODUCTION

This report documents research, best practices, and recommendations for pedestrian and vehicular treatments at uncontrolled crossings in the City of Pasadena. It is a follow-up study to the 2011 report, City of Pasadena Pedestrian Safety Study at Signalized Intersections, which focuses primarily on signalized intersections. This new report includes an update on research, best practices and the City's treatment toolbox, while providing new application of treatments at uncontrolled locations.

Volume I of this report expands on best practices, research, and tools for treatments at uncontrolled locations and signalized locations. Volume II focuses specifically on 60 uncontrolled locations studied in May 2016, documenting each location's recent collision history, vehicular speed and volume, pedestrian volume, and site characteristics. Volume II also includes a suggested prioritization for implementation of treatments at the 60 studied locations.

Treatments in this report are designated as “basic” or “enhanced”, and categorized by type as striping, signals/signage, geometric, or other treatments. Each treatment also includes an indication of vehicular volume, ADT, and number of roadway lanes with which it is compatible. The data, treatments, and approaches included in this report are based on best engineering practices from the federal to the local level. Engineering considerations are central to this report and creating communities that make it easier and more comfortable to travel by foot. In addition to engineering, best practices for enhancing walkability rely on other E’s, including: education, enforcement, encouragement, and evaluation. The E’s complement each other by helping road users understand how to travel safely and lawfully, enforcing right-of-way, and understanding how the investments made impact travel patterns and safety outcomes. This report focuses on engineering considerations, with a focus and specific understanding on City of Pasadena’s context.

The City of Pasadena commissioned this report as part of continued efforts focused on creating safe and comfortable multi-modal environments throughout the city. Looking forward, the City may consider following the lead of other world-class cities in adopting Vision Zero polices to further enhance an already strong stance on increasing pedestrian safety. Cities such as Santa Barbara, San Diego, Fort Lauderdale, and Austin could be valuable resources for inspiration and application.

This report was produced in cooperation with the City of Pasadena. The suggestions presented in this report are based on field observations, time spent in the City of Pasadena by the authors, and general knowledge of best practices in pedestrian design and safety. These suggestions are intended to guide City staff in making decisions for future safety improvements in the City, and may not incorporate all factors that are relevant to specific pedestrian safety issues in the City or at individual locations.
LITERATURE REVIEW AND SUMMARY OF BEST PRACTICES

The chapter presents the findings in a review of recent literature regarding pedestrian safety at uncontrolled crossings, and is organized into three sections: Marking Crosswalks at Uncontrolled Locations, Manual on Uniform Traffic Control Devices (MUTCD) Standards, and Pedestrian Treatments for Uncontrolled Locations. When available, treatments options include a definition, crash reduction factor (CRF), and conclusions based on research of included sources.

MARKING CROSSWALKS AT UNCONTROLLED LOCATIONS

A large body of research examines pedestrian safety and potential or observed outcomes associated with different crossing treatments. The general consensus across the literature is that the inclusion of marked crosswalks alone at uncontrolled locations crossing multi-lane, high-volume roads is associated with higher pedestrian collision rates and shorter driver yield times. An uncontrolled location can include any point on a roadway where traffic control devices are not present, such as the intersection of two streets or a midblock crossing between two intersections.

Zegeer, Stewart, Huang, and Lagerwey\(^1\) conducted one of the most comprehensive studies comparing pedestrian safety at marked and unmarked uncontrolled crossing locations. The study compared the pedestrian crash rate at 1,000 marked and 1,000 unmarked crossings. The marked crosswalks included high visibility continental markings, but did not include any traffic-calming measures. A subset of the marked crosswalks included supplemental advanced pedestrian warning devices or signage.

At uncontrolled locations along 2-lane roads and low volume (≤12,000 ADT) multi-lane roads, the study found there was no statistically significant difference in the pedestrian crash rate between marked crosswalks and unmarked crossings. At uncontrolled locations along multi-lane roads with moderate to high volumes (>12,000 ADT) the pedestrian crash rate is statistically significantly higher at marked compared to unmarked crossings. The presence of a median on multi-lane roads was associated with a lower pedestrian crash rate at both marked and unmarked uncontrolled crossings. For multi-lane roads with high vehicle volumes (>15,000 ADT), the uncontrolled crossing with marked crosswalks were associated with a statistically significant higher pedestrian crash rate.

\(^1\) This is also the central study of the 2005 FHWA report
Zegeer et al. provide guidance through a matrix for identifying locations that are candidates for marked crosswalks and locations for which marked crosswalks are not recommended without additional pedestrian enhancements (Figure 1).

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

Figure 2. From report recommending guidelines for installing marked crosswalks and other pedestrian improvements at uncontrolled locations. C = Candidate for marked crosswalks; P = Possible increase in pedestrian crash risk if other enhancements are not used; N = Marked crosswalks alone are insufficient due to increase in crash risk. (Zegeer, et al. 2005).
When reviewing case-control studies like the Zegeer et al. study discussed above, it is important to be aware of a possible selection bias. It is conceivable that the marked crosswalks were at locations that differ in safety characteristics beyond number of lanes. Any combination of environmental, design, or behavioral differences may also contribute to the differences in observed crash rate between the marked and unmarked locations.

A 2002 study found that the pedestrian collision risk at uncontrolled locations was 3.6 times higher at marked crosswalks compared to unmarked crosswalks (Koepsell, et al. 2002). In 2008, Mitman and Ragland published a study that compared driver behavior at marked and unmarked crosswalks along low-speed arterials (Mitman and Ragland, 2008). The study found that drivers were more likely to yield to pedestrians in marked crosswalks compared to unmarked crosswalks. Researchers posit that the increase in yield behavior at marked crosswalks may be associated with the increase in multiple-threat collisions at marked crosswalks. Pedestrians also demonstrate behavior differences at marked vs. unmarked crosswalks. Pedestrians at unmarked crosswalks waited for longer gaps in traffic than pedestrians at marked crosswalks (Mitman and Ragland, 2008). This difference in pedestrian behavior may be, partially, in response to the lower likelihood of drivers yielding at the unmarked locations.

The additional caution demonstrated by pedestrians and the reduced yield rates demonstrated by drivers may be a result of confusion around legal right-of-way at unmarked crosswalks. In 2007, Mitman and Ragland conducted intercept surveys and focus groups that revealed an overall lack of knowledge by users around right-of-way laws at unmarked locations (Mitman and Ragland, 2007).

Based on the literature and research, the inclusion of a marked crosswalk without any other pedestrian crossing treatments is not generally recommended along multi-lane high volume roadways. When considering whether to mark a crosswalk it is important to understand that the increased risk associated with these crossings should not eliminate the inclusion of a crosswalk. Instead - especially in cases with multiple lanes, high vehicle volumes, and a high speed limit – engineering judgment should be used to consider contextually appropriate crossing enhancements.

Federal Highway Administration (FHWA) guidance highlights the obligation of the road design to “get pedestrians safely across the street.” Each treatment option should be considered contextually and in combination with other treatments to create a road environment that directs pedestrians safely across the street. Distilling the design and implementation considerations to the single decision of whether or not to mark a crosswalk is not consistent with FHWA guidance (FHWA, 2005).
MUTCD STANDARDS

The 2014 California MUTCD (CA-MUTCD) states that at uncontrolled locations, the crosswalk, in combination with other road treatments, alert road users of a designated pedestrian crossing location and at non-intersections, a marked crosswalk legally establishes a pedestrian crossing location.

The CA-MUTCD also states that at both uncontrolled and stop-controlled locations, engineering studies should always precede the decision to mark a crosswalk. The engineering study should include a consideration of number of lanes, presence of a median, distance from nearest signalized intersection, pedestrian volumes and delays, traffic volumes and speeds, road geometry, alternative crossing points, visibility and lighting, and any other relevant factor.

The CA-MUTCD provides further guidance for identifying road conditions for which marked crosswalks alone are sufficient as opposed to road conditions for which marked crosswalks should be supported by additional treatments. These treatments are designed to “reduce traffic speeds, shorten crossing distances, enhance driver awareness of the crossing, and/or provide active warning of pedestrian presence.” The CA-MUTCD determines crosswalks alone to be insufficient in the following conditions:

- Speed limit exceeds 40 MPH, the roadway has four or more travel lanes and either:
  - No raised median or pedestrian island is present and ADT ≥ 12,000 vehicles
  - A raised median or pedestrian island is present and ADT ≥ 15,000 vehicles

For existing marked crosswalks at uncontrolled locations where the speed limit exceeds 40 MPH, the roadway has four or more travel lanes, and an ADT ≥ 12,000 vehicles, the CA-MUTCD recommends specific advanced warning treatments: advanced yield lines and “Yield Here to Pedestrians” signage (R1-5, R1-5a), parking restrictions to provide adequate visibility, pedestrian crossing warning signage (W11-2 and W16-7p), and a high-visibility crosswalk pattern.

PEDESTRIAN TREATMENTS FOR UNCONTROLLED LOCATIONS

There are many resources on pedestrian collision countermeasures, and a wide range of technical approaches to evaluate their effectiveness. The FHWA Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes (February 2013) reflects one of the most comprehensive reviews of quantitative research to date. The FHWA Toolbox compiles research on various pedestrian collision countermeasures to produce a single crash reduction factor for each countermeasure. The CRF is the
percentage reduction in pedestrian collisions that could be expected after implementing a given countermeasure. In cases where the countermeasure CRF was not available in the FHWA Toolbox, the CRF was sourced from the Crash Modification Factors Clearinghouse, which is also maintained by the FHWA.

The Pedestrian and Bicycle Information Center’s (PBIC) Evaluation of Pedestrian-Related Roadway Measures: A Summary of Available Research (April 2014) also provides a comprehensive and current review of effectiveness evaluation literature. This document supports the PEDSAFE Pedestrian Safety Guide and Countermeasure Selection System, which was published by FHWA in April 2014. The report compiles known studies that employ rigorous research methods into a comprehensive review of pedestrian collision countermeasure effectiveness.

The pedestrian treatments discussed here are all applicable to uncontrolled crossing locations.

**STRIPING TREATMENTS**

**Advance Yield Limit Line**

- With this tool a marking is placed in advance of crosswalk to increase pedestrian visibility to vehicles and reduce vehicle encroachment upon the crosswalk. Advance yield lines indicate that a driver should yield before approaching the pedestrian crossing. The MUTCD guidance is for yield lines to be placed four feet in advance of the crosswalk for single-lane approaches. For uncontrolled multi-lane approaches, the MUTCD guidance is that the yield lines should be placed 20’ to 50’ feet from the crosswalk.
- Research indicates that these advanced stop and yield lines are effective in increasing the rate at which motorists yield to pedestrians (Mead et al. 2014).
- A statistically significant increase in the rate of motorists yield to pedestrian from 69% to 85% (Van Houten et al. 2002).
- Additional research found advanced stop bars had a greater impact on motorists yielding rate in combination with other treatments (Hengel 2013). Specifically, the advanced yield markings had a greater impact on yield rates when coupled with a two-staged median crossing (Danish Offset) as opposed to a standard pedestrian refuge island (Nambisan et al. 2007).
- No CRFs available for advanced yield limit lines.

**Colored or Artistic Pavement in Crosswalks**

- Definition: Crosswalks with colored or artistically designed pavement between crosswalk lines. Two related but distinct purposes for such markings include:
  - Aesthetic enhancement of a neighborhood
  - Improved pedestrian safety
- In 2001, the FHWA issued an official ruling that the colored crosswalk had no discernible effect on pedestrian safety. In 2004 and 2005, the FHWA issued official rulings that stated any inclusion of retro-reflectivity into an aesthetic crosswalk treatment caused that treatment to be considered an official traffic control device. The rulings maintained that these aesthetically enhanced crosswalks were not associated with any improved pedestrian safety or reduction in pedestrian collisions.
• A 2011 ruling further stated that the inclusion of free form designs within the space of the crosswalk can reduce the contrast and effectiveness of the white transverse lines marking the crosswalk on the pavement. The inclusion of bright colorful patterns within the crosswalk may cause a “false sense of security” for all users. The FHWA approves only of subdued-colored pavement and design treatments that do not include retroreflective properties and exist between the legally marked crosswalks. Any aesthetic treatment should be uniform and regular, must not reduce the contrast of the crosswalk markings, and must not convey any message to the driver.
• No CRFs available for colored or artistic pavement in crosswalks.

High Visibility Crosswalks – Continental/Ladder Striping

• Definition: High visibility crosswalks with thick stripes perpendicular to direction of vehicular traffic are the standard striping. CA-MUTCD guidance includes an option to mark crosswalks with diagonal white lines at a 45 degree angle to the line of the crosswalk in cases where “substantial numbers of pedestrians cross” at uncontrolled locations.
• CRF Range: 19 – 40%
  o 40% reduction in vehicle/pedestrian collisions based on data from New York City (Chen et al. 2012); 37% reduction in vehicle/pedestrian collisions based on a comparison of standard and continental striped yellow crosswalks at schools in San Francisco (Feldman et al. 2010); 19% reduction in angle, head-on, left-turn, rear-end, rear-to-rear, right-turn, and sideswipe vehicle collisions based on data from New York City (Chen et al. 2012).
• Additional CRFs for high visibility crosswalks are under development as part of NCHRP 17-56 Development of Crash Reduction Factors for Uncontrolled Pedestrian Crossing Treatments.
• Additional research has shown that high-visibility crosswalks, especially those that reinforce the yielding of vehicles with stop bars 8-feet in advance of the crosswalk, improve vehicular yielding behavior (NACTO, 2013).

Marked Crosswalk for a Minor Street Approach

• Stripping on the far sides of a pedestrian crossing parallel to the direction of vehicular traffic and perpendicular to the minor street, which denote the proper location to cross a street.
• CRF: 65% reduction in all crash types and severities with the installation of a crosswalk at a stop-controlled minor approach (Haleem and Abdel-Aty 2010).

Temporary Painted Medians

• Definition: Pavement striping that separates lanes of traffic but does not provide a raised surface.
• Research has shown that pedestrian collisions rates were 33% lower on streets with 10 foot raised medians than on streets with 4 foot painted medians (Cairney, 1999).
• No CRFs available for temporary painted medians.

SIGNAL AND SIGNAGE TREATMENTS

Crosswalk Flags

• Definition: Brightly colored removal flags are placed at crosswalk to increase pedestrian visibility and clearly communicate their desire to cross the street.
- No CRFs available for crosswalk flags

**Flashing Beacons (including RRFB signals)**

- Definition: Flashing beacons highlighting crosswalks and pedestrian crossing signs through the addition of a flashing light. Rectangular Rapid Flash Beacons (RRFB) provide a high-visibility, brighter strobe-like flashing frequency. RRFB were given interim approval by the FHWA in 2008 (FHWA, 2009).
- Several studies have measured the rate of motorists yielding to pedestrians before and after the installation of an RRFB. Based on these studies, the RRFB is associated with an increase in yield rates of approximately 15% to 60% with over 70% of motorist yielding in all studies (Van Houten, Ellis, and Marmolejo, 2008; Pecheux, Bauer, and McLeod, 2009; Jua et al. 2009; Hunter, Srinivasan, and Martell 2009; FHWA, 2010; Ross, Serpico, and Lewis, 2011; Foster, Monsere, and Carlos, 2014; Domarad, Grisak, and Bolger, 2014).
- These treatments are most appropriate on multi-lane streets (Berkeley, 2013; McGrane, 2013).
- No CRFs available currently for flashing beacons - CRFs for RRFBs are under development as part of NCHRP 17-56 Development of Crash Reduction Factors for Uncontrolled Pedestrian Crossing Treatments.

**In-Roadway Lighting**

- Definition: Lights embedded in raised markers along both sides of an uncontrolled crosswalk, which are activated by a pedestrian push-button or pedestrian presence, sometimes with a strobe effect (Mead et al. 2014).
- In-roadway crosswalk lighting was associated with an increase in driver yielding and a decrease in motor vehicles speeds, but not consistently in all scenarios (VTRANS, 2011) (Mead et al. 2014). These are sometimes difficult to maintain, depending on weather and traffic conditions, and may confuse drivers if falsely activated (Berkeley, 2013).
- Some drawbacks of the treatment include the necessity to replace the lights whenever a road is repaved, the lack of visibility beyond the first car in a group, and difficulty in noticing the lights during daylight hours (Mead et al. 2014).
- A study in 2006 in Las Vegas, NV did not see a significant reduction in conflicts, but concluded that in-roadway lights did benefit pedestrian safety on low volume roads.
- These treatments are most appropriate for mid-block crosswalks on low volume roads.
- No CRFs available currently for in-pavement lighting - CRFs are under development as part of NCHRP 17-56 Development of Crash Reduction Factors for Uncontrolled Pedestrian Crossing Treatments.

**In-Street Pedestrian Signage**

- Definition: High-visibility pedestrian crossing signage placed in the street at a marked crosswalk.
- Research has shown increases in yield rate at locations with in-street crossing signs (Banerjee and Ragland 2007; Ellis, Van Houten, and Kim 2007; Hua et al. 2009).
- One study also found an association with a reduction in motorist speed with the presence of an in-street crossing sign and that the increase in motorist yielding was largest when the sign was placed directly in the middle of the crosswalk (Gedafa et al. 2014).
- Additional research has shown that without signage approximately 25% of drivers yielded to pedestrians; with a single in-street sign at the median, 57% of drivers yielded; with the addition of
two curbside signs to create a “gateway configuration”, approximately 80% of drivers yielded to pedestrians. When compared to pedestrian hybrid beacons, the “gateway configuration” (three in-street pedestrian signs, one located in the center median and one at each curb) performs similarly. The inclusion of the “gateway configuration” with the pedestrian hybrid beacon is associated with the highest motorist yield rates (Bennet, Manal, and Van Houten, 2014).

- These treatments are ideal for mid-block crosswalks, low-speed roads, unsignalized crossings, and two-lane roads (Berkeley, 2013).
- No CRFs available for in-street pedestrian signage.

**Other Pedestrian Signage**

Currently there are no specific CRFs identified for the following treatments. However, CRFs for unsignalized pedestrian crosswalk signs, pavement markings, in-roadway warning lights, and advanced yield markings are being included as part of NCHRP 17-56 *Development of Crash Reduction Factors for Uncontrolled Pedestrian Crossing Treatments*.

- **Fluorescent Strong Yellow-Green signage** was associated with higher yield rates (Clark, Hummer, and Dutt. 1996).
- **Overhead “Yield When Flashing” signage** 50 meters ahead of a crosswalk was associated in a reduction in vehicle-pedestrian conflicts (Van Houten et al. 1998).
- **Internally-illuminated overhead crosswalk signage** and high visibility crosswalks were associated with an increase in motorists yielding and with an increase in pedestrians using the crosswalk (Nitzburg and Knobluach, 1999).
- **Overhead yellow crosswalk signage** was associated with an increase in driver yielding and a decrease in pedestrians who ran, hesitated, or gave up crossing at the crosswalk (FHWA, 2000).
- **Overhead “Stop for Pedestrian in Crosswalk” signage activated by pedestrian button** along arterial roads with speeds limits of 40 mph was associated with a significant decrease in drivers yielding to pedestrians. The authors suggested that the treatment might have been insufficient alone and that optimal placement may not have been used (FHWA, 2000).
- **Roadside Pedestrian Crossing Signage** (both standard and high visibility) were associated with a reduction in vehicle-pedestrian conflicts (Van Houten et al. 2002).
- **Portable changeable message speed limit signs** at mid-block crossings were associated with reductions in motor vehicle speeds of 1-6 mph (Pedsafe II, 2009).
- **Roadside flashing pedestrian warning signs** were associated with an increase in driver yielding and a decrease in motor vehicles speeds (VTRANS 2011). Silicon Constellations manufactures the LumiSign W11-2, a MUTCD compliant pedestrian warning sign (W11-2) with synchronized LED flashing lights around the perimeter.
- **Speed limit reductions on roadway segments** were associated with an approximately 60% reduction in pedestrian crash rate on roadway segments with speed reduction signage compared to road segments without speed reduction signage (Chen et al. 2012).

**Pedestrian Hybrid Beacon (HAWK signal)**

- Definition: Pedestrian-activated warning light located on a mast arm over a pedestrian crossing. The beacon stays dark until activated. It has one yellow lens and two red lenses to indicate to drivers that a pedestrian is in the crosswalk. The pedestrian hybrid beacon was included, for the first time,
in the 2009 MUTCD. The 2014 CA-MUTCD includes a standard traffic signal (that does not meet a signal warrant) as an alternative to the standard pedestrian hybrid beacon.

- According to the 2014 CA-MUTCD guidance, pedestrian hybrid beacons should be considered as part of an engineering study in cases where:
  - Signal warrants are not met and gaps in traffic are not adequate for pedestrians to cross, vehicles speeds are too high for pedestrians to cross, or pedestrian delay is excessive.
  - The major street speed limit or 85th percentile speed is ≤ 35 MPH and the hourly major street volume, when plotted against a peak hour pedestrian volume lies above the applicable threshold line in Figure 3.
  - The major street speed limit or 85th percentile speed is > 35 MPH and the hourly major street volume, when plotted against a peak hour pedestrian volume lies above the applicable threshold line in Figure 4.

![Figure 3. Guidelines for the installation of Pedestrian Hybrid Beacons on low-speed roadways. (MUTCD, 2009).](image)

- CRF Range: 15-69%
  - 15% reduction in fatal and serious injury collisions; 69% reduction in vehicle/pedestrian collisions; 29% reduction in all collisions (Fitzpatrick and Park, 2010).

- Additional research found that pedestrian hybrid beacons were associated with increasing motorist yielding and decreasing the rates of pedestrians trapped at the middle of the crossing.
• These treatments are shown to reduce conflicts between vehicles and pedestrians, and decrease vehicular speeds. They are most useful where a full signal warrant cannot be met, but the speed or volume of vehicles make it difficult for pedestrians to cross between traffic gaps (Berkeley, 2013; McGrane, 2013).

• Additional CRFs under development as part of NCHRP 17-56 Development of Crash Reduction Factors for Uncontrolled Pedestrian Crossing Treatments.

Traffic Signal, with Pedestrian Signal, Where Warranted

• Definition: Standard traffic signal. A signal warrant does not, in itself, necessitate the installation of a traffic signal. Engineering judgment and an analysis of all road users, local land uses, and other external factors should be conducted before recommending a signal.

• CRF Range: 24 – 44%
  o 24% reduction in all collisions at intersections with annual ADT between 25,000 and 35,000 (Wang et al. 2014); 44% reduction in all collision types with the installation of a traffic signal in rural areas (Harkey et al. 2008); 39% reduction in all collision types with the installation of a traffic signal in urban areas (Abdel-Aty et al. 2014)

• A case-control study in New York City compared the pedestrian crash rate before and after signal installations at 447 intersections. Based on analysis of covariance (ANCOVA) adjustments, the study found a 1% increase in pedestrian crash rate with the addition of a signal. Results were not significant at the 0.05 level (Chen et al. 2012).

GEOMETRIC TREATMENTS

ADA/Directional Curb Ramps with Truncated Domes

• Definition: A pair of curb ramps fitted at a right angle and facing directly into crosswalks, as opposed to one curb ramp which faces the center of a street or intersection. The ramps a surfaced with a highly textured material of truncated domes, often in a bright color.

• The City of Austin, Texas worked closely with the US Access Board as ADA guidelines evolved and has continually adapted its designs to create accessible designs for all modes of transportation. This includes the provision of directional curb ramps with truncated domes. The implementation of curb ramps in Austin illustrated that even a simple policy requires a detailed understanding of need, coordination between several stakeholders, and a strong understanding of best practices. The collaborative evaluation of the curb ramps while policy was evolving allowed for the Access Board to also understand the success of new guidelines.

• No CRFs are available for directional curb ramps.

Bus Bulb-Outs, Other Traffic Calming near Transit Boarding

• Definition: Traffic calming and pedestrian protection devices near transit boarding locations, including bulb-outs.

• No CRFs available for bus bulb outs. See section on Corner bulb outs and curb extensions
**Chicane**

- Definition: Two or more alternating mid-block bulb-outs which create an S-curve in the roadway and discourage vehicular speed.
- No CRFs available for chicanes.

**Choker**

- Definition: Two opposed mid-block bulb-outs which decrease the roadway, discouraging vehicular speed and providing a shorter crossing distance if paired with a crosswalk.
- No CRFs available for chokers.

**Corner Bulb Outs and Curb Extensions**

- Definition: Raised devices, usually constructed from concrete and/or landscaping, that reduce the corner radius and/or narrow the roadway in order to reduce traffic speeds and shorten pedestrian crossing distances.
- Research shows significant decreases in pedestrian crossing delay and increases in motorists yielding to pedestrians (FHWA 2005; Hengel 2013; NACTO 2013; Berkeley, 2013).
- In Bethesda, Maryland, high vehicle speeds were posing problems for local pedestrians on Leland Street, an arterial roadway. Amongst the countermeasures employed to calm traffic on the street were reducing curb radii from 50 feet to 30 feet. With the redesigned streets, the 85th percentile speed was reduced from 32 mph to 27 mph (FHWA, 2013).
- No CRFs available currently - CRFs for curb extensions under development as part of NCHRP 17-56 Development of Crash Reduction Factors for Uncontrolled Pedestrian Crossing Treatments.

**Lane Width Reduction (lane narrowing, 12-foot to 9-foot lanes)**

- Definition: Reduction in vehicle travel lane width from 12-feet to 9-feet.
- CRF Range: 38 – 56%
  - 38% reduction in all collision types and severity along rural roads with between less than 56,000 Annual Average Daily Traffic (AADT); 56% reduction in all collision types and severities along rural roads with AADT between 1,600 and 139,000 (Abdel-Aty et al. 2014).
- In urban areas, lane widths of 10 feet are often appropriate as it increases the street’s safety without an effect on traffic operations. Wider lanes have a greater likelihood of side-swipe collisions. (NACTO 2013).

**Multiple Turn Lane Removal**

- Definition: Removal of one or more turn lanes when multiple turn lanes exist, in order to remove the double-threat of a vehicle/pedestrian collision.
- No CRFs available for removal of turn lanes.

**Pedestrian Overpass/Underpass**

- Definition: Complete separation of pedestrians from motor vehicle traffic, normally where no other pedestrian facility is available, and connects off-road trails and paths across major barriers. The device is recommended only where topography supports its use.
• No CRFs available for pedestrian overpasses and underpasses. However, these treatments entirely eliminate the vehicle-pedestrian conflict points and would theoretically have a CRF of 100 assuming the conditions and design prevented illegal at-grade crossings.

**Raised Pedestrian Crossing/Raised Crosswalks/Speed Tables and Raised Crosswalks**

• Definition: Pedestrian crossings that are elevated to the level of the sidewalk, with in-road ramps on each vehicle approach.
• CRF Range: 30-46%
  o 30% reduction in injury collisions across all modes and collision types; 46% reduction in pedestrian collisions (Elvik and Vaa, 2004)
• Additional CRFs for raised crosswalks are under development as part of NCHRP 17-56 Development of Crash Reduction Factors for Uncontrolled Pedestrian Crossing Treatments.
• While speed tables can exist on their own, when coinciding with or near a crosswalk, the two treatments should be combined into a raised crosswalk (NACTO, 2013).
• This treatment also brings the pedestrian upwards and more into the driver’s realm of attention, and is appropriate for streets with lower speeds, high pedestrian activity, and that are not emergency routes (Berkeley, 2013).

**Reduction in Curb Radii**

• Definition: The size of the curb radius determines the speed at which approaching vehicles can navigate a turn. Reduced turn radii force approaching vehicles to slow down when turning, while still accommodating emergency vehicles and the largest vehicle expected to typically navigate the intersection (i.e., the design vehicle).
• No CRFs available for reductions in curb radii. See section on Corner bulb outs and curb extensions for research on a similar treatment.

**Refuge Islands/Raised Median/Pedestrian Refuge Islands**

• Definition: Curbed sections in the center of the roadway that are vertically separated from vehicular traffic. Raised medians or refuge islands shorten crossing distances across wider roadways, and allow for pedestrians to cross a road while only focusing on one direction of vehicle traffic at a time (Berkeley 2013). Medians should be at least 4ft wide (preferably 6-10ft) and should be long enough to allow the expected number of pedestrian users to stand and wait to cross the second leg (FHWA, 2005, NATCO, 2013). The ideal length of a median is 40 ft., and it should extend past the crosswalk in order to further protect pedestrians and slow traffic (NATCO, 2013).
• Pedestrian CRF range 28.9% - 73%
  o 46% reduction in pedestrian collisions at marked crosswalks at uncontrolled locations (FHWA, 2005);
  o 39% reduction in pedestrian collisions at unmarked crosswalks at uncontrolled locations (FHWA, 2005);
  o 28.9% reduction in pedestrian collisions observed at signalized intersections (Alluri et al. 2012);
  o 33% reduction in pedestrian collision rates with the conversion of a 4 foot painted median to a 10 foot raised median (Cairney, 1999);
  o 73% reduction in mid-block pedestrian collisions (though overall, collisions increased by 136%) with the installation of a pedestrian refuge island.
• Additional CRFs for pedestrian refuge areas under development as part of NCHRP 17-56 Development of Crash Reduction Factors for Uncontrolled Pedestrian Crossing Treatments.

Roadway Cross Section Reduction from Four To Three Lanes (Road Diets)

• Definition: Reduction in number of roadway travel lanes from 2 lanes in each direction to 1 lane in each direction and a center turning lane.
• CRF: 29% reduction in all collision types along minor arterials in urban areas (Harkey et al. 2008).
• Additional research has showed a 41% reduction in pedestrian collisions along roadway segments with road diets and a 5% increase in pedestrian collision at intersections within road diet corridors (Chen et al. 2012). These results were not statistically significant.
• This is a good tool for decreasing vehicular speeds, especially when existing infrastructure prevents the use of curb extensions or chicanes, and ADTs indicate more than necessary roadway capacity. (Berkeley, 2013).

Rumble Strips

• Definition: Transverse grooved strips or raised ceramic pavement markers generally used to alert drivers to a change in roadway conditions through an audible and tactile vibration and rumbling.
• CRF Range: 34-36% reduction in all types of crashes without and with minor or serious injury respectively (Elvik and Vaa, 2004).

Speed Humps

• Definition: Raised pavement areas, typically 12- to 14-feet long and 3- to 4-inches high. Traditionally, humps have pavement markings and advanced warning signage.
• CRF Range: 40-50% reduction in all types of crashes with minor or serious injury (Elvik and Vaa, 2004).
• Additional research has showed a 22 to 23% reduction in 85th percentile speed\(^2\) before and after the installation of speed humps (12- and 14-foot humps respectively) (Ewings, 1999).
• Motorists are more likely to yield to pedestrians when traveling at lower speeds. Lower 85th percentile speeds have been associated with an increase in the rate of yielding motorists with 75% of motorists yielding at 20 mph and 40% of motorists yielding at 30 mph (Bertulis and Dulaski, 2014).
• Motorist speeds decrease 15-20 mph when speed humps are installed (NACTO, 2013).

Temporary Removable Pedestrian Refuge Island with Sign (Curb) On Two-Lane Road

• Definition: Small, painted, raised surface in the center of the roadway, with high-visibility pedestrian crossing signs.
• One study demonstrated a reduction in speeds after installation of the treatment (Kamyab et al. 2003).
• No CRFs available for temporary removable pedestrian refuge islands.

\(^2\) This represents the top speed at which 85% of drivers are travelling. Namely, 85% are driving at or below this speed. The 85th percentile speed is used to establish speed limits per the California Vehicle Code.
OTHER TREATMENTS

Intersection Lighting/Crosswalk Lighting

- **Definition:** Lighting between the crosswalk and oncoming vehicles, usually 10 feet before the crosswalk.
- **CRF:** 42% reduction in nighttime vehicle-pedestrian collision with injuries (Elvik and Vaa, 2004).
- **Additional research** found that vertical illumination of 20 illumination units (Ix) at a height of 5 feet over the crosswalk provided reasonable visibility and detection (Gibbons et al. 2008).
- The inclusion of an energy-efficient smart lighting system at a mid-block crosswalk with a low yield rate and with a high percentage of pedestrian collisions occurring at night was associated with statistically significant increase in the percentage of motorists yielding at greater than 10 feet before the crosswalk and the percentage of pedestrians who purposefully used the crosswalk (Nambisan et al. 2009).
- An experimental design compared pedestrian silhouette visibility in conditions with no lighting, with a streetlight directly over the crosswalk, a streetlight 7 feet ahead of the crosswalk, and reflective bollard luminaires with 28 watt lamps positioned 7 feet ahead of the crosswalk on both ends. Pedestrian silhouettes were placed in the crosswalk and reaction times were recorded at a testing station at a distance of 100 feet from the crosswalk. Reaction times were not statistically significant across treatments but were shorter, on average for the luminaires. Based on the low cost of installation, the research team recommended the installation of the luminary bollards (Bullough, Rea, and Zhang, 2012).
- Lighting at crosswalks is also recommended in the Urban Street Design Guide (NACTO, 2013).

Pedestrian-Scale Lighting

- **Definition:** Items such as parked cars, signage, landscaping, fencing, and street furniture should be placed in a location that will not obstruct sight distance. Pasadena has a policy requiring a sight distance triangle with legs measuring 25 feet from the property line.
- **No CRFs available** for pedestrian-scale lighting.

Removal of Sight Distance Obstructions

- **Definition:** Items such as parked cars, signage, landscaping, fencing, and street furniture should be placed in a location that will not obstruct sight distance. Pasadena has a policy requiring a sight distance triangle with legs measuring 25 feet from the property line.
- **CRF Range for vehicle collisions:** 11-56%
  - The reduction in vehicle collision rates for collision with injuries, fatalities, or property damage was 48%, 56%, and 11% respectively (Elvik and Vaa 2004).
- **No CRFs available** for pedestrian collisions with the removal of sight distance obstructions.
PEDESTRIAN TREATMENTS FOR SIGNALIZED INTERSECTIONS

STRIPING TREATMENTS

Advanced Stop Bar

- With this tool a stop line is placed in advance of crosswalk to increase pedestrian visibility to vehicles and reduce vehicle encroachment upon the crosswalk. Advance stop bars indicate that a driver should stop before approaching the pedestrian crossing. They are usually placed 4 feet away from the crossing.
- CRF: 67% reduction in angle collisions with the implementation of a centerline and stop bar and the replacement of 24-inch stop signs with 30-inch stop signes (Polanis 1999)
- The inclusion of an offset stop bar was associated with a higher rates of vehicles coming to a complete stop before conducting a right-turn-on-red (Zegeer and Cynecki 1986).

SIGNAL AND SIGNAGE TREATMENTS

Accessible Pedestrian Signals at Signalized Intersections

- Definition: Accessible pedestrian signals at signalized intersections are audible or transmitted tones or speech messages to assist visually impaired pedestrians in identifying when they have the right-of-way at a signalized intersection. This is required at newly signalized intersections with actuated pedestrian signals (Lalani et al. 2001).
- Bentzen et al. (1999) evaluated the ability of visually impaired pedestrians to successfully cross a signalized intersection with and without “Talking Signs,” a type of remote infrared Accessible Pedestrian Signal (APS). A successful crossing was recorded if the pedestrian was able to cross the intersection without conflict or without changing direction. The measures of evaluation were: began crossing during walk interval, began crossing within crosswalk, began crossing facing up curb, ended crossing within crosswalk, and needed no help deciding when to cross. In all five cases, the percentage of successful crossings was higher with the APS than without it.
- No CRFs available - Research on accessible pedestrian signals has not focused on the impact of the treatment on pedestrian collisions. However, research has shown that they are effective in decreasing start delay and increasing the number of crossings that stay within the crosswalk (Barlow et al. 2013).

All Red Clearance

- Definition: An all-red clearance phase provides a phase (1-3 seconds) where all vehicle indicators hold the red at an intersection.
- CRF Range for vehicle collisions: 14-20%
  - The reduction in vehicle collision rates for collision overall and with injury and fatalities was 20% and 14% respectively (Srinivasan et al. 2011).
- No CRFs available for pedestrian specific sight distance research
Countdown Signal

- Definition: The pedestrian countdown signal displays a countdown of the number of seconds remaining for a pedestrian crossing interval during the flash/don’t walk stage (Lalani et al. 2001).
- Lalani et al. cite Leonard et al. (1999), a study that evaluated countdown-type signals and found that while they did not prevent pedestrians from initiating crossing at the beginning of the flash-don’t walk phase, they did deter some pedestrians from starting to cross with too few seconds left.
- CRF Range: 0 – 70%
  - In Detroit and Kalamazoo Michigan, there was a 55 to 70% reduction in vehicle-pedestrian collisions (Vanhouten, LaPlante, and Gustafson, 2014).
  - A study in Toronto compared the number of collisions before and after the installation of a pedestrian countdown signal. The study found no statistically significant reduction (or increase) in crash rate associated with the installation of a pedestrian countdown signal (Camden et al. 2012).
- The city of Monterey, California has a high volume of pedestrian activity. At some busy intersections, pedestrians had large distances to cross and there was confusion and conflicts between pedestrians and motorists. The City decided to test pedestrian countdown signals at signalized intersections to see whether it would improve clarity between pedestrians and motorists. The City chose two intersections for implementation that were equipped with countdown devices. Studies noted that prior to implementation of countdowns, pedestrians would enter the intersection during the flash don’t walk phase, whereas afterwards most pedestrians waited for the next phase once the countdown was less than 10 seconds. Additionally, pedestrians interviewed noted that having the countdown device helped in understanding pedestrian signals. Pedestrian Countdown Signals were also installed in San Francisco, where subsequent studies identified that with countdowns there were fewer pedestrians in the crosswalk once the signal turned red (decrease from 14% to 9%), and the observed vehicle/pedestrian conflicts decreased (FHWA PedSafe 2013).

Flashing Yellow Left Arrow

- Definition: A flashing yellow left-turn arrow allows permissive left turns and warns motorists of potential conflicts with pedestrians in the crosswalk
- CRF Range for vehicle collisions: 10-14%
  - The reduction in collision rates for vehicle collisions overall and vehicle left-turn collisions specifically were 10% and 14% respectively (Schattler et al. 2015)).
- No CRFs available for pedestrian specific sight distance research

Full Time Recall/Fixed Time Pedestrian Intervals

- Definition: Full time recall/fixed time pedestrian intervals are pre-timed signals give pedestrians the walk signal without requiring push-button action.
- No CRFs available for full time recall or fixed time pedestrian intervals.

Increase Length of Pedestrian Phase

- With this tool, the amount of time for pedestrian clearance is increased to allow for slower walk speeds through an intersection. Generally, the extension allows for a pedestrian to cross the
intersection while walking at a speed of 2.5-3.5 feet/second instead of the standard 3-5 feet/second. The timing may be increased with a separate button or a longer button push (Reynolds and Ridgeway).

- CRF Range: 45-50%
  - 45% reduction in vehicle collisions (angle, head-on, left-turn, rear-end, rear-to-rear, right-turn, sideswipe) (Chen et al. 2012)
  - 50% reduction in pedestrian-vehicle collisions (Chen et al. 2012)

**Leading Pedestrian Phase/Leading Pedestrian Interval**

- With this device, a signal modification is made such that the pedestrian walk phase begins 3-5 seconds in advance of turning vehicles with permitted left-turn or right-turn movements. The objective is to permit pedestrians to cross several seconds before potentially conflicting motor vehicles receive a green indication (Lalani et al. 2001).
- Case studies note the benefits of installing leading pedestrian intervals. In St. Petersburg, FL, Retting et al. (1997) observed a decrease in right-of-way violations when leading pedestrian intervals were installed. In San Francisco, Fleck (2000) noted similar results.
- CRF Range: 29-45
  - The aggregate reducing in pedestrian–vehicle crash rates at signalized intersections with and without a leading pedestrian interval was 37% (significant at 90% confidence level). The disaggregate analysis showed that the CRF was higher at intersections with higher pedestrian volumes (Fayish and Gross, 2009).

**Limited Signage/Sign Clutter Evaluation**

- Definition: Road signs and street signs at intersections may distract motorists from the road. Unnecessary signage should be removed and relocated so as to present motorists with only signage relevant to the operation of the intersection.
- No CRFs available for using limited signage or reducing sigh clutter.

**Peak Hour Pedestrian Recall**

- Definition: Peak hour pedestrian recall phasing provides a guaranteed walk phase for each crossing at a signal during peak hours, regardless of whether the pedestrian push button has been activated.
- No CRFs available for peak hour pedestrian recall.

**Pedestrian Detection**

- For this tool, infrared, microwave, or video detectors are installed at signalized intersections to detect pedestrians. This can be used to increase the length of a pedestrian signal or to actuate a pedestrian phase (Reynolds and Ridgeway).
- While this device is promising, its effectiveness is still under study and it should be consider an experimental device. The tool has been used in Los Angeles, CA (Reynolds and Ridgeway).
- Further reading on this tool: Hughes et al. 2000.
- Research conducted at mid-block crossings has found that used a pedestrian detection device to automatically illuminate the pedestrian crossing signage. The study found an increase in the rate of drivers yielding and pedestrians diverting to the crosswalk (Nambisan 2009).
A study conducted at a signalized location using pedestrian detection to extend the pedestrian phase concluded that the devices provided only minimal pedestrian safety improvements (Lovejoy et al. 2012).

No CRFs available for pedestrian detection.

**Pedestrian Scramble**

- Definition: A pedestrian scramble (or Barnes Dance) is a phase during which no vehicles are in the intersection, so pedestrians can cross diagonally or conventionally
- CRF Range: 51-63%
  - An evaluation of vehicle operations using ICU analysis identified that most intersections continued to operate sufficiently despite the added phase. After nine years of implementation, a before-and-after study was conducted by the City of Beverly Hills to evaluate pedestrian safety at the intersections. An overall decrease in vehicle/pedestrian collisions of 63% was realized (FHWA, PedSafe 2013).
  - A study evaluating impact of several pedestrian countermeasures on crash rates at signalized intersections attributed a 51% reduction in vehicle-pedestrian crash rate resulting from the installation of the pedestrian scramble (controlling for all other treatments) (Chen et al. 2012).

**Prohibit Right Turn on Red**

- Definition: Prohibits vehicles from turning right when signal has a red indication.
- CRF Range for Implementing Right Turn on Red: -10 to -69% (increase in collision rate)
  - 10 to 60% increase in right-turn collision types (Elvik and Vaa 2004)
  - 69% increase in vehicle-bicycle and vehicle-pedestrian (AASHTO 2010)
- Additional research has showed that Right Turn on Red provisions do not have a meaningful impact on pedestrian safety:
  - Zegeer and Cyniecki (1986) found that the likelihood of a right-turn-on-green collision was higher than a right-turn-on-red collisions.
  - Lord (2003) found that, based on the proportion of collisions attributed to right-turn-on-red movements, right-turn-on-red provisions are not a safety problem for pedestrians.

**Protected Left-Turn Phase**

- Left turns are the highest-risk movement at an intersection. Providing a protected left turn phase improves safety and intersection efficiency for all modes (FHWA, *Safety at Signalized Intersections*).
- CRF Range for permissive/protected left-turn phase conversion: 11-99%
  - CRF: 99% reduction in angle collisions (convert permissive or permissive/protected to protected only) (Harkey 2008); 16% reduction in left-turn collisions (convert permissive to permissive/protected) (AASHTO 2010, Simpson and Troy 2015)
  - Additional research has demonstrated that implementing a left turn phase can reduce the pedestrian crash rate by approximately 34% (45% reduction at treatment sites and an 11% reduction at control sites).
- CRF Range for vehicle collision after prohibiting left-turns: 64-77%
  - 72-77% reduction in vehicle collision rates after prohibiting left-turns and U-turns
  - 64-68% reducing in vehicle collision rate after prohibiting left-turns only
Removal of Unwarranted Traffic Signals

- Definition: Traffic signals replaced with all-way stop signs.
- CRF: 18% reduction in pedestrian collisions (research is specific to one-way streets) (Persaud et al. 1997).

GEOMETRY TREATMENTS

Far Side Bus Stops

- Far-side bus stops allow pedestrians to cross behind the bus, improving pedestrian visibility. Far side bus stops also enhance transit operations by provided a guaranteed merging opportunity for buses. Exceptions for far-side bus stops include considerations for bus routing, sufficient sidewalk area, and conflicts with parking, land uses, or driveways.
- No CRFs available for far side bus locations.

Improved Right Turn Slip-Lane Design

- Better the “pork chop” or right turn slip-lanes, which are separated from the rest of the travel lanes by a striped or raised median area.
- CRF Range for vehicle collisions: 5% reduction in vehicle collision rates was 5% (Preston and Schoenecker 1999).
- No CRFs available for pedestrian collisions with improved right turn slip-lane design.

Intersection Conversion to Roundabout

- Definition: Roundabout installed at a previously unsignalized intersections or to replace a former traffic signal. Roundabouts are large circular islands, placed in the middle of an intersection, which direct flow in a continuous circular direction around the intersection. Roundabouts can reduce the number of conflict points, compared to an uncontrolled intersection, and decrease vehicle speeds due to intersection geometry.
- CRF: 29% reduction in collisions for conversion with 2-way, minor-road stop-control intersection to roundabouts in urban areas (Rodegerdts et al. 2007).
- Research has not focused on the impact of roundabouts as a countermeasure for pedestrian collisions, but it has produced varied results on the rates of drivers yielding to pedestrians with concerns emerging particularly for multi-lane roundabouts.
- NACTO does not recommend the use of channelized turning and pork chop islands because drivers often do not yield to crossing pedestrians.
- Additional research from the Crash Modification Factors Clearinghouse shows a 73% reduction in pedestrian collisions after conversion of intersections to roundabouts, but it does not specify if those intersections were signalized or unsignalized prior to installation of the treatment (Schoon and van Minnen 1994).
OTHER TREATMENTS

Driveway improvements/access management

- Access management strategies can reduce the number of driveway crossings that pedestrians encounter and result in a wider sidewalk through more efficient allocation of space. Pasadena’s Department of Transportation recently drafted Policies and Procedures and Driveway Design to help address potential conflicts.
- No CRFs available for access management with regard to pedestrian collisions
TREATMENT TOOLBOX

This chapter presents the recommended tools in striping, signalization, signage, geometry and other categories for improving both uncontrolled and controlled crossing locations. It is organized into a table, and includes each tool’s name, description, crash reduction factor (CRF), and eligibility for application. All treatments included in the toolbox are also discussed in the Literature Review.

DETERMINING HOW & WHEN TO MARK UNCONTROLLED LOCATIONS

The 2000 Uniform Vehicle Code and Model Traffic Ordinance (Uniform Vehicle Code) (Section 1-112) defines a crosswalk as:

a. "That part of a roadway at an intersection included within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs, or in the absence of curbs, from the edges of the traversable roadway; and in the absence of a sidewalk on one side of the roadway, the part of a roadway included within the extension of the lateral lines of the existing sidewalk at right angles to the centerline.

b. Any portion of a roadway at an intersection or elsewhere distinctly indicated for pedestrian crossing by lines or other markings on the surface." (Source: Federal Highway Administration)

As a result, crossings can be broken down into three categories:

1. **Uncontrolled Marked Crossing**: Crosswalks that are striped midblock or at intersections not controlled by traffic signals or stop signs
2. **Controlled Marked Crossing**: Crosswalks that are striped midblock or at intersections controlled by traffic signals or stop signs
3. **Unmarked Crossing**: Crosswalks that are not striped at intersections with or without a traffic signal or stop sign

This report focuses on how to treat marked uncontrolled locations and a process for determining when uncontrolled locations should be marked with crossings.

The following is the recommended practice for providing pedestrian treatments at uncontrolled intersections and mid-block locations. The most common crosswalk of this type will be at intersections where a minor side street is stop controlled and a major street is uncontrolled.

Crossings should be marked where all of the following occur:

- Sufficient demand exists to justify the installation of a crosswalk (see Demand Considerations below).
- The location has sufficient sight distance (as measured by stopping sight distance calculations) and/or sight distance will be improved prior to crosswalk marking.
- Safety considerations do not preclude a crosswalk
DEMAND CONSIDERATIONS

Uncontrolled and mid-block crossings should be identified as a candidate for marking if there is a demonstrated need for a crosswalk. Figure 5 provides a visual summary of the demand considerations. Engineering judgment will ultimately be used to select locations appropriate for a marked, uncontrolled crossing. Enhanced treatments beyond basic striping and signing may be needed for uncontrolled locations if they meet the following conditions:

- Multi-lane streets (three or more lanes); or
- Two-lane streets with daily traffic volumes (ADT) greater than 12,000; or
- Streets with posted speed limit exceeding 25 miles per hour

TREATMENT IDENTIFICATION

Following Chart 5, Table 1 includes a list of treatments for uncontrolled locations, as well as each one’s applicable context.

This report largely deals with the category of unmarked crossings and helps examine questions specifically regarding when and how crosswalks should be marked at uncontrolled locations. However, locations will remain, such as four-way or two-way stop-controlled locations, where unmarked crosswalks exist across all for legs. While every situation is unique due to characteristics like sight distance, vehicle speeds, number of lanes, and vehicle/pedestrian volumes, the following provides guidance for the marking of crosswalks and applying consistent standards and treatments for marking crosswalks at controlled locations:

- Controlled marked crossings:
  - Signalized intersections: standard parallel white lines across all four legs
    - Exceptions:
      - Consider high-visibility crosswalk striping near sensitive generators such as schools, libraries, parks, hospitals, senior/community centers, or commercial districts
      - Consider restricting crossings if sight distance or some other consideration may not allow for a safe crossing
  - All-way and two-way/side-street stop-controlled intersections: no crosswalk markings for controlled two-lane roadways
    - Exceptions:
      - Commercial districts and corridors (i.e., stop-controlled minor streets along Colorado Boulevard)
      - Three or more lane roadways, where pedestrians have additional exposure due to longer crossing distances and increased vehicle activity
      - Consider high-visibility crosswalk striping near sensitive generators such as schools, libraries, parks, hospitals, or senior/community centers
      - Consider restricting crossings if sight distance or some other consideration may not allow for a safe crossing

- Uncontrolled marked crossings: see the treatments and approach described in this report
Should a crosswalk be installed?

- **20 pedestrians per hour cross** (in any two hours, not necessarily consecutive) → **NO**
- **Yes**
- Nearest appropriately marked or protected crosswalk is at least 300 ft or more away → **NO**
- **Yes**
- Pedestrians can be easily seen from a feasible stopping sight distance → **NO**
  - **Yes**
  - It is feasible to remove sight obstruction or lower the speed limit → **NO**
  - **Yes**
  - Use Pedestrian Toolbox and Guidance to determine treatment options → **Feasible**
- **Insufficient need to justify a marked crossing** → **NO**
- **Direct pedestrians to the nearest marked or protected crossing** → **OR**
- **Consider installing a stop sign, signal, or grade separation** → **OR**

Figure 5. Feasibility Analysis for Treatments at Uncontrolled Locations
## UNCONTROLLED LOCATIONS - BASIC TREATMENTS

### STRIPING TREATMENTS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yield Line</strong> (MUTCD Section 3B.16)</td>
<td>Yield lines (also referred to as “sharks’ teeth”) are placed 20 to 50 feet in advance of multi-lane marked, uncontrolled crosswalks (CA-MUTCD). When a roadway has 3 or more lanes, the yield line should be placed further from the crosswalk in an advanced position. “Yield Here to Pedestrian” (R1-5/R1-5a, white sign in photo) must be used in conjunction with advanced yield limit lines (CA-MUTCD).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRF</th>
<th>ADT</th>
<th>Speed Limit</th>
<th>Number of Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>Any</td>
<td>Any</td>
<td>Any</td>
</tr>
</tbody>
</table>

| **High-Visibility Crosswalk** (MUTCD Section 3B.18) | Crosswalks with thick stripes perpendicular to direction of vehicular traffic are a common application. CA-MUTCD guidance includes an option to mark crosswalks with diagonal white lines at a 45 degree angle to the line of the crosswalk in cases where “substantial numbers of pedestrians cross” at uncontrolled locations. Installation of a marked crosswalk only may not be appropriate for certain conditions. See toolbox applicability matrix. |

<table>
<thead>
<tr>
<th>CRF</th>
<th>ADT</th>
<th>Speed Limit</th>
<th>Number of Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>19 – 40%</td>
<td>Any</td>
<td>Any</td>
<td>Any</td>
</tr>
</tbody>
</table>
# UNCONTROLLED LOCATIONS - BASIC TREATMENTS

## SIGNAL/SIGNAGE TREATMENTS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In-Streets Pedestrian Signage</strong> (MUTCD Section 2B.12)</td>
<td>High-visibility pedestrian crossing signage placed in the street at a marked crosswalk. Roadside pedestrian crossing signage may be used in conjunction with in-street pedestrian signage (2014 California MUTCD).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRF</th>
<th>ADT</th>
<th>Speed Limit</th>
<th>Number of Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>≤15,000</td>
<td>≤ 35 MPH</td>
<td>2- to 3-lane</td>
</tr>
</tbody>
</table>

| **MUTCD Roadside Signage** (MUTCD Section 2B.11) | The 2014 California MUTCD permits the use of two primary roadside pedestrian crossing signs: **Yield Here to Pedestrians** (far left photo) and the **Pedestrian Crossing** (middle and right photo). The Pedestrian Crossing sign can be either fluorescent yellow-green or yellow and placed in advance of the crosswalk with an AHEAD placard or at the crosswalk with an arrow placard. |

<table>
<thead>
<tr>
<th>CRF</th>
<th>ADT</th>
<th>Speed Limit</th>
<th>Number of Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>Any</td>
<td>Any</td>
<td>Any</td>
</tr>
</tbody>
</table>
UNCONTROLLED LOCATIONS - BASIC TREATMENTS

GEOMETRIC TREATMENTS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median, Refugee Island or Split Pedestrian Crossover (MUTCD Section 3I.06)</td>
<td>Sections in the center of the roadway that are vertically or visually separated from vehicular traffic. Raised medians or refuge islands shorten crossing distances across wider roadways, and allow for pedestrians to cross a road while only focusing on one direction of vehicle traffic at a time. When enhanced as a Split Pedestrian Crossover, the crossing is staggered such that a pedestrian crosses half the street and then walks toward traffic to reach the second half of the crosswalk.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRF</th>
<th>ADT</th>
<th>Speed Limit</th>
<th>Number of Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>29-73%</td>
<td>Any</td>
<td>Any</td>
<td>2-lane or more</td>
</tr>
</tbody>
</table>

| Road Diets | Reduction in number of roadway travel lanes from 2 lanes in each direction to 1 lane in each direction, a center turning lane, and may allow for bike lanes. Road diets reduce the number of lanes pedestrians must cross. |

<table>
<thead>
<tr>
<th>CRF</th>
<th>ADT</th>
<th>Speed Limit</th>
<th>Number of Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>29%</td>
<td>≤ 23,000</td>
<td>N/A</td>
<td>4-lane</td>
</tr>
</tbody>
</table>
UNCONTROLLED LOCATIONS - BASIC TREATMENTS

OTHER TREATMENTS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Removal of Sight Distance Obstructions</strong></td>
<td>Items such as parked cars, signage, landscaping, fencing, and street furniture should be placed in a location that will not obstruct sight distance. Pasadena has a policy requiring a sight distance triangle with legs measuring 25 feet from the property line.</td>
</tr>
<tr>
<td>CRF</td>
<td></td>
</tr>
<tr>
<td>ADT</td>
<td></td>
</tr>
<tr>
<td>Speed Limit</td>
<td></td>
</tr>
<tr>
<td>Number of Lanes</td>
<td></td>
</tr>
<tr>
<td>11–56% (vehicle collisions only)</td>
<td>Any</td>
</tr>
</tbody>
</table>

| **Traffic Signal, with Pedestrian Signal, Where Warranted**       | Standard traffic signal. A signal warrant does not, in itself, necessitate the installation of a traffic signal. Engineering judgment and an analysis of all road users, local land uses, and other external factors should be conducted before recommending a signal. |
| CRF |
| ADT |
| Speed Limit |
| Number of Lanes |
| 24 – 44%                                                   | ≥ 15,000                                                                                                                                       | ≥ 35 MPH                                                                                       | 3-lane or more                                                                                     |
UNCONTROLLED LOCATIONS - ENAHANCED TREATMENTS

SIGNAL/SIGNAGE TREATMENTS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
<th>CRF</th>
<th>ADT</th>
<th>Speed Limit</th>
<th>Number of Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flashing Beacons (Including RRFB Signals)</strong></td>
<td>Flashing beacons highlighting crosswalks and pedestrian crossing signs through the addition of a flashing light. Rectangular Rapid Flash Beacons (RRFB) provide a high visibility, brighter strobe-like flashing frequency. RRFB were given interim approval by the FHWA in 2008.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><a href="#">Image source: FHWA MUTCD</a></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>In-Roadway Lighting (MUTCD Section 4N.02)</strong></td>
<td>Crosswalk lighting embedded in the roadway at even intervals, which lights upon being actuated by a pedestrian or pedestrian push-button in order to enhance the crossing visibility to vehicles.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><a href="#">Image source: FHWA MUTCD</a></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3 Received MUTCD Interim Approval for IA-11 in 2008: [http://mutcd.fhwa.dot.gov/resources/interim_approval/ia11/fhwamemo.htm](http://mutcd.fhwa.dot.gov/resources/interim_approval/ia11/fhwamemo.htm)
### UNCONTROLLED LOCATIONS - ENHANCED TREATMENTS

#### SIGNAL/SIGNAGE TREATMENTS (CONTINUED)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LED-Enhanced Signage</strong> (MUTCD Section 2A.07)</td>
<td>Pedestrian crossing signage, often MUTCD preferred style, with embedded or external lights in order to enhance the visibility of the signage.</td>
</tr>
<tr>
<td><img src="image" alt="LED-Enhanced Signage" /></td>
<td></td>
</tr>
<tr>
<td><strong>CRF</strong></td>
<td><strong>ADT</strong></td>
</tr>
<tr>
<td>N/A</td>
<td>Any</td>
</tr>
</tbody>
</table>

| **Pedestrian Hybrid Beacon (HAWK)** (MUTCD Section 4F) | Pedestrian-activated warning light located on a mast arm over a pedestrian crossing. The beacon stays dark until activated. It has one yellow lens and two red lenses to indicate to drivers that a pedestrian is in the crosswalk. The pedestrian hybrid beacon was included, for the first time, in the 2009 MUTCD. The 2014 CA-MUTCD includes a standard traffic signal (that does not meet a signal warrant) as an alternative to the standard pedestrian hybrid beacon. |
| ![Pedestrian Hybrid Beacon (HAWK)](image) |                                                                                                                                                                                                 |
| **CRF** | **ADT** | **Speed Limit** | **Number of Lanes** |
| 15-69%  | >12,000 | >45 MPH         | 4-lane or more      |
## UNCONTROLLED LOCATIONS - ENHANCED TREATMENTS

### GEOMETRIC TREATMENTS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
<th>CRF</th>
<th>ADT</th>
<th>Speed Limit</th>
<th>Number of Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chicane</strong></td>
<td>Two or more alternating mid-block bulb-outs which create an S-curve in the roadway and discourage vehicular speeding.</td>
<td>N/A</td>
<td>&lt; 15,000</td>
<td>&lt;40 MPH</td>
<td>2-lane</td>
</tr>
<tr>
<td><strong>Choker</strong></td>
<td>Two opposed mid-block bulb-outs which decrease the roadway width, discouraging vehicular speeding and provide a shorter crossing distance if paired with a crosswalk.</td>
<td>N/A</td>
<td>&lt; 15,000</td>
<td>&lt;40 MPH</td>
<td>2-lane or more</td>
</tr>
</tbody>
</table>
### GEOMETRIC TREATMENTS (CONTINUED)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corner Bulb Outs and Curb Extensions</td>
<td>Raised devices, usually constructed from concrete and/or landscaping, that reduce the corner radius and/or narrow the roadway in order to reduce traffic speeds, shorten pedestrian crossing distances, and improve visibility.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRF</th>
<th>ADT</th>
<th>Speed Limit</th>
<th>Number of Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>Any</td>
<td>Any</td>
<td>2- to 4-lane</td>
</tr>
</tbody>
</table>

| Lane Width Reduction                | Reduction in vehicle travel lane width from 12-feet to 9-feet or 10-feet.                                                                                                                                                          |

<table>
<thead>
<tr>
<th>CRF</th>
<th>ADT</th>
<th>Speed Limit</th>
<th>Number of Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>38 - 56%*</td>
<td>≤ 25,000</td>
<td>&lt;35 MPH</td>
<td>Up to 4-lane</td>
</tr>
</tbody>
</table>

*for 12- to 9-feet lanes
### Raised Pedestrian Crossing/Speed Table (MUTCD Section 3B.25, Figure 3B-30)

Pedestrian crossings that are elevated to the level of the sidewalk. In-road grade change is similar to a speed hump (see next page for further information).

<table>
<thead>
<tr>
<th>CRF</th>
<th>ADT</th>
<th>Speed Limit</th>
<th>Number of Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-46%</td>
<td>≤15,000</td>
<td>&lt;35 MPH</td>
<td>Any</td>
</tr>
</tbody>
</table>

### Speed Humps (MUTCD Section 3B.25, 3B.26, Figure 3B-29, 3B-31)

Raised pavement areas, typically 12- to 14-feet long and 3- to 4-inches high. Traditionally, humps have pavement markings and advanced warning signage.

<table>
<thead>
<tr>
<th>CRF</th>
<th>ADT</th>
<th>Speed Limit</th>
<th>Number of Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>40-50%</td>
<td>≤15,000</td>
<td>&lt;35 MPH</td>
<td>Any</td>
</tr>
</tbody>
</table>
FURTHER INFORMATION REGARDING RAISED PEDESTRIAN CROSSINGS AND SPEED TABLES

Standards regarding the placement of speed tables are not available in formal resources such as the Highway Design Manual (HDM) or Manual on Uniform Traffic Control Devices (MUTCD). Speed tables are used as vertical deflection to reduce travel speeds and can be placed in numerous locations. For further information and images, refer to ‘Uncontrolled Locations – Enhanced Treatments: Geometric Treatments’ of the Treatment Toolbox (page 34).

As shown in Table 2 and Table 3, this treatment is identified as applicable in settings where the speed limit is 30 miles per hour or less. Traffic calming guidance, such as the U.S. Traffic Calming Manual, recommends consistent spacing between devices in range of the 300 to 500 feet, so as to provide consistent treatments and expectations along the corridor. In the absence of formal standards, it is suggested that a minimum distance of 50 to 100 feet be provided between the placement of speed tables and infrastructure such as intersections and driveways.

If a speed table is being used also as a raised crossing, its placement would be based on the desired location of the crossing, taking into consideration the locations of nearby crossings and intersections. Per the Feasibility Analysis for Treatments at Uncontrolled Locations, a raised crossing would generally not be recommended within 300 feet of an existing marked crossing, including marked crosswalks at intersections. A raised crosswalk within 300 feet of a traffic signal is not recommended due to the potential for interrupting the effectiveness of the signal at controlling traffic. It would be acceptable to install a raised crossing at a controlled or uncontrolled location, per the guidance in Table 2 and Table 3.
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marked Crosswalk</td>
<td>Stripping on the far sides of a pedestrian crossing parallel to the direction of vehicular traffic, which denote the proper location to cross a street.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRF</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varies</td>
<td>Recommended at all signalized or stop-controlled intersections.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop Line</td>
<td>Standard advance stop bars must be placed a minimum of four feet in advance of marked crosswalk (CA-MUTCD)s.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRF</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>67%</td>
<td>Where space allows, recommended at all signalized or stop-controlled intersections.</td>
</tr>
</tbody>
</table>
**SIGNALIZED LOCATIONS - BASIC TREATMENTS**

**SIGNAL/SIGNAGE TREATMENTS**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Countdown Signal</strong> (MUTCD Section 4E.07)</td>
<td>Displays a “countdown” of the number of seconds remaining for the pedestrian crossing interval.</td>
</tr>
<tr>
<td><img src="image" alt="Countdown Signal" /></td>
<td></td>
</tr>
<tr>
<td><strong>CRF</strong></td>
<td><strong>Applicability</strong></td>
</tr>
<tr>
<td>0-70%</td>
<td>Recommended at all signalized.</td>
</tr>
</tbody>
</table>

| **Increase Length of Pedestrian Phase** (MUTCD Section 4E.06) | The 2009 Federal MUTCD requires reduction of the pedestrian walking speed from 4.0 feet per second to 3.5 feet per second to reflect average pedestrian walking speeds. The walking speed could be further reduced to accommodate vulnerable populations such as children and the elderly. |
| ![Increase Length of Pedestrian Phase](image) |                                                                                                                                                                                                             |
| **CRF**                                       | **Applicability**                                                                                           |
| 45-50%                                        | The use of 3.5 ft./sec standard walking speed is recommended at all signalized intersections. Additional reductions should be considered near a school or retirement facility.                        |
### SIGNALIZED LOCATIONS - BASIC TREATMENTS

**SIGNAL/SIGNAGE TREATMENTS (CONTINUED)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pedestrian Recall (Peak Hour or Full Time)</strong> <em>(MUTCD Section 4E.11)</em></td>
<td>Provides a guaranteed walk phase for each crossing at a signal during peak hours, regardless of whether the pedestrian push button has been activated.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRF</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>Recommended in areas of high peak-hour or daily pedestrian activity, such as near a school, transit station, or downtown district.</td>
</tr>
</tbody>
</table>

### GEOMETRIC TREATMENTS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Far-Side Bus Stops</strong></td>
<td>Far-side bus stops allow pedestrians to cross behind the bus, improving pedestrian visibility. Far side bus stops also enhance transit operations by provided a guaranteed merging opportunity for buses. Exceptions for far-side bus stops include considerations for bus routing, sufficient sidewalk area, and conflicts with parking, land uses, or driveways.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRF</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>Recommended at all signalized or stop-controlled intersections.</td>
</tr>
</tbody>
</table>
# SIGNALIZED LOCATIONS - ENHANCED TREATMENTS

## SIGNAL/SIGNAGE TREATMENTS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All Red Clearance</strong> (MUTCD Section 4D.26)</td>
<td>Provides a phase (1-2 seconds) where all vehicle indicators hold the red at an intersection.</td>
</tr>
<tr>
<td><img src="image1" alt="All Red Clearance" /></td>
<td></td>
</tr>
<tr>
<td><strong>Flashing Yellow Left Arrow</strong> (MUTCD Section Section 4D.17, 4D.18)</td>
<td>A flashing yellow left-turn arrow allows permissive left turns and warns motorists of potential conflicts with pedestrians in the crosswalk.</td>
</tr>
<tr>
<td><img src="image2" alt="Flashing Yellow Left Arrow" /></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRF</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-20%</td>
<td>Recommended in areas of high pedestrian activity.</td>
</tr>
<tr>
<td>10-14%</td>
<td>Recommended for permissive left turns at signalized intersections.</td>
</tr>
</tbody>
</table>
### Leading Pedestrian Interval (MUTCD Section 4E.06)

A signal modification such that the pedestrian walk phase begins 3 seconds in advance of turning vehicles with permitted left-turn or right-turn movements. The objective is to permit pedestrians to cross several seconds before potentially conflicting motor vehicles receive a green indication.

<table>
<thead>
<tr>
<th>CRF</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>29-45%</td>
<td>Recommended in areas of high pedestrian and/or high vehicular activity.</td>
</tr>
</tbody>
</table>

### Pedestrian Detection (MUTCD Section 4E.08)

Infrared, microwave, or video detectors installed at signalized intersections to detect pedestrians.

<table>
<thead>
<tr>
<th>CRF</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>Recommended in areas of high pedestrian and/or high vehicular activity.</td>
</tr>
</tbody>
</table>
### SIGNALIZED LOCATIONS - ENHANCED TREATMENTS

#### SIGNAL/SIGNAGE TREATMENTS (CONTINUED)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pedestrian Scramble/Barnes Dance</strong> (MUTCD Section 3B.18, Figure 3B-20)</td>
<td>A pedestrian scramble (or Barnes Dance) is a phase during which no vehicles are in the intersection, so pedestrians can cross diagonally or conventionally.</td>
</tr>
<tr>
<td><strong>Prohibited Right-Turn on Red</strong> (MUTCD Section 2B.54)</td>
<td>Prohibits vehicles from turning right when signal has a red indication.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRF</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>51-66%</td>
<td>Recommended in areas of high pedestrian and/or high vehicular activity.</td>
</tr>
<tr>
<td>11-69%</td>
<td>Recommended in areas of high pedestrian, high vehicular activity, or locations with a demonstrated crash history involving right-hooks.</td>
</tr>
</tbody>
</table>
### SIGNALIZED LOCATIONS - ENHANCED TREATMENTS

#### SIGNAL/SIGNAGE TREATMENTS (CONTINUED)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
<th>CRF</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prohibited Left-Turn</strong> (MUTCD Section 4D.17 - 4D.20)</td>
<td>Prohibits vehicles from turning left at a signal in order to allow pedestrians a crossing without conflicting with vehicle turning movements. Left-turning drivers must turn before or after the intersection at a different identified location.</td>
<td>N/A</td>
<td>Recommended in areas of high pedestrian and lower vehicular activity. Consider use at locations with a history of left-turn vehicle-pedestrian crashes.</td>
</tr>
<tr>
<td><strong>Protected Left Turn</strong> (MUTCD Section 4D.17, 4D.19)</td>
<td>Protected left turns give vehicles that are turning left an exclusive phase that does not coincide with the pedestrian walk phase. This eliminates the pedestrian-vehicle conflict between permissive lefts and pedestrians in a crosswalk.</td>
<td>11-99%</td>
<td>Recommended in areas of high pedestrian and/or high vehicular activity.</td>
</tr>
</tbody>
</table>
### GEOMETRIC TREATMENTS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intersection Conversion to Roundabout</strong> (MUTCD Section 3C.01)</td>
<td>Roundabout installed at a previously unsignalized intersections or to replace a traffic signal. They are large circular islands, placed in the middle of an intersection, which direct flow in a continuous circular direction around the intersection. Roundabouts can reduce the number of conflict points, compared to an uncontrolled intersection, and decrease vehicle speeds.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRF</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>29%</td>
<td>Recommended in areas of high vehicular activity.</td>
</tr>
</tbody>
</table>
APPLICATION OF TREATMENTS AT UNCONTROLLED LOCATIONS

Included here is a set of tables indicating treatment recommendations for uncontrolled crossings with varying average daily traffic (ADT), posted speed limits, and number of lanes. FHWA research identified a possible increase in collision rate with the inclusion of marked crosswalks alone (without additional treatments) at high volume, high speed, and multi-lane uncontrolled locations. This table indicates whether or not a marked crosswalk alone may be sufficient and breaks down the treatment options applicable for high volume, high speed, and multi-lane roadways.

Generally, treatments are cumulative and crossings at uncontrolled locations on roads with 4-lanes, high volumes, and high speeds should include additional treatments compared to shorter, lower volume, lower speed uncontrolled crossing locations. However, treatments with vertical or horizontal vehicle deflection (e.g., in-road signage, raised crosswalks, speed humps, chicane, and chokers) are recommended only for lower volume, lower speed locations.

The guidance in this document is focused on crossings of major roadways, where they intersect minor cross streets. Assessing observed demand by taking pedestrian counts helps inform the potential need for a crosswalk across the minor street. At crossings of minor streets, marked crosswalks and additional treatments should be considered for locations with high pedestrian generators and/or generators of vulnerable users, such as schools or parks.

Representative figures are also included to illustrate recommended combinations of treatments. These tables and figures are intended as guides; not all locations are suitable for marked crosswalks and an engineering study should precede the decision to mark a crosswalk regardless of the road conditions.


Table 2. Treatments Applicable for Uncontrolled Pedestrian Crossings Across 2- and 3-lane Roadways

Colored cells indicate that a corresponding conceptual diagram of these treatments is available in Figure 6*, Figure 7^, Figure 8+, and Figure 9=.

<table>
<thead>
<tr>
<th>Type</th>
<th>Category</th>
<th>Treatment</th>
<th>Average Daily Traffic</th>
<th>&lt;15,000 [d]</th>
<th>≥15,000 [d]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>≤30 MPH</td>
<td>35 MPH</td>
</tr>
<tr>
<td>[a] Marked Crosswalk Alone May be Sufficient (2-lanes)</td>
<td></td>
<td></td>
<td></td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>[a] Marked Crosswalk Alone May be Sufficient (3-lanes)</td>
<td></td>
<td></td>
<td></td>
<td>only ADT &lt;12,000</td>
<td>only ADT &lt;9,000</td>
</tr>
<tr>
<td>Striping</td>
<td>Basic</td>
<td>Yield Line [b]</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Striping</td>
<td>Basic</td>
<td>High visibility crosswalks (Continental/Ladder Striping) [b]</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Signal/Signage</td>
<td>Basic</td>
<td>In-street Pedestrian Signage</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Signal/Signage</td>
<td>Basic</td>
<td>Roadside Signage [b]</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Signal/Signage</td>
<td>Enhanced</td>
<td>Flashing Beacons (Including RRFB) [b,c]</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Signal/Signage</td>
<td>Enhanced</td>
<td>LED-Enhanced Signage [c]</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Signal/Signage</td>
<td>Enhanced</td>
<td>Traffic signal, with pedestrian signal, where warranted [c]</td>
<td>3-lane</td>
<td>3-lane</td>
<td>3-lane</td>
</tr>
<tr>
<td>Geometry</td>
<td>Enhanced</td>
<td>Median, Refugee Island or Split Pedestrian Crossover</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Geometry</td>
<td>Enhanced</td>
<td>Chicane</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Geometry</td>
<td>Enhanced</td>
<td>Choker</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Geometry</td>
<td>Enhanced</td>
<td>Corner Bulb Outs and Curb Extensions</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Geometry</td>
<td>Enhanced</td>
<td>Lane Width Reduction</td>
<td>x</td>
<td>x</td>
<td>ADT &lt;25,000</td>
</tr>
<tr>
<td>Geometry</td>
<td>Enhanced</td>
<td>Raised Pedestrian Crossing/Speed Table</td>
<td>x</td>
<td>ADT &lt;25,000</td>
<td></td>
</tr>
<tr>
<td>Geometry</td>
<td>Enhanced</td>
<td>Speed humps</td>
<td>x</td>
<td>ADT &lt;25,000</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>Basic</td>
<td>Removal of Sight Distance Obstructions</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

[a] FHWA recommendations indicate that under low-volume, low-speed conditions, marking a crosswalk alone may be sufficient for uncontrolled crossings; under higher volume, higher speed conditions, additional treatments are highly recommended due to potential increases in pedestrian crash rates without any additional treatments.

[b] Treatments may be packaged together. Crossing treatments consisting of a yield line, high visibility crosswalk, roadside signage, and RRFB are a suggested treatment package.

[c] LED-Enhanced Signage, Flashing Beacons, and Traffic Signals provide similar functions. A single enhanced signal/signage treatment should be chosen based on an engineering study.

[d] Treatments are cumulative. For roads with higher volumes and speeds, additional treatments should be considered to enhance comfort and visibility at crossings.
Figures 6-9: Conceptual Diagrams of Treatments Applicable for Uncontrolled Pedestrian Crossings Across 2- and 3-lane Roadways

Figure 6: Basic Treatments *

Yield line, high visibility crosswalk, roadside signage

Figure 7: Enhanced Treatments, V1 ^

Basic treatments, plus flashing beacons

Figure 8: Enhanced Treatments, V2 +

Enhanced V1, plus a median

Figure 9: Enhanced Treatments, V3 =

Enhanced V2, plus a raised crosswalk
Table 3. Treatments Applicable for Uncontrolled Pedestrian Crossings Across 4-lane Roadways (With and Without Medians)

Colored cells indicate that a corresponding conceptual diagram of these treatments is available in Figure 10*, Figure 11^, Figure 12+, and Figure 13=.

<table>
<thead>
<tr>
<th>Type</th>
<th>Category</th>
<th>Treatment</th>
<th>ADT &lt;15,000 [d]</th>
<th>15,000-25,000 [d]</th>
<th>&gt;25,000 [d]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Striping</td>
<td>Basic</td>
<td>Yield Line [b]</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Striping</td>
<td>Basic</td>
<td>High visibility crosswalks (Continental/Ladder Striping) [b]</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Signal/signage</td>
<td>Basic</td>
<td>Roadside Signage [b]</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Signal/signage</td>
<td>Basic</td>
<td>Flashing Beacons (Including RRFB) [b,c]</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Signal/signage</td>
<td>Enhanced</td>
<td>LED-Enhanced Signage [c]</td>
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<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Signal/signage</td>
<td>Enhanced</td>
<td>Pedestrian hybrid beacon (&quot;HAWK signal&quot;) [c]</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Signal/signage</td>
<td>Enhanced</td>
<td>Traffic signal, with pedestrian signal, where warranted [c]</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Geometry</td>
<td>Basic</td>
<td>Median, Refugee Island or Split Pedestrian Crossover [b]</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Geometry</td>
<td>Enhanced</td>
<td>Road Diet</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Geometry</td>
<td>Enhanced</td>
<td>Choker</td>
<td>x</td>
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<tr>
<td>Geometry</td>
<td>Enhanced</td>
<td>Corner Bulb Outs and Curb Extensions</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Geometry</td>
<td>Enhanced</td>
<td>Lane Width Reduction</td>
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<td>x</td>
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<tr>
<td>Geometry</td>
<td>Enhanced</td>
<td>Raised Pedestrian Crossing/Speed Table</td>
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<td>x</td>
<td></td>
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<tr>
<td>Geometry</td>
<td>Enhanced</td>
<td>Speed humps</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>Basic</td>
<td>Removal of Sight Distance Obstructions</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

[a] FHWA recommendations indicate that under low-volume, low-speed conditions, marking a crosswalk alone may be sufficient for uncontrolled crossings; under higher volume, higher speed conditions, additional treatments are highly recommended due to potential increases in pedestrian crash rates without any additional treatments.

[b] Treatments may be packaged together. Crossing treatments consisting of a yield line, high visibility crosswalk, roadside signage, RRFB, and median refuge island are a suggested treatment package.

[c] LED-Enhanced Signage, Flashing Beacons, Pedestrian Hybrid Beacons, and Traffic Signals provide similar functions. A single enhanced signal/signage treatment should be chosen based on an engineering study.

[d] Treatments are cumulative. For roads with higher volumes and speeds, additional treatments should be considered to enhance comfort and visibility at crossings.
Figures 10-13: Conceptual Diagrams of Treatments Applicable for Uncontrolled Pedestrian Crossings Across 4-lane Roadways

**Figure 10: Basic Treatments**

- Yield line, high visibility crosswalk, flashing beacons

**Figure 11: Enhanced Treatments, V1**

- Basic treatments, with pedestrian hybrid beacon (in-lieu of RRFB) and stop bars

**Figure 12: Enhanced Treatments, V2**

- Enhanced V1, plus a median and/or curb extensions

**Figure 13: Enhanced Treatments, V3**

- Enhanced V2, plus a road diet, and an RRFB instead of pedestrian hybrid beacons
REFERENCES


