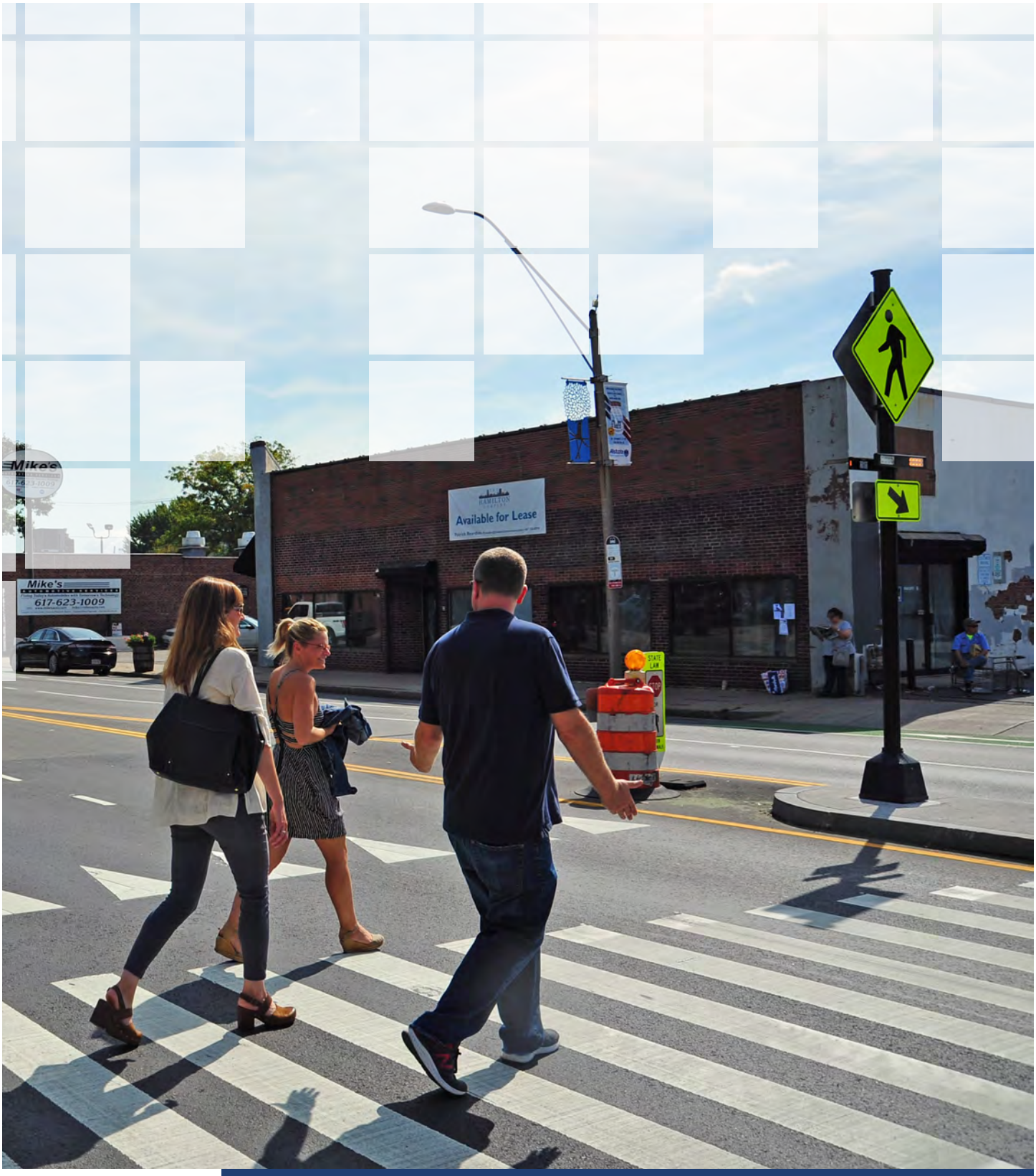

Kansas Department of Transportation

Crosswalk Guidance & Guide to Crosswalk Countermeasures

October 2022

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Crosswalk Guidance

Introduction to Crosswalk Guidance

The following provisions for crosswalk markings and the Federal Highway Administration (FHWA) Safe Transportation for Every Pedestrian (STEP) countermeasures at intersections are provided as guidance by Kansas Department of Transportation (KDOT) for its state highway system. While the guidance has widespread applicability, implementation of it will be for new crosswalk markings associated with highway projects or requests associated with safety enhancements. This crosswalk placement guidance can also be used for crossings of non-state highways that are classified as arterials and collectors.

The inclusion of crosswalk markings and the supporting STEP countermeasures shall be considered as part of resurfacing, reconstruction, and new projects consistent with the guidance. Since most marked crosswalks will be on City Connecting Links (CCLIP-SP), community partnerships are essential. Cities will be responsible for all maintenance of markings and crossing countermeasures on connecting links once they are initially applied, except when resurfacing or reconstruction projects eliminate the markings. Those markings will be reapplied at the same match percentage as the overall resurfacing or reconstruction project. There will be a standard 10 percent match requirement applied to projects where Highway Safety Improvement Project funds are used.

Crosswalk Locations, Criteria, and Guidance

The placement of crosswalk markings should not occur at random. Kansas state law stipulates that crosswalks are created by the linear extension of sidewalks, regardless of the presence of pavement markings. Automatically marking all crosswalks is not a recommended practice nor is it sustainable from a maintenance perspective. Marked crosswalks must be installed selectively and often with additional crosswalk countermeasures (also referred to as treatments or enhancements in this guidance). Before installing new marked crosswalks, according the Manual of Uniform Control Devices (MUTCD), an engineering study is needed to determine whether the location is suitable for a marked crosswalk. For consideration of straightforward installations of crosswalks, such a study becomes a function of vehicle speed, number of travel lanes, traffic volume along with engineering judgment (see Table 1 and Table 3 of this guide). A simple site review may be necessary at some locations. More involved crossings will require a more in-depth study of pedestrian volume, vehicle speed, sight distance, vehicle mix, a site review, along with other factors. Below is a basic summary of where crosswalks should generally be marked. Additional guidance is provided later in this document.

CONTROLLED INTERSECTIONS

» At signalized intersections, marked crosswalks should be placed across all approaches that have adequate American Disabilities Act (ADA) and pedestrian accommodations/ displays. Limited right-of-way and other development and timing factors may mean that there is inadequate pedestrian access to some legs of the intersections. In these cases, coordination efforts with the communities should proceed to plan for establishing crosswalk access and markings to all legs of these intersections in urban and suburban areas.

» At all-way stops, marked crosswalks should be placed across all roads as extensions of sidewalks, or where there is any evidence of pedestrian movement (such as worn paths on the roadside, transit stops, adjacent land uses that generate pedestrian trips – schools, parks, retail, dense residential development, etc.).

UNCONTROLLED/PARTIALLY CONTROLLED INTERSECTIONS

» At intersections, where only the side road is required to stop or yield at an arterial or a collector street, marked crosswalks should be considered across side roads where there is sidewalk, or any evidence of pedestrian movement (such as worn paths on the roadside, transit stops, adjacent land uses that generate pedestrian trips – schools, parks, retail, dense residential development, etc.).

» Marked crosswalks and/or additional crossing enhancements should be placed across the state route or main route in accordance with Table 1 when there is no control for the crosswalk. In general, all new crosswalk markings across streets of 3-lanes or more should not only be marked but should also include additional safety countermeasures. See Table 1 and Table 3.

» Marked crosswalks may be used at non-signalized street crossing locations in designated school zones to delineate preferred pedestrian paths across roadways. Use of adult crossing guards, school signs and markings, and/or traffic signals with pedestrian signals (when warranted) should be considered in conjunction with the marked crosswalk, as needed.

» Crosswalks and pedestrian crossing improvements at uncontrolled mid-block locations should be considered on a case-by-case basis based on sound engineering judgment or an engineering study.

Crosswalk markings should not be installed at locations with poor sight distance, complex or confusing designs, or substantial heavy truck volume without first providing adequate design features and/or traffic control devices. Additionally, combinations of higher traffic volumes, speeds, and number of traffic lanes call for the provision of crosswalk treatments (countermeasures) to help support and reinforce the safety of the crosswalk. Table 1 provides guidance from FHWA Safety Effects of Marked Versus Unmarked Crosswalks on when crosswalk markings are recommended or when they should be supplemented with additional safety countermeasures. It should be noted that a designation of Ⓟ or "**N**" does not mean "do nothing", it means additional treatments are warranted in this location. Detailed discussions and graphics of crosswalk treatments (STEP countermeasures) for uncontrolled intersections are provided later in the third section of this guidance for those crossings listed as Ⓟ and "**N**" in Table 1.

Crosswalk Guidance

Important Notes for Table 1

» These guidelines are for **new crosswalks** and include intersection and midblock locations with no traffic signals or stop signs on the major approach to the crossing. They do not apply to school crossings.

» Adding crosswalks alone will not necessarily make most crossings safer, nor will they always result in more vehicles stopping for or yielding to pedestrians. Whether or not marked crosswalks are installed, it is very important, and often essential, to consider and incorporate other pedestrian facility crossing countermeasures or treatments (e.g., raised median, roadway narrowing, enhanced crosswalk visibility, beacons, lighting, etc.), as needed, to improve the safety of the crossing. See the last section of this guide and Table 3 and Table 4. These are general recommendations; good engineering judgment should be used in individual cases for deciding where to install crosswalks.

» Existing marked crosswalks that do not meet this guidance should not be automatically removed but should be considered for additional enhancements to meet the guidance.

» In general, where the speed limit exceeds 40 mph, marked crosswalks alone should not be used at unsignalized locations.

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

Table 1: FHWA guidance on the use of marked crosswalks by roadway speed, volume, and number of lanes

Roadway Type (number of travel lanes and median type)	Vehicle ADT < 9,000			Vehicle ADT 9,000-12,000			Vehicle ADT 12,000-15,000			Vehicle ADT > 15,000		
	Speed limit (mph)											
	≤30	35	≥40	≤30	35	≥40	≤30	35	≥40	≤30	35	≥40
Two Lanes	C	C	P	C	C	P	C	C	N	C	P	N
Three Lanes	C	C	P	C	P	P	P	P	N	P	N	N
Mutli-lane (four or more lanes) with raised median	C	C	P	C	P	N	P	P	N	N	N	N
Mutli-lane (four or more lanes) without raised median	C	P	N	P	P	N	N	N	N	N	N	N

Table 1 Key

C = Candidate sites for marked crosswalks. Marked crosswalks must be installed carefully and selectively. Before installing new marked crosswalks, an engineering study is needed to determine whether the location is suitable for a marked crosswalk. For an engineering study, a site review may be sufficient at some locations (see the following section). A more in-depth engineering study of pedestrian volume, vehicle speed, sight distance, vehicle mix, and other factors may be needed at other sites, but those are generally indicated as **P** or **N** in the table.

P = Possible increase in pedestrian crash risk may occur if crosswalks are added without other pedestrian facility crosswalk treatments. These locations should be closely monitored and enhanced with other pedestrian crossing improvements, if necessary, before adding a marked crosswalk. See the next section of this guide and Table 3.

N = Marked crosswalks alone are insufficient, since pedestrian crash risk may be increased by providing marked crosswalks alone. Consider using other crossing treatments to improve crossing safety for pedestrians (see Table 3)

Crosswalk Guidance

CROSSWALK EVALUATION PROCESS

Requests may be made to assess specific locations for crosswalk markings and crossing countermeasures, which may trigger the additional consideration of nearby crosswalks. Consideration and evaluation of numerous crosswalks within a corridor as part of resurfacing, reconstruction, or new highway projects may also occur as part of a more systematic evaluation. Because separation distances are recommended between crosswalk markings, the placement of any crosswalk marking and treatment, especially on a new road segment, will affect other potential crosswalk locations within a corridor. Therefore, the guidance provided in this section will be considered for a corridor or longer street segment and not just for a specific crossing site.

As indicated above, marking decisions for many crosswalks can be straightforward and rather easy to decide. Others will be more difficult when sight-lines are problematic or when vehicle speeds, vehicle volumes, and the number of traffic lanes complicate the decision-making process. Figure 1 indicates the general decision-making process to mark a crosswalk, what type of crosswalk marking to use, and if additional safety countermeasures should also be implemented. The consideration of data and use of thresholds is provided below and should be used with the flowchart.

COMMON THRESHOLDS AND CONSIDERATIONS

The following thresholds provide additional guidance on crosswalk placement. These thresholds should be used in conjunction with the Crosswalk Placement Process flowchart and Table 1 and Table 3.

» **Roadway lanes and speed limit:** The actual speed of motor vehicle traffic, the number of traffic lanes and the volume of traffic - especially during peak hours - has a major influence on the safety of pedestrians and their ease in crossing a street. In the past, vehicle gap times were often measured in order to determine if a crosswalk should be installed. However, research has resulted in how the key variables (speed, number of lanes, and traffic volumes) can act in combination with each providing guidance on where marked crosswalks and crosswalk treatments should be used . These variables and the resulting crosswalk guidance are provided in Table 1.

» **Multi-use paths and school crossings:** These should receive a marked crossing, either standard or enhanced. See Table 3 for countermeasures to accompany higher speed crossings.

» **Distance to nearest marked crossing:** If there are no special crossing conditions like a multi-use path or school crossing, it may be acceptable not to mark crosswalks if there are nearby crosswalks. The acceptable distance between marked crossings varies by neighborhood typology and is generalized in Table 2 below.

Table 2: Neighborhood Typology Distance between marked crossings

Neighborhood Typology Distance between marked crossings	
Downtown, Main Streets, Commercial areas	330 ft (1/16th mile)
Residential Grid	660 ft (1/8th mile) to 1,050 ft (1/5th mile)
Lower Density curvilinear with cul-de-sac	1,320 ft (1/4 mile)

Kansas DOT - Crosswalk Marking Flowchart

The flowchart below should be used to determine when a crosswalk should be marked in Kansas, and the type of markings to use.

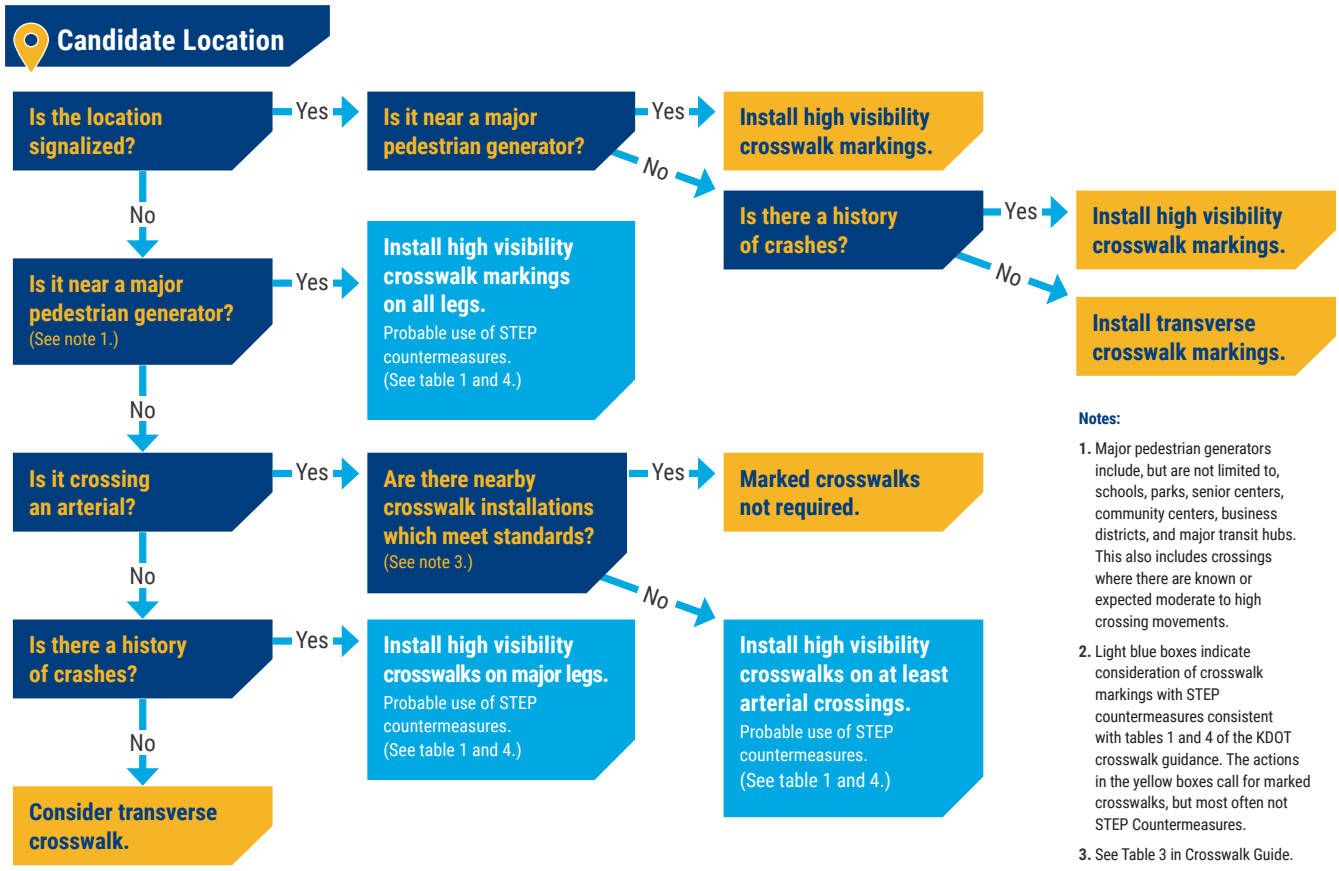

Figure 1: Kansas DOT Crosswalk Marking Flowchart

» **Stopping sight distance:** Stopping sight distance should be adequate and unobstructed before crosswalks. Adequate stopping sight distance is calculated using table in the appendix. If the stopping sight distance is not deemed adequate, obstructions should be removed before installing a marked crossing. If this is not possible, other nearby intersections should be considered or traffic signals should be installed at the location if all other thresholds are met.

» **Illumination:** All standard and enhanced crossings should have adequate illumination. If illumination is deemed inadequate, it should be installed along with the crosswalk. If illumination absolutely cannot be addressed, a signalized crossing (pedestrian hybrid beacon, Rectangular Rapid-Flashing Beacon (RRFB) or traffic signal) should be considered.

» **Concerns about safety, driver compliance or frequent turning conflicts:** If concerns are present, a crossing with additional treatments should be provided. This may include locations where:

- Crashes or near misses have been reported
- Other pedestrian trip generators besides transit stops or schools are present
- Intersection geometry is complex or confusing
- Vehicle turning speeds are higher than is typically expected

ROLE OF SAFETY REVIEWS, SAFETY AUDITS AND COMMUNITY INVOLVEMENT

Often a Road Safety Audit (RSA) is conducted as part of a street reconstruction or is provided as an independent safety review of a street or corridor. A RSA is a formal safety performance examination by an independent, multidisciplinary team. It qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users. A RSA considers all users of the roadway and human factors and generates a formal report and response upon its conclusion. The agency can use the field conditions inventory and any other information and analysis (i.e. crash type summary) during the RSA process. RSAs typically produce multiple planning-level countermeasure recommendations for the study corridor or area. It will include an assessment of intersections for pedestrian safety.

Like traditional RSAs, pedestrian RSAs are performed by a multidisciplinary team of experts or agency representatives, use structured prompt lists, and consider the surrounding socioeconomic and land use context. The materials for a pedestrian RSA provide more detail on pedestrian safety issues and examine elements such as signage, obstructions, signals, bus stop locations, drainage, and lighting. These tools can help identify possible deficiencies at intersections and potential locations for treatments.

An alternative to a formal RSA—which is more likely to occur with KDOT projects—also involves an on-site evaluation of pedestrian conditions including representatives from multiple agency departments and stakeholder interest groups. An informal on-site evaluation can collect information about pedestrian crossings and produce recommendations. This type of review covers sight distance issues, pedestrian and motorist behaviors, pedestrian volumes, lighting and visibility enhancements, etc.

As a result of these reviews and audits, agencies will be closer to producing recommendations for the placement of crosswalk markings and any additional treatments.

Crosswalk Countermeasure Selection Guide

The crossing evaluation process and/or Table 1 may indicate that additional crosswalk countermeasures are necessary for specific locations. Table 3 identifies appropriate crossing countermeasures/treatments based on traffic speed, volume of traffic, and number of lanes of traffic for unsignalized intersections. The table should be used under these circumstances:

- Whenever the combination of speed, volume of traffic and number of lanes results in the identification of a possible increase in crash risk (identified as Ⓟ in Table 1) or that a marked crosswalk alone is insufficient to address pedestrian safety (identified as "**N**" in Table 1).
- Whenever the Crosswalk Evaluation Process in the second section of this guide leads you to these treatments.
- Under such circumstances, more substantial crossing treatments or countermeasures may be necessary.

The countermeasures are selected based on safety research, best practices, and established national guidelines. Each matrix cell indicates possibilities that may be appropriate for designated pedestrian crossings. Consideration of all potential treatment options will occur when a pedestrian crossing is established resulting in the selection of a preferred crossing treatment or group of crossing treatments. Consideration of the crossing characteristics such as pedestrian volume, operational speeds, land use context, and other site features will be made when selecting countermeasures. The use of the MUTCD and/or other relevant national, State, and local guidelines when making the final selection of countermeasures are also appropriate and recommended.
As an example of how to use the table: If a 5-lane road with no raised median, an annual average daily traffic (AADT) of 12,000, and a 35 mph posted speed limit is evaluated, the matrix recommends that high-visibility crosswalks, adequate lighting, and parking restrictions on the approaches be included. In addition, strong consideration of adding advance "Yield Here to Pedestrians" signs and yield lines, pedestrian refuge islands, and Pedestrian Hybrid Beacons (PHBs) should occur. Other candidate treatments include implementing a Road Diet along the corridor and adding curb extensions.

Not all of the countermeasures listed in the matrix cell should necessarily be installed at a crossing. However, to further increase safety and visibility of pedestrian crossings, multiple countermeasures may be integrated. For example, the Pedestrian Hybrid Beacon (PHB) is often installed in conjunction with advance stop markings and signs. Also, Road Diets present opportunities for adding pedestrian refuge islands and curb extensions at key crossing locations. Agencies should consider roadway geometry and the MUTCD when integrating multiple countermeasures.

Another way to identify a countermeasure or treatment is by the safety issue it addresses. The results of the crash analysis, road safety audit, and/or stakeholder input provides a better understanding of the risk factors at uncontrolled crossing locations. The countermeasures listed can improve the visibility of crossing locations and reduce crashes, and they each address at least one additional safety concern associated with a higher risk of collision and/or severe injury. These additional safety issues include excessive vehicle

Guide to Crosswalk Countermeasures

Table 3: Recommended pedestrian crossing countermeasures based on roadway configuration, speed, and volume

Roadway Configuration	Posted Speed Limit and AADT								
	Vehicle AADT <9,000			Vehicle AADT 9,000–15,000			Vehicle AADT >15,000		
	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph
2 lanes (1 lane in each direction)	❶ 2 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6 7 9	① 5 6 7 9	① 5 6 ❾
3 lanes with raised median (1 lane in each direction)	❶ 2 3 4 5	❶ ❸ 5 7 9	① ❸ 5 ❼ ❾	① 3 4 5	① ❸ 5 ❼ ❾	① ❸ 5 ❼ ❾	① ❸ 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❾
3 lanes w/o raised median (1 lane in each direction with a two-way left-turn lane)	❶ 2 3 4 5 6 7 9	❶ ❸ 5 6 7 9	① ❸ 5 6 ❾	① 3 4 5 6 7 9	① ❸ 5 6 ❼ ❾	① ❸ 5 6 ❾	① ❸ 4 5 6 7 9	① ❸ 5 6 ❾	① ❸ 5 6 ❾
4+ lanes with raised median (2 or more lanes in each direction)	❶ ❸ 5 7 8 9	❶ ❸ 5 7 8 9	① ❸ 5 8 ❾	① ❸ 5 7 8 9	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 8 ❾
4+ lanes w/o raised median (2 or more lanes in each direction)	❶ ❸ 5 6 7 8 9	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 8 ❾

Given the set of conditions in a cell,

\# Signifies that the countermeasure is a candidate treatment at a marked uncontrolled crossing location.

● Signifies that the countermeasure should always be considered, but not mandated or required, based upon engineering judgment at a marked uncontrolled crossing location.

○ Signifies that crosswalk visibility enhancements should always occur in conjunction with other identified countermeasures.*

The absence of a number signifies that the countermeasure is generally not an appropriate treatment, but exceptions may be considered following engineering judgment.

1 High-visibility crosswalk markings, parking restrictions on crosswalk approach, adequate nighttime lighting levels, and crossing warning signs
2 Raised crosswalk
3 Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line
4 In-Street Pedestrian Crossing sign
5 Curb extension
6 Pedestrian refuge island
7 Rectangular Rapid-Flashing Beacon (RRFB)**
8 Road Diet
9 Pedestrian Hybrid Beacon (PHB)**

Refer to Chapter 4, 'Using Table 1 and Table 2 to Select Countermeasures,' for more information about using multiple countermeasures.

***It should be noted that the PHB and RRFB are not both installed at the same crossing location.*

This table was developed using information from: Zegeer, C.V., J.R. Stewart, H.H. Huang, P.A. Lagerwey, J. Feaganes, and B.J. Campbell. (2005). Safety effects of marked versus unmarked crosswalks at uncontrolled locations: Final report and recommended guidelines. FHWA, No. FHWA-HRT-04-100, Washington, D.C.; FHWA. Manual on Uniform Traffic Control Devices, 2009 Edition. (revised 2012). Chapter 4F, Pedestrian Hybrid Beacons. FHWA, Washington, D.C.; FHWA. Crash Modification Factors (CMF) Clearinghouse. http://www.cmfclearinghouse.org/; FHWA. Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE). http://www.pedbikesafe.org/PEDSAFE/; Zegeer, C., R. Srinivasan, B. Lan, D. Carter, S. Smith, C. Sundstrom, N.J. Thirsk, J. Zegeer, C. Lyon, E. Ferguson, and R. Van Houten. (2017). NCHRP Report 841: Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments. Transportation Research Board, Washington, D.C.; Thomas, Thirsk, and Zegeer. (2016). NCHRP Synthesis 498: Application of Pedestrian Crossing Treatments for Streets and Highways. Transportation Research Board, Washington, D.C.; and personal interviews with selected pedestrian safety practitioners.

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Table 4: Safety issues addressed per countermeasure

Pedestrian Crash Countermeasure for Uncontrolled Crossings	Safety Issue Addressed				
	Conflicts at crossing locations	Excessive vehicle speed	Inadequate conspicuity/ visibility	Drivers not yielding to pedestrians in crosswalks	Insufficient separation from traffic
Crosswalk visibility enhancement					
High-visibility crosswalk markings*					
Parking restriction on crosswalk approach*					
Improved nighttime lighting*					
Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line*					
In-Street Pedestrian Crossing sign*					
Curb extension*					
Raised crosswalk					
Pedestrian refuge island					
Pedestrian Hybrid Beacon					
Road Diet					
Rectangular Rapid-Flashing Beacon					

*These countermeasures make up the STEP countermeasure "crosswalk visibility enhancements." Multiple countermeasures may be implemented at a location as part of crosswalk visibility enhancements.

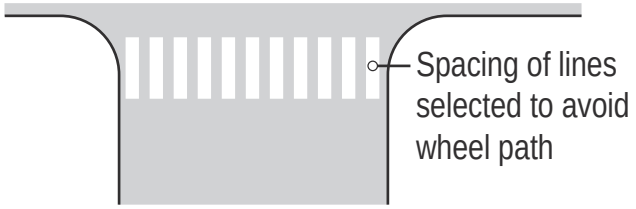
speed, inadequate conspicuity/visibility, drivers not yielding to pedestrians in crosswalks, and insufficient separation from traffic. Table 4 shows the specific safety issues that each countermeasure may address. For example, the addition of PHBs has been consistently shown to improve motorist yielding by 90 percent or greater, when compared with no traffic control or warning type devices.

TREATMENTS (COUNTERMEASURES) FOR UNCONTROLLED INTERSECTIONS

This subsection describes considerations for implementation of each of the countermeasures included in Table 3 and Table 4.

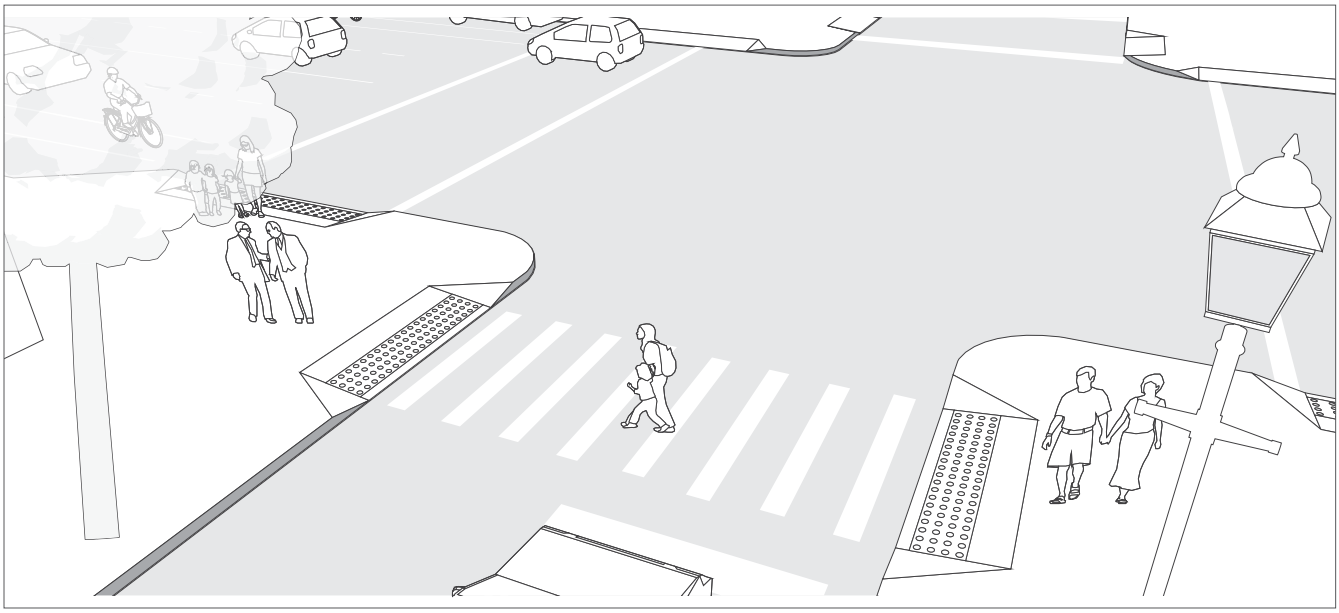
Crosswalk Visibility Enhancements. Crosswalk visibility enhancements include a wide variety of treatments—high visibility markings, parking restrictions, overhead illumination, crossing signs, advanced yield lines, and bulb-outs—that are often combined with one another. The most common is the high-visibility markings that come in a variety of crosswalk striping designs, such as ladder, continental, or bar pairs. A high-visibility crosswalk is much easier for an approaching motorist to see than the traditional parallel lines. KDOT currently recommends the use of high-visibility crosswalk markings whenever a crosswalk marking is installed (see below). The high-visibility markings may be supplemented with the pedestrian crossing warning signs (sign W11-2 in the MUTCD) on each approach to the crosswalk. MUTCD Section 2C.50— Non-Vehicular Warning Signs and Section 3B.18—Crosswalk Markings provide additional information. See Figure 2 for an example high-visibility crosswalk marking and see Appendix C for a separate technical sheet.

STANDARD CROSSWALK DESIGN



All standard crosswalks should include the following design elements.

Figure 2: Example Continental-Style Crosswalk Markings



Guide to Crosswalk Countermeasures

Continental-style crosswalk markings

» Longitudinal lines 12- to 24-inches wide and separated by gaps of 12- to 60-inches. The design of the lines and gaps should avoid the wheel paths if possible, and the gap between the lines should not exceed 2.5 times the width of the longitudinal lines.

» Where brick crosswalks are standard, lateral stripes are included on both sides of the brick.

High-visibility materials

» Cold plastic pavement markings should be used to mark crosswalks whenever possible.

Curb ramps

» Crosswalk markings should be located so that curb ramps are within the extension of the crosswalk markings.

» Curb ramps should follow all Public Right of Way Accessibility Guidelines (PROWAG) criteria for detectable warning surfaces, slope, and size.

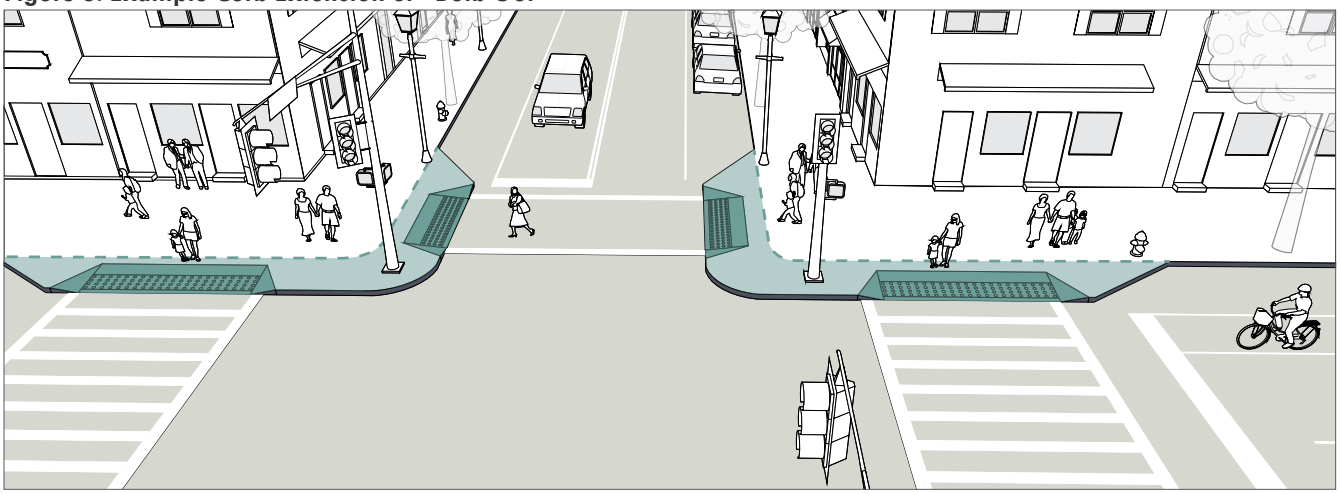
Crosswalks should also be accompanied with **parking restrictions** on the crosswalk approach at all established pedestrian crossings (both approaches) so there is adequate sight distance for motorists on the approaches to the crossings and ample sight distance for pedestrians attempting to cross. The minimum setback is 20 feet where speeds are 25 mph or less, and 30 feet between 26 mph and 35 mph. If this cannot be done, the curbs should be "bulbed out" to allow the pedestrian to see past the parked vehicle along the street. Adjacent bus stops should be placed downstream of the crosswalk and not on the crosswalk approach.

Providing an appropriate level of **overhead street lighting** at all established pedestrian crossings is important. Consideration should be given to placing the lights in advance of the crosswalk on both sides of the street and on both approaches to better light the front of the pedestrian and avoid silhouette lighting (where possible).

In-street Pedestrian Crossing signs are placed in the middle and on the lane lines of the road at a crossing and are often used in conjunction with refuge islands. These signs may be appropriate on 2-lane or 3-lane roads with speed limits of 30 mph or less. On higher-speed, higher-volume, and/ or multilane roads, this treatment may not be as visually prominent; therefore, it may be less effective (drivers may not notice the signs in time to stop in advance of the crosswalk). For such roadways, more robust treatments will be needed. When making the choice to use these signs, KDOT should consider making a plan and securing a funding source for the maintenance and prompt replacement of damaged signs. The MUTCD permits in street pedestrian signs for installation on centerlines and along lane lines. MUTCD Section 2B.12—In-Street and Overhead Pedestrian Crossing Signs contains additional information about these signs. See Appendix C for technical sheet on Crosswalk Enhancements.

Advance Yield Here to Pedestrians Signs and Yield Lines are placed between 20 and 50 feet in advance of the marked crosswalk along with the "shark's teeth" yield line. This is a candidate treatment that can be used for any uncontrolled pedestrian crossing, but should be strongly considered for any mid-block pedestrian crossing on roads with four or more lanes and/or roads with speed limits of 35 mph or greater. MUTCD Section 2B.11—Yield Here To Pedestrians Signs and Stop Here For Pedestrians Signs and Section 3B.16—Stop and Yield Lines contain additional information. See Appendix C for separate technical sheet.

Figure 3: Example Curb Extension or "Bulb Out"



A **Curb Extension** or **"Bulb Out"** extends the sidewalk or curb line into the street or parking lane, thus reducing the street width and improving sight distance between the driver and pedestrian. A curb extension is a candidate treatment for any uncontrolled pedestrian crossing, particularly where parking lanes exist. Curb extensions should not extend into paths of travel for bicyclists. See Appendix C for separate technical sheet and Figure 3.

Raised crosswalks. Raised crosswalks function as an extension of the sidewalk and allow a pedestrian to cross the street at a constant grade. A raised crosswalk is typically a candidate treatment on 2-lane or 3-lane roads with speed limits of 30 mph or less and AADTs below 9,000. Raised crossings are often avoided on streets with high truck/bus volumes, emergency routes, and arterial streets. Drainage needs to be accommodated. See MUTCD Section 3B.25—Speed Hump Markings for additional information about markings that can be used alongside raised crosswalks. See Appendix C for separate technical sheet and Figure 4.

Figure 4: Example of a Raised Crosswalk

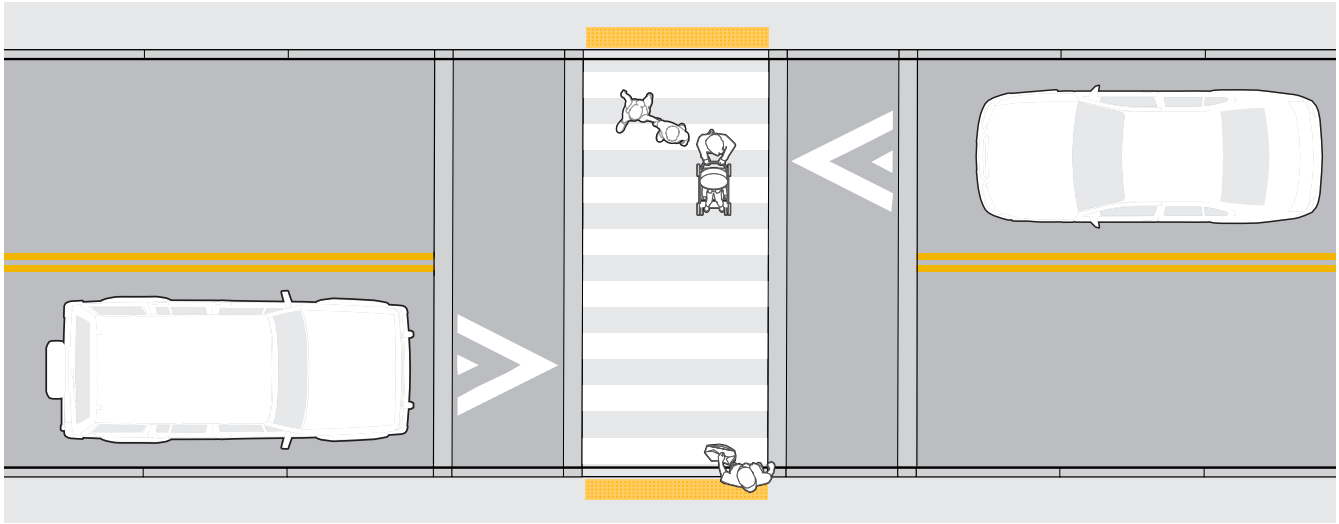
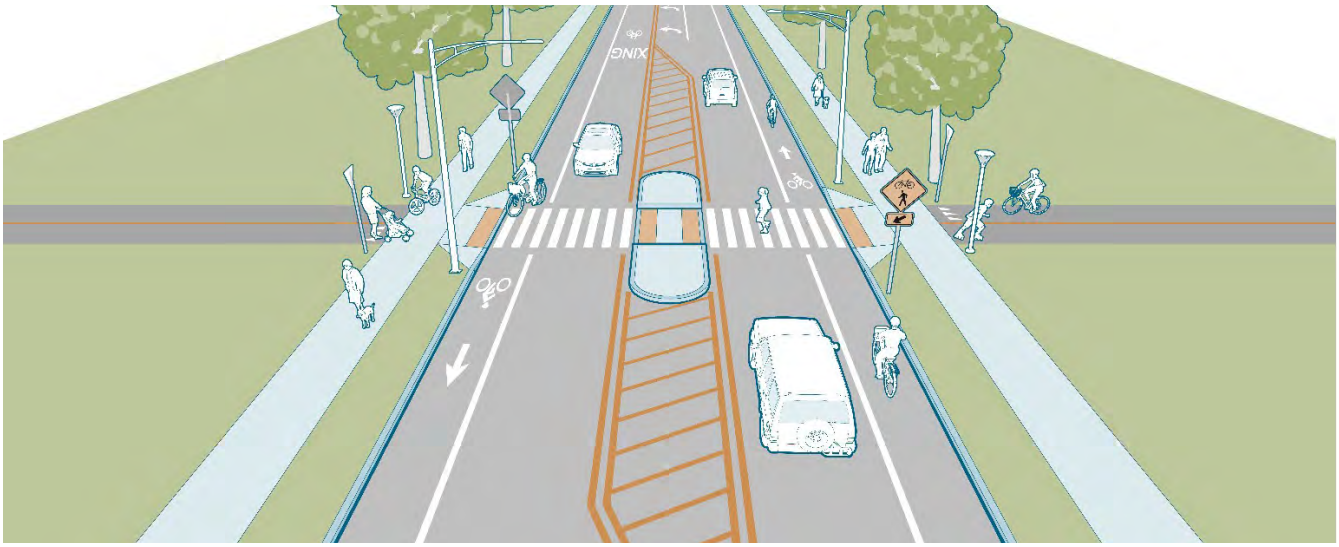
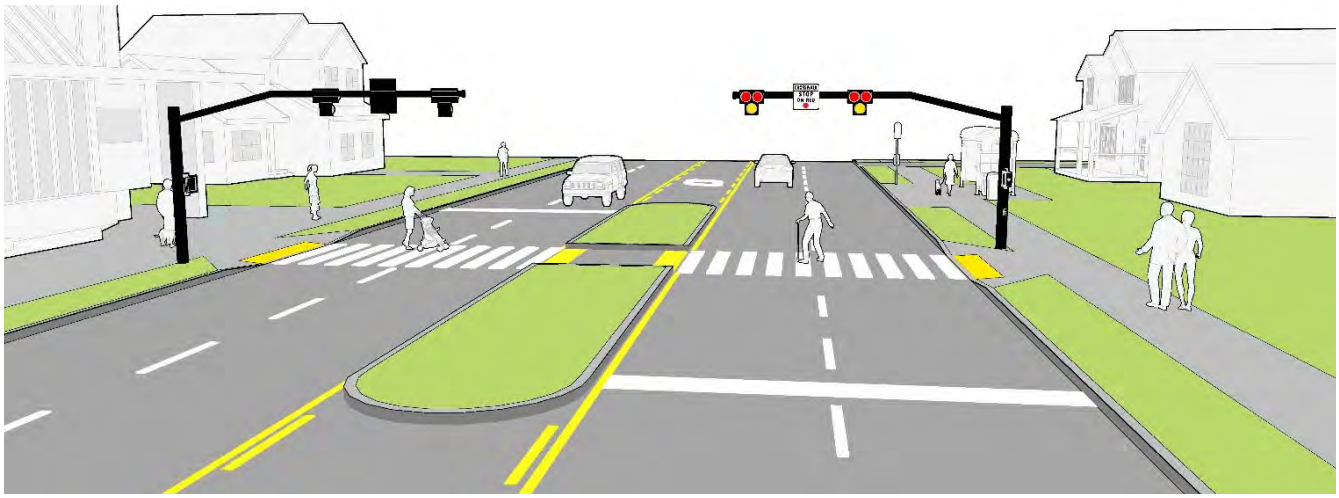


Figure 5: Example Pedestrian Refuge Island



Pedestrian Refuge Island. A pedestrian refuge island or a median crossing island is typically constructed in the middle of a 2-way street and provides a place for pedestrians to stand and wait for motorists to stop or yield. This countermeasure is highly desirable for midblock pedestrian crossings on roads with four or more lanes and should be considered for undivided crossings of four or more lanes with speed limits of 35 mph or greater and/or AADTs of 9,000 or greater. Crossing islands may also be a candidate treatment for uncontrolled pedestrian crossings on 3-lane or 2-lane roads, especially where the street is wide and/or where vehicle speed or volumes are moderate to high. Crossing islands create a two-stage crossing opportunity for pedestrians enabling pedestrians to cross one direction of traffic at a time. The minimum pedestrian refuge island width is approximately 6 feet. MUTCD Section 3B.10—Approach Markings for Obstructions, Section 3B.18—Crosswalk Markings, and Section 3B.23—Curb Markings provide additional information. See Appendix C for separate technical sheet and Figure 5.

Figure 6: Example Pedestrian Hybrid Beacon



Pedestrian Hybrid Beacon. A PHB consists of two red lights above a single yellow light and is used in conjunction with pedestrian signals installed at each end of a marked crosswalk. The PHB has been referred to as the **H**igh-intensity **A**ctivated cross**W**al**K** beacon (**HAWK**), but the MUTCD refers to this device as the PHB. Unlike a traffic signal, the PHB is unlit until a pedestrian activates it via pushbutton or other form of detection. When activated, the beacon displays a sequence of flashing and solid lights that control vehicular traffic while the pedestrian signals indicate the pedestrian walk interval and a pedestrian clearance interval. The PHB should meet the installation guidelines—based on speed, pedestrian volume, vehicular volume, and crossing length—as provided in Section 4F.01 of the MUTCD (See Figure 4F-1 for speeds of 35 mph or less; Figure 4F-2 for speeds greater than 35 mph). Research indicates that PHBs are most effective at roads with three or more lanes that have AADTs above 9,000. PHBs should be strongly considered for all midblock crossings where the roadway speed limits are equal to or greater than 40 mph. See Appendix C for separate technical sheet and Figure 6.

Refer to Table 3 and Table 4 for other conditions where PHBs should be strongly considered. It should be noted that the PHB and RRFB are not both installed at the same crossing location. PHBs have also been installed successfully at intersections (not just mid-block) under certain conditions. Since the current MUTCD guidance is to locate PHBs at least 100 feet away from an intersection, engineering judgment/ engineering study must be carefully applied if considering an installation at an intersection.

Road Diet. A Road Diet reconfigures the roadway. A frequently-implemented Road Diet involves converting a 4-lane, undivided roadway into a 3-lane roadway with a center turn lane. This is a candidate treatment for any undivided road with wide travel lanes or multiple lanes that can be narrowed or repurposed to improve pedestrian crossing safety. After conducting a traffic analysis to consider its feasibility, there may be a determination that a Road Diet is a good candidate for use on roads with four or more lanes and traffic volumes of approximately 20,000 or less. In some cases, agencies have successfully implemented Road Diets on roads with an AADT of up to 25,000. By reducing the width of the

Figure 7: Example Rectangular Rapid-Flashing Beacons

roadway, pedestrians benefit from shorter crossing distances and often bike lanes or streetscape features can be added. Road Diets are often effectively accomplished during pavement resurfacing. See Appendix C for separate technical sheet.

Rectangular Rapid-Flashing Beacon. A RRFB is a pedestrian-actuated enhancement used in combination with a pedestrian, school, or trail crossing warning sign to improve safety at uncontrolled, marked crosswalks. The device includes two rectangular-shaped yellow indications, each with an LED-array-based light source, that flash with high frequency when activated. RRFBs may be used to enhance the conspicuity of standard pedestrian and school crossing warning signs at uncontrolled marked crosswalks. RRFBs shall not be used with a flashing school speed assembly. See Appendix C for separate technical sheet.

RRFBs are placed on both ends of a crosswalk. If the crosswalk contains a pedestrian refuge island or other type of median, an RRFB should be placed to the right of the crosswalk and on the median (instead of the left side of the crosswalk). The RRFB's irregular flashing pattern is unlit when not activated and can be activated manually by pedestrians using a push button or passively by a pedestrian detection system. The RRFB is a treatment option at many types of established pedestrian crossings. Research indicates RRFBs can result in motorist yielding rates as high as 98 percent at marked crosswalks. However, yielding rates as low as 19 percent have also been noted. Compliance rates varied most per the city location, posted speed limit, crossing distance, and whether the road was one or two-way traffic. RRFBs are particularly effective at multilane crossings with speed limits less than 40 mph. Consider the PHB instead of RRFBs for roadways with higher speeds. Table 3 provides specific conditions where practitioners should strongly consider the PHB instead of the RRFB. See Figure 7 for an example of RRFBs paired with a pedestrian crossing island a striped advanced stop line.

This device is not currently included in the MUTCD, but FHWA has issued Interim Approval 21 (IA-21) for the use of the RRFB. KDOT has interim approval to use RRFBs with permission for all agencies within Kansas to use it. IA-21 provides additional information about the conditions of use, including dimensions, placement, and flashing requirements. IA-21 does not provide guidance or criteria based on number of lanes, speed, or traffic volumes.

Appendix A: Data Collection

Based on the guidance and procedure established by the KDOT crosswalk guidance, the following information included in this appendix item is often collected and considered when marking options and adding enhancements for crosswalks. Not all of the following data will need to be collected or analyzed for every crosswalk installation.

» **Current crossing control:** Note if the crossing is controlled by a stop sign or a traffic signal. If it is, it considered controlled. At a two-way stop-controlled intersection, the two legs not controlled by the stop (almost always the main road crossings) are considered uncontrolled.

» **Presence of sidewalks:** Kansas state law defines crosswalks as the linear extensions of sidewalks whether they are marked or unmarked. While a crosswalk can be legally established through markings where there are no sidewalks leading up to it, a more common practice entails marking crosswalks as connections to sidewalks and curb ramps (it is still an acceptable practice to mark crosswalks across a major street, which has a sidewalks flanking one or both sides, even though the side streets intersecting the major street might not have sidewalks leading up to the major street).

» **Roadway lanes and speed limit:** Note the posted roadway speed. Note the number of vehicle lanes (including parking and travel lanes), direction of vehicular travel (one- or two-way), and whether there is a raised median present.

» **Vehicle gap time:** The tables in this guide are a suitable and a very functional way to estimate gap availability without additional calculations. However, if more precision is desired collecting data for a gap analysis is possible if the proposed location is an uncontrolled location with 2 lanes and a posted speed of 30 mph or less. Data should be collected for at least 24 hours. Gap times should be calculated during the two peak hours of the day. These are typically the AM and PM commuting time periods. In some cases, such as near a school or a location impacted by a shift change, the peak hours may be outside the traditional AM and PM commuting time periods.

A minimum adequate gap time for a typical pedestrian to be able to identify a gap and cross the street is calculated as:

$$\frac{(Roadway\ Width)}{(3.5\ feet/second)} + 1$$

It may be appropriate to use a 3.0 ft/sec or slower walking speed based on the expected pedestrian population, such as locations with senior walking routes or school crossings.

Table 5: Sample Gap Times for Typical Roadway Widths and Walking Speeds

Roadway width	Crossing time (seconds)	
	3.5 ft/sec	3 ft/sec
40 ft	13	15
45 ft	14	16
50 ft	16	18
55 ft	17	20
60 ft	19	21

Common values based on these two walking speeds are displayed in Table 5.

» **School crossing:** Note if the proposed location is a designated school crossing, and/or crosses a roadway adjacent to a school in the same block as the school. This could be a midblock crossing lined up with a school entrance, a crossing at an intersection at the end of the block of the school, and/or any other crossing designated as a school crossing per a community's or school district's school crossing designation process.

» **Distance to nearest marked or controlled crossing:** Measure the distance from the proposed location to the nearest marked crossing of the same road.

» **Stopping sight distance:** Use Table 6 below to determine the required stopping sight distance based upon the roadway's speed limit. Then, measure the given distance in either direction from the proposed location and note if there are any obstacles obstructing drivers' view of the location.

Table 6: Stopping Sight Distance Selection (2011 AASHTO Green Book)

Vehicle Speed (mph)	Calculated Stopping Sight Distance (ft)
15	76.7
20	111.9
25	151.9
30	196.6
35	246.2
40	300.6
45	359.7
50	423.7
55	492.5

» **Level of illumination:** Observe the location at night time and note whether visibility from street lights and positioning of those lights are adequate for drivers to see pedestrians in the crosswalk or if lighting should be improved. If overhead illumination is not feasible, beacons may be a viable option and need to be considered.

» **Crash evaluation:** Observe crash reports completed by law enforcement agencies which may include information about driver and pedestrian actions, as well as environmental conditions when and where the crash occurred. These data are helpful to understand safety issues in the area. Crash data may be geocoded and mapped. The agency can collect crash maps, request crash reports (as needed), and contact public health officials for other pedestrian injury data.

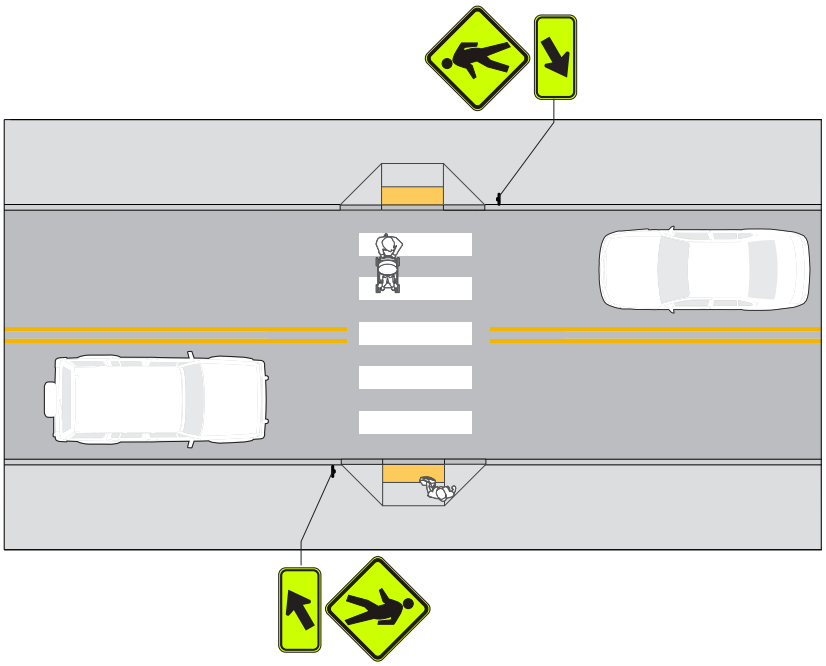
Appendix B: Example Crossing Treatments Types for Enhanced Crosswalks

Figure 8 through Figure 14 are example plan view diagrams for crossing treatment types for enhanced crosswalks. Table 7 provides descriptions of each crosswalk treatment types and indicates what signs and signals are used. Depending on crosswalk locations, specific crosswalk sign colors should be selected per the latest edition of the Kansas Highway Sign Manual.

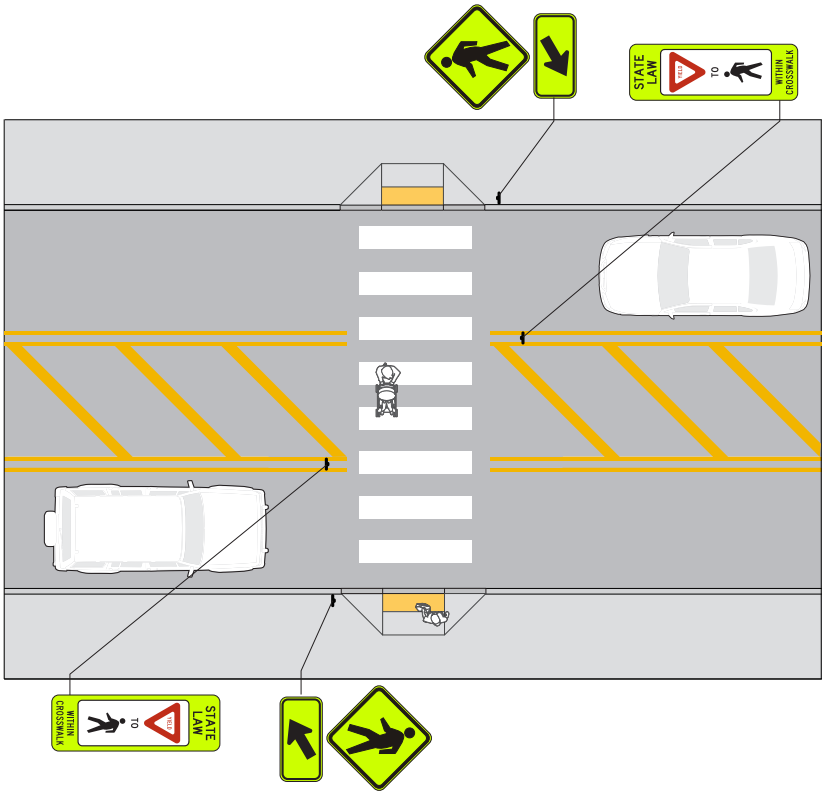
Table 7: Enhanced Crosswalk Treatment Type Descriptions for Figure 8 through Figure 14

Crossing Treatment Type	Treatment Descriptions	Signs/Signals
A	High visibility markings and standard signage	» Standard (W11-2) pedestrian warning signs side-mounted with down arrow (W16-7) or overhead at crossing location » S1-1 signs for School Crossing
B1	High visibility markings and standard signage, plus in-roadway yield signs	» "State Law - Yield to Pedestrians" (R1-6) signs mounted on flexible in roadway panel at crossing location » Standard (W11-2) pedestrian warning signs side-mounted with down arrow (W16-7) or overhead at crossing location » S1-1 signs for School Crossing
B2	High visibility markings, plus "state law" signage (modified R1-6)	» Modified "State Law - Yield to Pedestrians" (R1-6a or R1-9) signs side-mounted with down arrow (W16-7) or overhead at crossing location » S1-1 signs for School Crossings
C1	High visibility markings, plus "state law" signage (modified R1-6) plus side/median mounted yield signs and advanced yield lines	» Modified "State Law - Yield to Pedestrians" (R1-6a or R1-9) signs side-mounted with down arrow (W16-7) or overhead at crossing location » "Yield here to pedestrians" (R1-5) signs and yield lines in advance of the crossing » S1-1 signs for School Crossing locations
C2	High visibility markings, plus "state law" signage (modified R1-6) plusside/median mounted yield signs and advanced yield lines, plus raised crosswalk	» Modified "State Law - Yield to Pedestrians" (R1-6a or R1-9) signs side-mounted with down arrow (W16-7) or overhead at crossing location » "Yield here to pedestrians" (R1-5) signs and yield lines in advance of the crossing location » S1-1 signs for School Crossings » Speed table added to raise crosswalk to sidewalk level
D	High visibility markings and standard signage, side mounted yield signs and advanced yield lines, plus Rectangular Rapid Flashing Beacon (RRFB)	» "Yield here to pedestrians" (R1-5) signs and yield lines in advance of the crossing » Standard (W11-2) pedestrian warning signs with RRFB side-mounted with down arrow (W16-7) or overhead » S1-1 signs for School Crossing locations
E	High visibility markings and standard signage, overhead stop for crosswalk signs and stop bars, plus signalization	» Traffic Signal or Pedestrian Hybrid Beacon (HAWK), based on warrants and engineering judgement. (Traffic signals are generally preferred, except when a HAWK signal is better aligned with intersection geometry and/or traffic warrants) » "Stop here on red" (R10-6) signs and stop bars in advance of the crossing » Standard (W11-2) pedestrian warning signs side-mounted with down arrow (W16-7) or overhead » "Crosswalk Stop on Red" (R10-23) sign mounted overhead adjacent to signal face » S1-1 signs for School Crossing locations

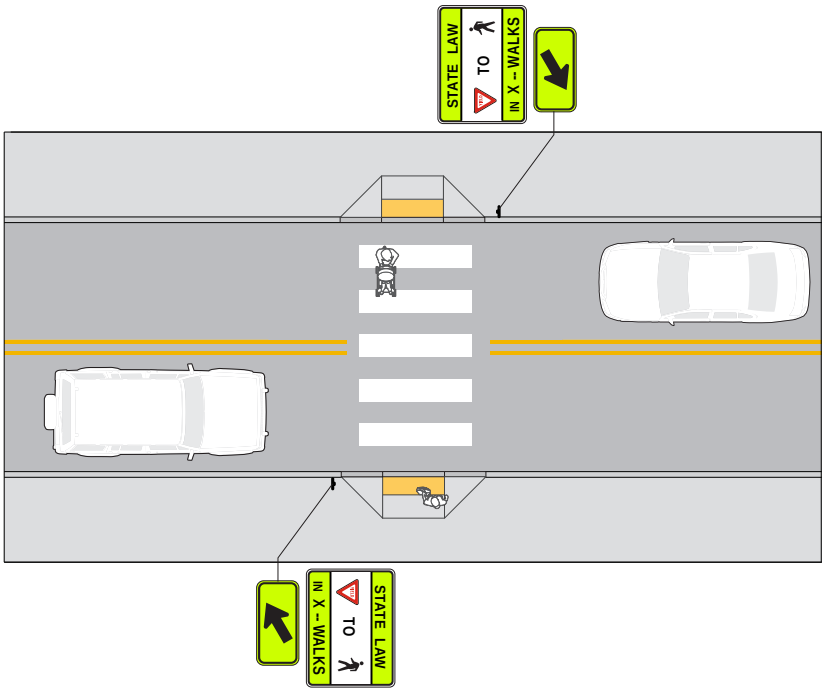
A **Figure 8: High visibility markings and standard signage**



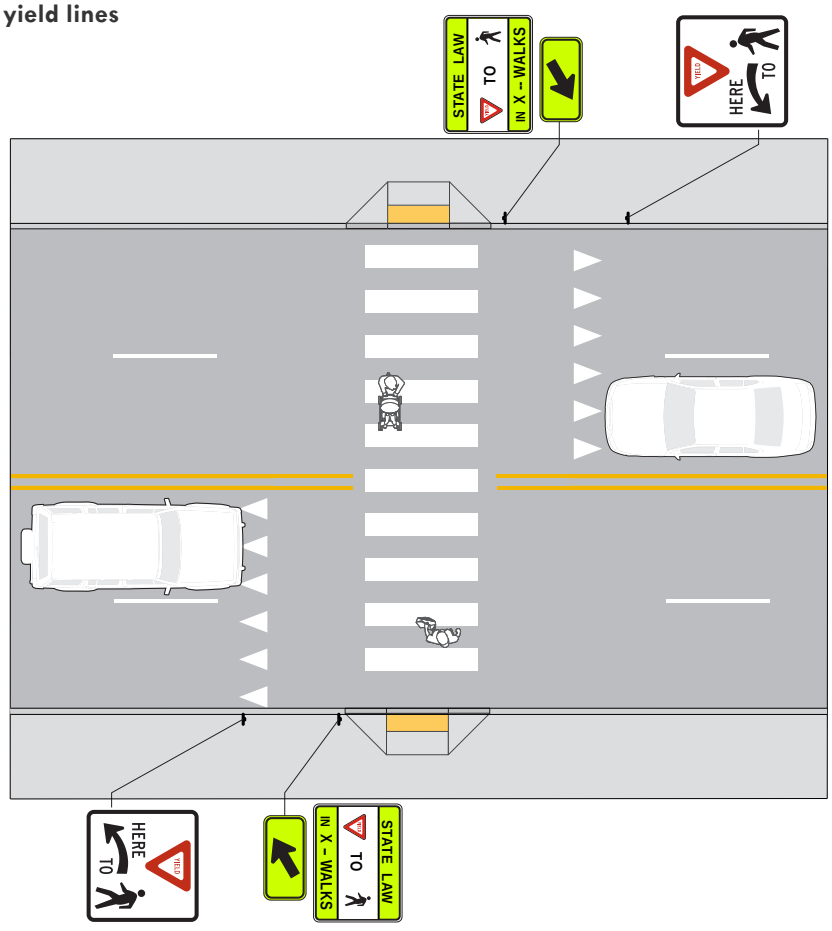
B1 **Figure 9: High visibility markings, standard crossing signage, and in-road yield signs**



B2 Figure 10: High visibility markings and "state law" signage (modified R1-6)

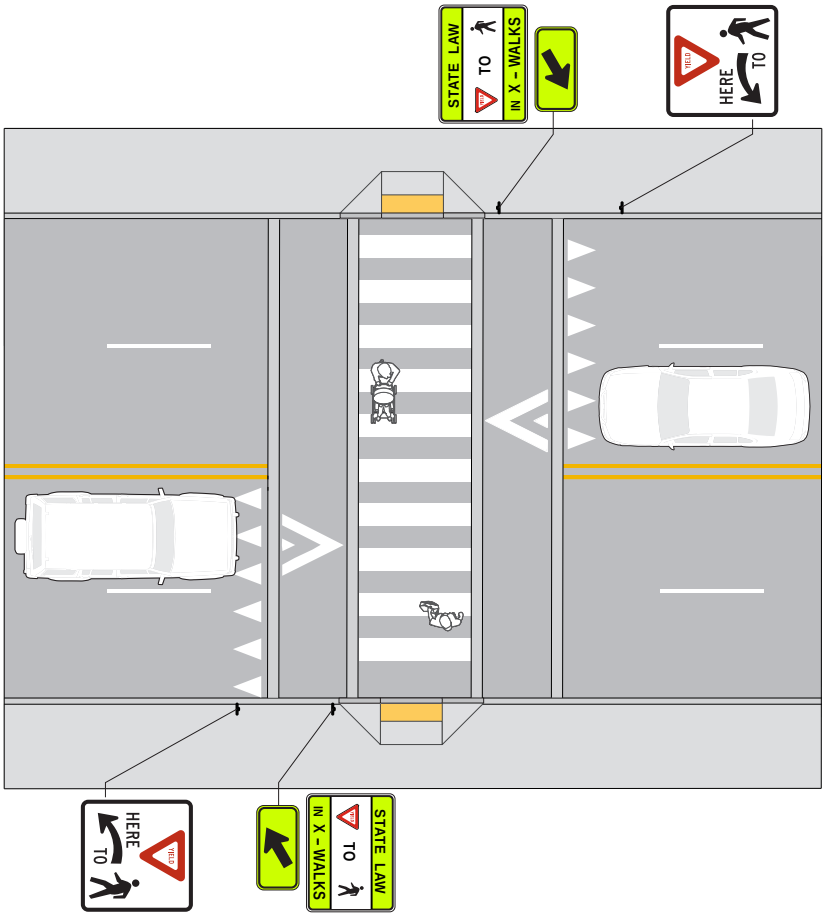


C1 Figure 11: High visibility markings, "state law" signage (modified R1-6), side/median mounted yield signs, and advanced yield lines

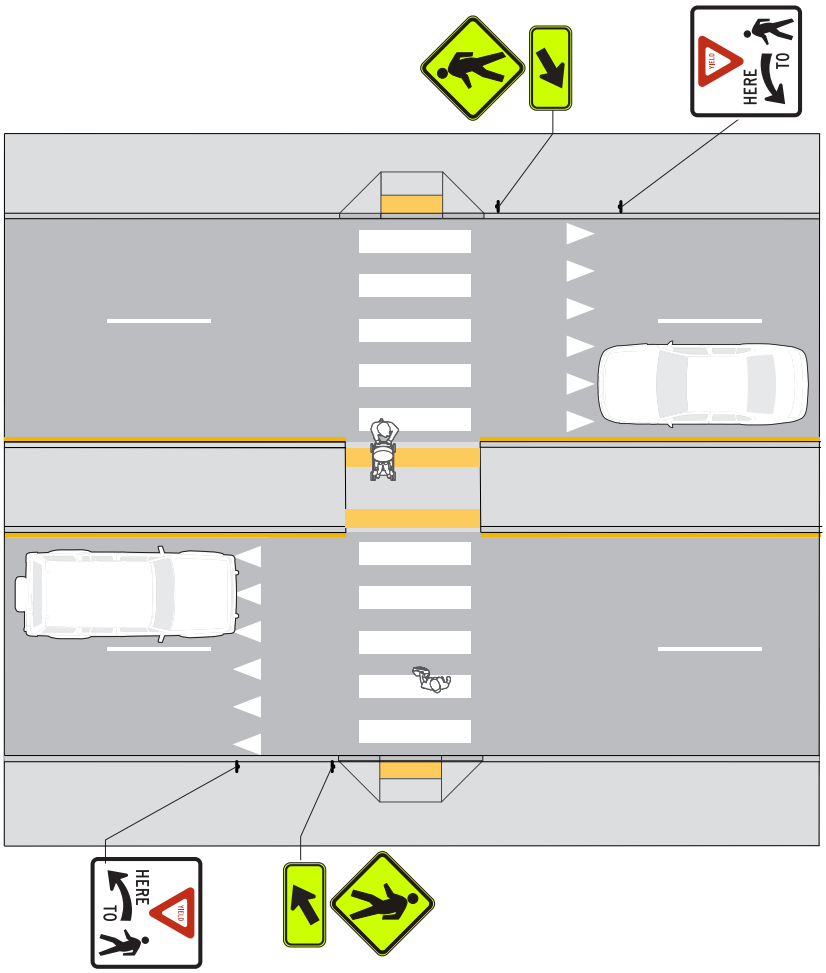


C2

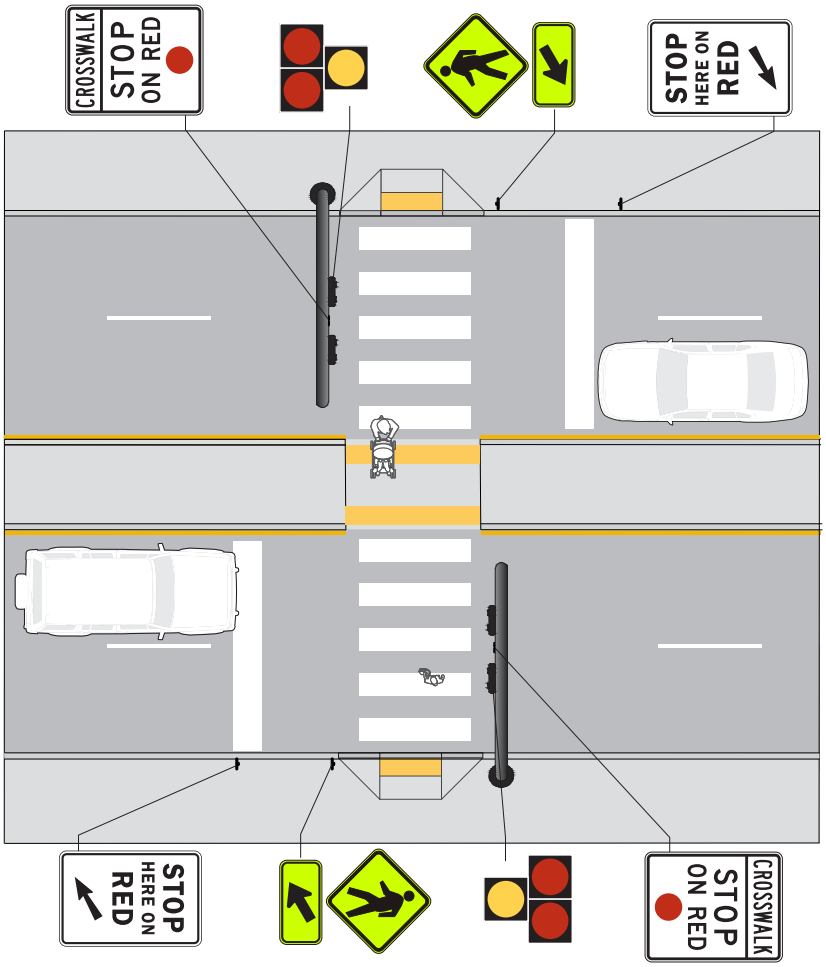
Figure 12: High visibility markings, "state law" signage (modified R1-6) side/median mounted yield signs, advanced yield lines, and raised crosswalk



D **Figure 13: High visibility markings and standard signage, side mounted yield signs, advanced yield lines, and RRFB**



E **Figure 14: High visibility markings and standard signage, overhead stop for crosswalk signs and stop bars, and signalization**



Appendix C: FHWA AND KDOT COUNTERMEASURE TECHNICAL SHEETS

FHWA COUNTERMEASURE TECHNICAL SHEETS

The pages in this section of the appendix include the FHWA Countermeasure Technical Sheets listed below. The technical sheets provide an overview of the countermeasure, other countermeasure they are often paired with, considerations, and cost estimates.

- Pedestrian Hybrid Beacon
- Crosswalk Visibility Enhancements[1]
- Pedestrian Refuge Island
- Raised Crosswalk
- Road Diet
- Rectangular Rapid-Flashing Beacon

KDOT COUNTERMEASURE TECHNICAL SHEETS

Following the FHWA Countermeasure Technical Sheets included in this appendix there are three additional Countermeasure Technical Sheets that were developed for this guide. These additional technical sheets provide more detail on the topics listed below.

- Crosswalks and High-Visibility Markings
- Curb Extensions
- Advance Yield Lines

1 This Countermeasure Technical Sheet covers crosswalks and high-visibility markings, curb extensions, and advance yield. Those treatments have been selected to be expanded into separate KDOT Countermeasure Technical Sheets.

Pedestrian Hybrid Beacon (PHB)

SAFE TRANSPORTATION FOR EVERY PEDESTRIAN

COUNTERMEASURE TECH SHEET

A Pedestrian Hybrid Beacon head consists of two red lenses above a single yellow lens. Unlike a traffic signal, the PHB rests in dark until a pedestrian activates it via pushbutton or other form of detection. When activated, the beacon displays a sequence of flashing and solid lights that indicate the pedestrian walk interval and when it is safe for drivers to proceed (see figure on back page).

The PHB is often considered for installation at locations where pedestrians need to cross and vehicle speeds or volumes are high, but traffic signal warrants are not met. These devices have been successfully used at school crossings, parks, senior centers, and other pedestrian crossings on multilane streets. PHBs are typically installed at the side of the road or on mast arms over midblock pedestrian crossings.

High speeds and multiple lanes of traffic create challenges for pedestrians crossing at unsignalized locations.

PHBs can warn and control traffic at unsignalized locations and assist pedestrians in crossing a street or highway at a marked crosswalk.

PHBs can reduce pedestrian crashes by

55%

FEATURES:

- **Beacons stop all lanes of traffic, which can reduce pedestrian crashes.**

OFTEN USED WITH:

- **High-visibility crosswalk markings**
- **Raised islands**
- **Advance STOP or YIELD signs and markings**

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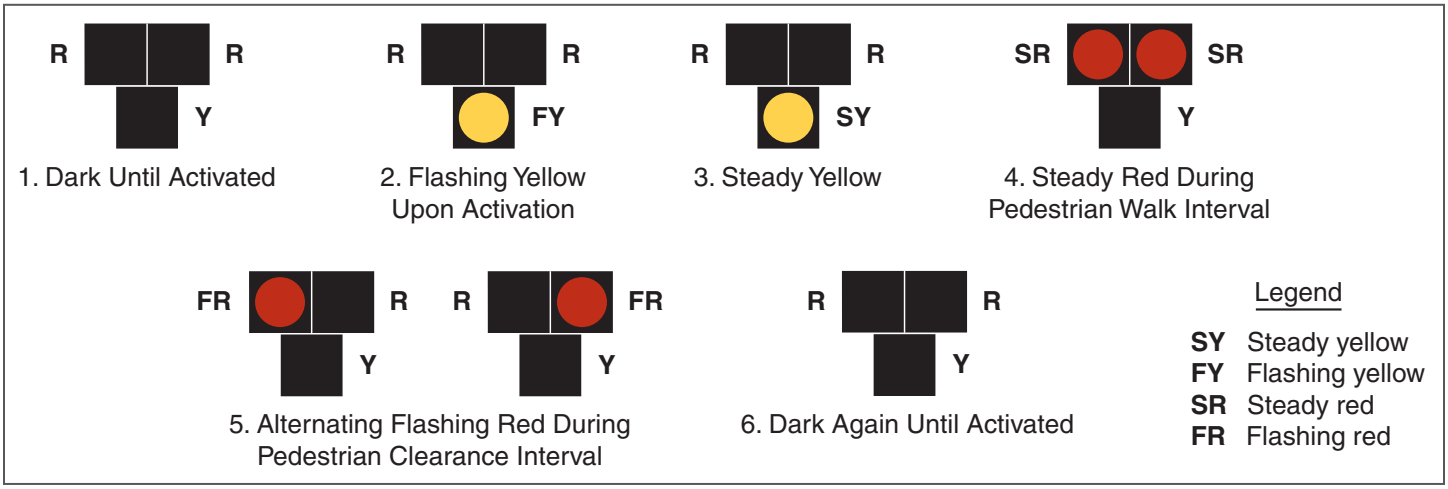
EDC

Pedestrian Hybrid Beacon (PHB)

EDC-4 STEP: https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/step.cfm

Figure 4F-3. Sequence for a Pedestrian Hybrid Beacon from FHWA's *Manual on Uniform Traffic Control Devices*, 2009 Edition, p. 511



When a pedestrian activates a PHB, a flashing yellow light is followed by a solid yellow light, alerting drivers to slow. A solid red light requires drivers to stop while pedestrians have the right-of-way to cross the street. When the pedestrian signals display a flashing DON'T WALK indication, the overhead beacon flashes red, and drivers may proceed if the crosswalk is clear.

CONSIDERATIONS

PHBs are a candidate treatment for roads with three or more lanes that generally have annual average daily traffic (AADT) above 9,000. PHBs should be strongly considered for all midblock and intersection crossings where the roadway speed limits are equal to or greater than 40 miles per hour (mph). The PHB should meet the application guidelines provided in the Manual on Uniform Traffic Control Devices for existing or projected pedestrian volumes.

PHBs are intended for installation at midblock locations, but can be installed at intersections. They should only be installed in conjunction with marked crosswalks and pedestrian countdown signals.

When PHBs are not in common use in a community, consider conducting an outreach effort to educate the public and law enforcement officers on the PHBs' purpose and use.

COST

The PHB is often less expensive than a full traffic signal installation. The costs range from $21,000 to $128,000, with an average per unit cost of $57,680.

References

Zegeer, C., R. Srinivasan, B. Lan, D. Carter, S. Smith, C. Sundstrom, N.J. Thirsk, J. Zegeer, C. Lyon, E. Ferguson, and R. Van Houten. (2017). NCHRP Report 841: Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments. Transportation Research Board, Washington, D.C.

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Bushell, M., Poole, B., Zegeer, C., & Rodriguez, D. (2013). Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public. *Pedestrian and Bicycle Information Center.*

Crosswalk Visibility Enhancements

SAFE TRANSPORTATION FOR EVERY PEDESTRIAN

COUNTERMEASURE TECH SHEET

This example combines curb extensions, high-visibility markings, overhead lighting, and in-street signs on a two-lane roadway.

This group of countermeasures includes improved lighting, advance or in-street warning signage, pavement markings, and geometric design elements. Such features may be used in combination to indicate optimal or preferred locations for people to cross and to help reinforce the driver requirement to yield the right-of-way to pedestrians at crossing locations.

For multi-lane roadway crossings where vehicle AADTs are in excess of 10,000, a marked crosswalk alone is typically not sufficient (Zegeer, 2005). Under such conditions, more substantial crossing improvements are also needed to prevent an increase in pedestrian crash potential. Examples of more substantial treatments include the refuge island, PHB, and RRFB.

Poor lighting conditions, obstructions such as parked cars, and horizontal or vertical roadway curvature can reduce visibility at crosswalks, contributing to higher crash rates.

Crosswalk visibility enhancements help make crosswalks and/or pedestrians more visible and can help pedestrians decide where to cross.

Crosswalk visibility enhancements can reduce crashes by

23–48%

FEATURES:

- High visibility marking improves visibility of the crosswalk compared to the standard parallel lines.
- Parking restriction on the crosswalk approach improves the sightlines for motorists and pedestrians.
- Advance STOP or YIELD markings & signs reduce the risk of a multiple threat crash.
- Curb extension improves sight distance between drivers and pedestrians and narrows crossing distance.
- In street STOP or YIELD signs may improve driver yielding rates.

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Crosswalk Visibility Enhancements

EDC-4 STEP: https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/step.cfm

High-visibility crosswalk marking. High-visibility crosswalks are preferred over parallel line crosswalks and should be provided at all established midblock pedestrian crossings. They should also be considered at uncontrolled intersections.

Parking restriction on the crosswalk approach. Parking restriction can include the removal of parking space markings, installation of new "parking prohibition" pavement markings or curb paint, and signs. The minimum setback is 20 feet in advance of the crosswalk where speeds are 25 mph or less, and 30 feet where speeds are between 26 and 35 mph.

Advance YIELD or STOP markings and signs.[1] The stop bar or "sharks teeth" yield markings are placed 20 to 50 feet in advance of a marked crosswalk to indicate where vehicles are required to stop or yield in compliance with the accompanying "STOP Here for Pedestrians" or "YIELD Here to Pedestrians" sign.

Curb extension. This treatment, also referred to as bulb-outs, extends the sidewalk or curb line out into the parking lane, which reduces the effective street width. Curb extensions must not extend into travel lanes and should not extend across bicycle lanes.

Improved nighttime lighting. Consideration should be given to placing lights in advance of midblock and intersection crosswalks on both approaches to illuminate the front of the pedestrian and avoid creating a silhouette.

In-street STOP or YIELD to pedestrian sign.[2] These signs serve to remind road users of laws regarding right-of-way, and they may be appropriate on 2-lane or 3-lane roads where speeds limits are 30 mph or less. The sign can be placed in between travel lanes or in a median.

COST

Countermeasure	Range	Average
High visibility crosswalk marking	$600-5,700 each	$2,540 each
Lighting	*Varies based on fixture type and utility service agreement*	
Parking restriction	*Varies based on the required signs and pavement markings*	
Curb extension	$2,000-20,000	$13,000 each
Advance STOP/YIELD sign	N/A	$300 each
Advance STOP/YIELD line	N/A	$320 each
In-street STOP/YIELD sign	N/A	$240 each

[1]MUTCD section 2B.12 In-Street and Overhead Pedestrian Crossing Signs (R1-6, R1-6a, R1-9, and R1-9a)

[2]MUTCD reference:Section 2B.11 Yield Here To Pedestrians Signs and Stop Here For Pedestrians Signs (R1-5 Series)

References

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Federal Highway Administration. (2013). Multiple webpages in PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System:

- Marked Crosswalks and Enhancements: http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=4
- Lighting and Illumination: http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=8
- Parking Restrictions: http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=9
- Curb Extensions: http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=5
- Advance Stop/Yield Lines: http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=13

Pedestrian Refuge Island

SAFE TRANSPORTATION FOR EVERY PEDESTRIAN

COUNTERMEASURE TECH SHEET

A pedestrian refuge island is a median with a refuge area that is intended to help protect pedestrians who are crossing a multilane road. This countermeasure is sometimes referred to as a crossing island, refuge island, or pedestrian island. The presence of a pedestrian refuge island at a midblock location or intersection allows pedestrians to focus on one direction of traffic at a time as they cross, and gives them a place to wait for an adequate gap in oncoming traffic before finishing the second phase of a crossing.

Refuge islands are highly desirable for midblock pedestrian crossings on roads with four or more travel lanes, especially where speed limits are 35 mph or greater and/or where annual average daily traffic (AADT) is 9,000 or higher. They are also a candidate treatment option for uncontrolled pedestrian crossings on 3-lane or 2-lane roads that have high vehicle speeds or volumes. When installed at a midblock crossing, the island should be supplemented with a marked high-visibility crosswalk.

The combination of a long crossing distance and multiple lanes of oncoming traffic can create an unsafe pedestrian environment.

A pedestrian refuge island can improve safety and comfort by providing pedestrians with the option of waiting in the median area before beginning the next stage of the crossing.

Pedestrian refuge islands can reduce pedestrian crashes by

32%

FEATURES:

- Median can enhance visibility of the crossing and reduce speed of approaching vehicles.
- Refuge area provides a place to rest and reduces the amount of time a pedestrian is in the roadway

OFTEN USED WITH:

- Crosswalk visibility enhancements
- Curb extensions (where road width allows)

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EDC

Pedestrian Refuge Island

EDC-4 STEP: https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/step.cfm

Asheville, NC. Photo: Lyubov Zuyeva, pedbikeimages.org

CONSIDERATIONS

The design must accommodate pedestrians with disabilities. Islands should be at least 4 feet wide (preferably 8 feet) and of adequate length to allow the anticipated number of pedestrians to stand and wait for gaps in traffic before crossing. The cut-through must include detectable warnings if island width is at least 6 feet.

Islands should be illuminated or highlighted with street lights, signs, and/or reflectors to ensure that they are visible to motorists. They can be constructed so that crossing pedestrians are directed to the right, so they can more easily view oncoming traffic after they are halfway through the crossing. If applicable, evaluate the impact of the island on bicycle facility design.

COST

The cost of a median island depends on its size and construction materials. The costs range from $2,140 to $41,170 per island, depending on the length of the island, with an average cost of $13,520. The average cost per square foot is approximately $10. Costs will be higher for concrete islands versus asphalt islands, though the lifespan of concrete is longer compared to the lifespan of asphalt. Cost reductions may be realized if the refuge island can be incorporated into planned roadway improvements or utility work.

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Zegeer, C., R. Srinivasan, B. Lan, D. Carter, S. Smith, C. Sundstrom, N.J. Thirsk, J. Zegeer, C. Lyon, E. Ferguson, and R. Van Houten. (2017). NCHRP Report 841: Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments. Transportation Research Board, Washington, D.C.

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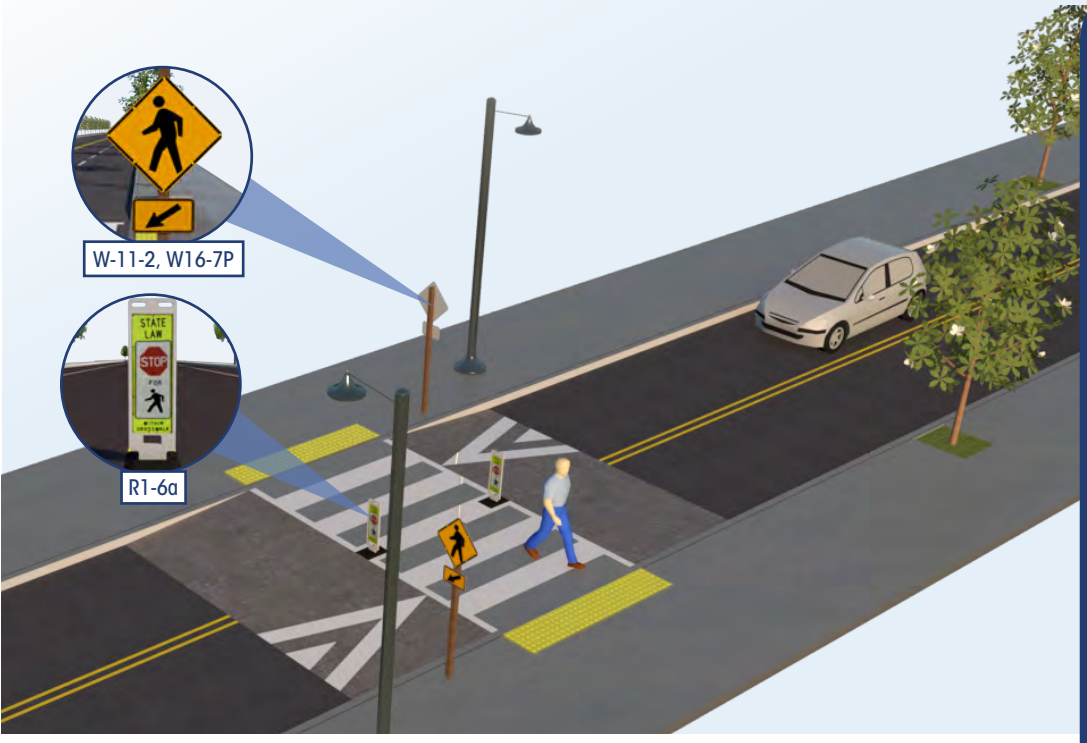
Raised Crosswalk

SAFE TRANSPORTATION FOR EVERY PEDESTRIAN

COUNTERMEASURE TECH SHEET



Raised crosswalks are ramped speed tables spanning the entire width of the roadway, often placed at midblock crossing locations. The crosswalk is demarcated with paint and/or special paving materials. These crosswalks act as traffic-calming measures that allow the pedestrian to cross at grade with the sidewalk.

In addition to their use on local and collector streets, raised crosswalks can be installed in campus settings, shopping centers, and pick-up/drop-off zones (e.g., airports, schools, transit centers).

Raised crosswalks are flush with the height of the sidewalk. The crosswalk table is typically at least 10 feet wide and designed to allow the front and rear wheels of a passenger vehicle to be on top of the table at the same time. Detectable warnings (truncated domes) and curb ramps are installed at the street edge for pedestrians with impaired vision.

Local and collector roads with high speeds pose a significant challenge for pedestrians crossing the roadway.

A raised crosswalk can reduce vehicle speeds and enhance the pedestrian crossing environment.

Raised crosswalks can reduce pedestrian crashes by

45%

FEATURES:

- **Elevated crossing makes the pedestrian more prominent in the driver's field of vision, and allows pedestrians to cross at grade with the sidewalk**
- **Approach ramps may reduce vehicle speeds and improve motorist yielding**

OFTEN USED WITH:

- **Crosswalk visibility enhancements**

U.S. Department of Transportation
Federal Highway Administration

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EDC

Raised Crosswalk

EDC-4 STEP: https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/step.cfm

Boston, MA. Photo: Peter Furth / nacto.org

CONSIDERATIONS

Raised crosswalks are typically installed on 2-lane or 3-lane roads with speed limits of 30 mph or less and annual average daily traffic (AADT) below about 9,000. Raised crossings should generally be avoided on truck routes, emergency routes, and arterial streets.

Drainage can be an issue. Raised crosswalks may be installed with curb extensions where parking exists. They may also be used at intersections, particularly at the entrance of the minor street.

Since this countermeasure can cause discomfort and noise (especially with larger vehicles), it may be appropriate to get public buy-in. Raised crosswalks may not be appropriate for bus transit routes or primary emergency vehicle routes. For States that experience regular snowfall, snowplowing can be a concern.

COST

The cost associated with a raised crosswalk ranges from $7,110 to $30,880 each, with the average cost estimated at $8,170.

References

Federal Highway Administration. (2013). "Raised Pedestrian Crossings" in PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System. Available: http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=7

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Road Diet

SAFE TRANSPORTATION FOR EVERY PEDESTRIAN

COUNTERMEASURE TECH SHEET

Before

After

Multilane roads can take longer to cross and vehicle speeds may be high.

Road Diets can decrease the lane crossing distance and reduce vehicle speeds.

Road Diets can reduce total crashes by

19–47%*

*19% in urban areas, 47% in suburban areas.

FEATURES:

- Reduced crossing distance and exposure.
- Reduced vehicle speeds.
- Promote Complete Streets.
- Provide space for installing curb extensions and widening sidewalks.
- Create space for bicycle, transit, and/or parking lanes.

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EDC

Road Diet

EDC-4 STEP: https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/step.cfm

A typical Road Diet converts an existing four-lane, undivided roadway to two through lanes and a center, two-way left turn lane. This design allows left-turning drivers to exit the traffic stream while waiting for a gap to complete their turn and frees up space that can be reallocated to other uses, including:

- Pedestrian refuge island
- Crosswalk visibility enhancements, such as curb extensions
- On-street parking, with parking restrictions on crosswalk approaches
- Widened sidewalks and landscaped buffers
- Bicycle lane and/or transit lanes

A Road Diet can be a relatively low-cost safety solution, particularly where only pavement marking modifications are required to implement the reconfigured roadway design. When planning in conjunction with reconstruction or overlay projects, the change in cross section may be completed without any additional cost.

CONSIDERATIONS

While Road Diets are effective countermeasures for midblock collisions, they are not recommended for all multilane roadways. Typically, a suitable roadway has a current and future average daily traffic (ADT) equal to or less than about 20,000. In some instances, Road Diets have been successfully used on roads with ADTs as high as 25,000.

FHWA's Road Diet Informational Guide provides a closer look at the safety and operational benefits of Road Diets to help agencies determine if this countermeasure may suit their needs. Communities will need to consider a range of factors, including:

- Vehicle speed
- Level of Service (LOS)
- Quality of Service
- Vehicle volume (ADT)
- The operation and volume of pedestrians, bicyclists, transit, and freight
- Peak hour and peak direction traffic flow
- Vehicle turning volumes and patterns
- Frequency of stopping and slow moving vehicles
- Presence of parallel roadways

Since Road Diets may be new or uncommon in a community, consider conducting an outreach effort to educate the public on the purpose and potential benefits.

COST

The cost associated with a Road Diet can vary widely. Restriping costs for the three lanes plus bicycle lanes are estimated at $25,000 to $40,000 per mile, depending on the amount of lane lines that need to be repainted. When a Road Diet involves geometric features like extended sidewalks, curb extensions, a raised median or refuge island, the costs can increase to $100,000 or more per mile.

References

Pawlovich, M.D., W. Li, A. Carriquiry, and T. Welch. "Iowa's Experience with Road Diet Measures—Use of Bayesian Approach to Assess Impacts on Crash Frequencies and Crash Rates." Transportation Research Record: Journal of the Transportation Research Board, No. 1953, Transportation Research Board, Washington, D.C., 2006.

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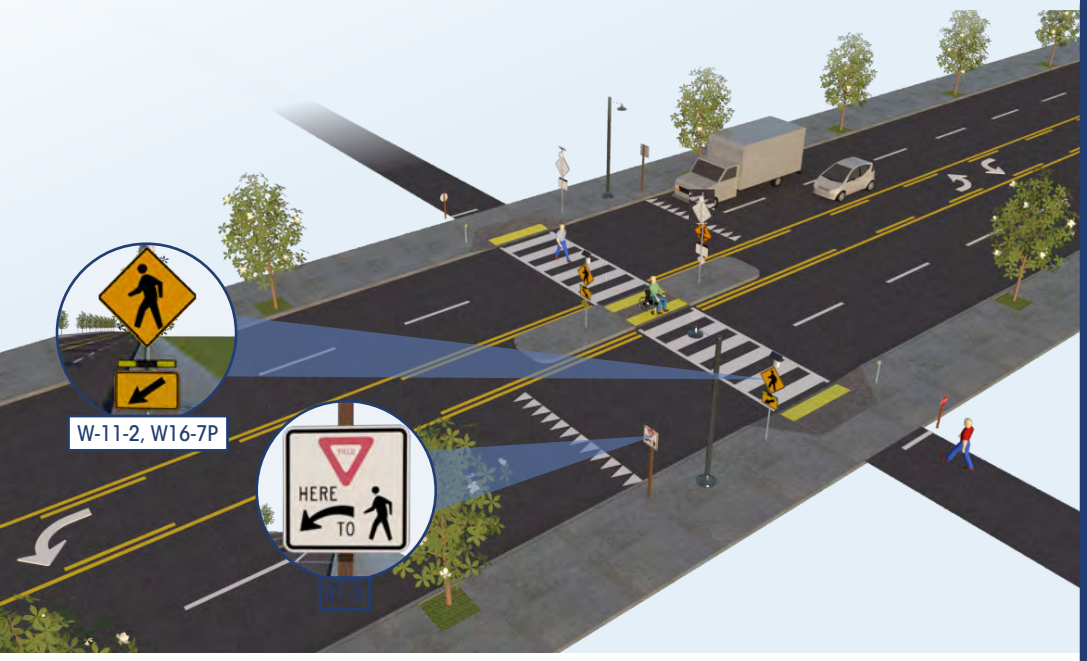
Federal Highway Administration. (2013). "Lane Reduction (Road Diet)" in PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System. Available: http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=19

Rectangular Rapid-Flashing Beacon (RRFB)



RRFBs are pedestrian-actuated conspicuity enhancements used in combination with a pedestrian, school, or trail crossing warning sign to improve safety at uncontrolled, marked crosswalks. The device includes two rectangular-shaped yellow indications, each with an LED-array-based light source, that flash with high frequency when activated.

The RRFB is a treatment option at many types of established pedestrian crossings. Research indicates RRFBs can result in motorist yielding rates as high as 98 percent at marked crosswalks. However, yielding rates as low as 19 percent have also been noted. Compliance rates varied most per the city location, posted speed limit, crossing distance, and whether the road was one- or two-way. RRFBs are particularly effective at multilane crossings with speed limits less than 40 mph. Consider the Pedestrian Hybrid Beacon (PHB) instead for roadways with higher speeds. FHWA's *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations* (HSA-17-072) provides specific conditions where practitioners should strongly consider the PHB instead of the RRFB.

Multiple lanes of traffic create challenges for pedestrians crossing at unsignalized locations.

RRFBs can make crosswalks and/or pedestrians more visible at a marked crosswalk.

RRFBs can reduce pedestrian crashes by

47%

FEATURES:

- Enhanced warning improves motorist yielding

OFTEN USED WITH:

- Crosswalk visibility enhancements
- Pedestrian refuge island
- Advance STOP or YIELD markings and signs

U.S. Department of Transportation
Federal Highway Administration

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EDC

Rectangular Rapid-Flashing Beacon (RRFB)

EDC-4 STEP: https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/step.cfm

Princeton, NJ. Photo: VHB

CONSIDERATIONS

FHWA has issued interim approval for the use of the RRFB (IA-21). State and local agencies must request and receive permission to use this interim approval before they can use the RRFB. IA-21 does not provide guidance or criteria based on number of lanes, speed, or traffic volumes.

RRFBs are placed on both ends of a crosswalk. If the crosswalk contains a pedestrian refuge island or other type of median, an RRFB should be placed to the right of the crosswalk and on the median (instead of the left side of the crosswalk).

RRFBs typically draw power from standalone solar panel units, but may also be wired to a traditional power source. IA-21 provides conditions for the use of accessible pedestrian features with the RRFB assembly. When RRFBs are not in common use in a community, consider conducting an outreach effort to educate the public and law enforcement officers on their purpose and use.

COST

The cost associated with RRFB installation ranges from $4,500 to $52,000 each, with the average cost estimated at $22,250. These costs include the complete system installation with labor and materials.

References

MUTCD section 2B.12 In-Street and Overhead Pedestrian Crossing Signs (R1-6, R1-6a, R1-9, and R1-9a).

Fitzpatrick, K., M. Brewer, R. Avelar, and T. Lindheimer. "Will You Stop for Me? Roadway Design and Traffic Control Device Influences on Drivers Yielding to Pedestrians in a Crosswalk with a Rectangular Rapid-Flashing Beacon." Report No. TTI-CTS-0010. Texas A&M Transportation Institute, College Station, Texas. June 2016. https://static.tti.tamu.edu/tti.tamu.edu/documents/TTI-CTS-0010.pdf

Federal Highway Administration. (2018). MUTCD – Interim Approval for Optional Use of Pedestrian-Actuated Rectangular Rapid-Flashing Beacons at Uncontrolled Marked Crosswalks (IA-21). U.S. Department of Transportation, Washington, DC.

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Advance Yield Here to Pedestrians Lines and Signs

KANSAS DEPARTMENT OF TRANSPORTATION

COUNTERMEASURE TECH SHEET

Photo: Toole Design

A common pedestrian crash occurs at crosswalks of multi-lane roadways called a *multiple threat*. It results when a driver in one lane stops to let the pedestrian cross, whose vehicle blocks the sight lines of the driver in the other lane of a multi-lane approach. The driver of the second vehicle then advances through the crosswalk and hits the crossing pedestrian(s). Advance yield lines discourage drivers from yielding or stopping too close to crosswalks and also allows pedestrians to see if a driver is stopping or not stopping and can take evasive action.

Kansas has a yield to pedestrian law thus agencies will use an advanced yield line (shark teeth) and R1-5 or R1-5a signs when this treatment is used in the state. The MUTCD requires R1-5 or R1-5a signs when yield lines are used in advance of a crosswalk with an uncontrolled multi-lane approach.

R1-5 Yield to Pedestrian Sign

Advance yield here to pedestrians lines and signs can reduce crashes by 25%

FEATURES

- **Are used in advance of a crosswalk and placed 20 to 50 feet before the nearest crosswalk line**
- **Parking should be prohibited in the area between the yield line and the crosswalk**
- **Yield lines and yield signs must be used together according to the MUTCD**

OFTEN USED WITH

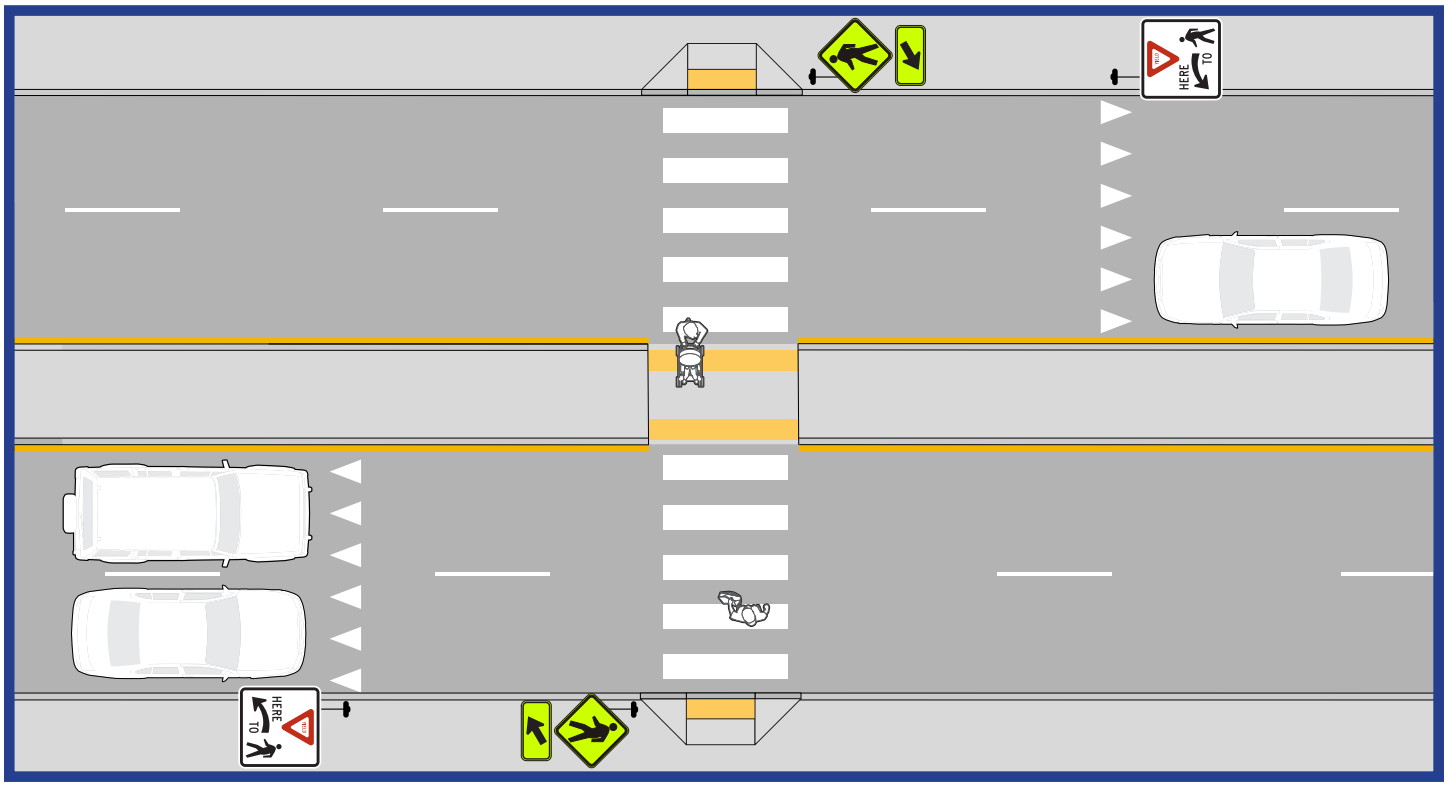
- **High Speeds and multiple lane of traffic**
- **Pedestrian refuge Islands, rectangular rapid flashing beacons, and raised crosswalk**

Kansas Department of Transportation

Advance Yield Here to Pedestrians Lines and Signs

Kansas Department of Transportation: Countermeasure Tech Sheet

Figure 1. Unsignalized crossing with pedestrian refuge island and advanced yield markings



The installation of advance yield or stop markings and signs can reduce pedestrian crashes by up to 25 percent. For more information, see *NCHRP Research Report 841: Development of Crash Modification Factors for uncontrolled Pedestrian Crossing Treatments.*

CONSIDERATIONS OF ADVANCED YIELD LINES AND SIGNS:

- Is a candidate treatment primarily for mid-block crossings.
- Treatment should be strongly considered for any established pedestrian crossing on roads with four or more lanes and/or roads with speed limits of 35 mph or greater.
- Frequently used with other crosswalk visibility enhancements and other STEP countermeasures (raised crosswalk, rectangular rapid flashing beacon, pedestrian refuge island).
- May need to experiment with the line placement; drivers might ignore markings and signage if placed too far in advance of the crosswalk.

ADDITIONAL RESOURCES:

Federal Highway Administration (2013), PEDSAFE: *HTTP://WWW.PEDBIKESAFE.ORG/PEDSAFE/COUNTERMEASURES_DETAIL.CFM?CM_NUM=13*

MUTCD Section 2B.11 Yield Here To Pedestrians Signs and Stop Here For Pedestrians Signs (R1-5 Series). *HTTPS://MUTCD.FHWA.DOT.GOV/HTM/2009/PART2/PART2B.HTM#FIGURE2B02 AND SECTION 7C.04 STOP AND YIELD LINES HTTPS://MUTCD.FHWA.DOT.GOV/HTM/2003/PART7/PART7C.HTM*

Curb Extensions

KANSAS DEPARTMENT OF TRANSPORTATION

COUNTERMEASURE TECH SHEET

Photo: Toole Design

Curb extensions, also known as push-outs, bulb-outs, or bump-outs, are created by reducing the width of the street. This is done by extending the sidewalk at corners or at mid-block locations. Curb extensions are intended to improve pedestrian visibility, calm traffic, and provide extra space on sidewalks for walking and gathering. In addition to shortening crossing distances, curb extensions create more compact intersections, resulting in smaller corner radii and reduce vehicle turning speeds.

CONSIDERATIONS OF CURB EXTENSIONS:

» Curb extensions are most appropriate where there is an on-street parking lane. They should not extend more than 6 feet from the curb or into bike lanes.

» The turning needs of emergency and larger vehicles need to be considered in curb extension design, especially at intersections with significant truck or bus traffic. However, speeds should be relatively slow in a pedestrian

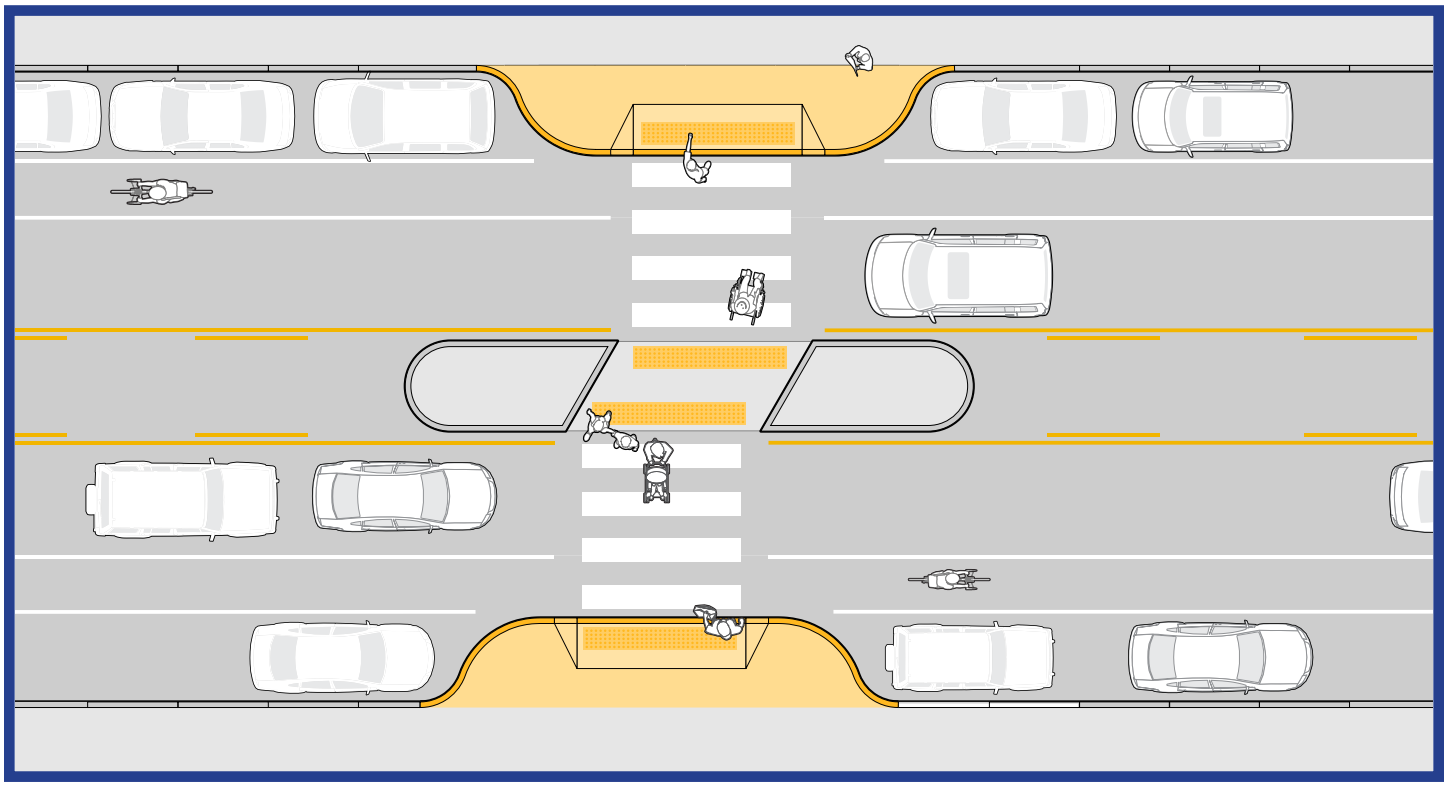
FEATURES

- **Provide additional space for pedestrians.**
- **Slow motor vehicle speeds by reducing the width of streets and smaller turning radii at intersections.**
- **Reduce pedestrian crossing distance resulting in potential conflicts with motorists.**
- **Slow the speed of motorists making turns at intersections.**
- **Create additional space for ADA compliant curb ramps.**
- **Improve visibility between pedestrians and other street users.**
- **Prevent people from parking too close to or on crosswalks.**
- **Create space for utilities, signs, and amenities such as bus shelters or waiting areas, bicycle parking, public seating, street vendors, and greenscape elements.**

Curb Extensions

Kansas Department of Transportation: Countermeasure Tech Sheet

Figure 1. Unsignalized crossing with pedestrian refuge island and advanced yield markings



- environment so all vehicles should be traveling at speeds conducive to tighter turns.
- When designing curb extensions, it is not always necessary to facilitate a turn by a vehicle from a curb lane to a curb lane. Vehicles can encroach into adjacent lanes safely where volumes are low, or speeds are slow.
- When curb extensions conflict with turning movements, reducing the width and/or length of the curb extension should be prioritized over elimination.
- Often emergency access is improved when curb extensions are used since intersections are kept clear of parked cars. Emergency vehicles can climb a curb where they would not be able to move a parked car.
- Bus bulbs are curb extensions that are lengthened to provide space for a transit stop.
- Curb extension design should facilitate adequate drainage.

RESOURCES:

- Federal Highway Administration (2013), PEDSAFE-Curb Extensions: *HTTP://WWW.PEDBIKESAFE.ORG/PEDSAFE/COUNTERMEASURES_DETAIL.CFM?CM_NUM=5*
- NACTO (2013), Urban Street Design Guide: *HTTPS://NACTO.ORG/PUBLICATION/URBAN-STREET-DESIGN-GUIDE/STREET-DESIGN-ELEMENTS/CURB-EXTENSIONS/*

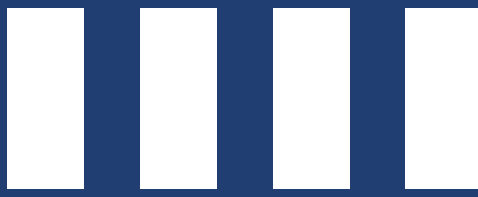
Marked Crosswalks and High-Visibility Markings

KANSAS DEPARTMENT OF TRANSPORTATION

COUNTERMEASURE TECH SHEET

It is important to create safe places for pedestrians to cross roadways at regular intervals. Pedestrians are sensitive to indirect travel, and reasonable accommodation should be made to make crossings both convenient and safe at locations with adequate visibility. According to Kansas State Statutes legal crosswalks exist at all locations where sidewalks meet the street, regardless of whether a crosswalk is marked or not. While drivers are legally required to yield to pedestrians within all crosswalks, providing marked crosswalks communicates to drivers that pedestrians may be present and helps guide pedestrians to locations where it is best to cross the street.

Marked crosswalks should be installed where there is an expectation of pedestrians crossing the street such as near schools, parks or other activity generators (crossing locations may differ for urban, suburban, and rural environments). Without the associated features mentioned as part of STEP (visibility enhancements, signage, islands, curb extensions,



Continental Crosswalk Markings

High-visibility markings can reduce crashes by

18-39%

FEATURES OF HIGH-VISIBILITY MARKINGS:

- **Improves visibility of the crosswalk compared to the standard parallel lines.**
- **Consists of two components – enhanced marking material and a more prominent marking design**
- **Often used with other crosswalk visibility enhancements such as signage, advance markings, overhead lighting, in-street signs, and bump-outs**
- **Almost always used with other countermeasures – refuge islands, beacons, and raised crosswalks**

Marked Crosswalks and High-Visibility Markings

Kansas Department of Transportation: Countermeasure Tech Sheet

illumination, etc.) marked crosswalks on their own do not necessarily increase or decrease the security of a pedestrian crossing the roadway. Increasing the visibility of a crosswalk using high-visibility markings is just one of many treatment types of a broader strategy included in FHWA's Crosswalk Visibility Enhancements Countermeasure Tech Sheet.

High-visibility crosswalk markings make it easier for drivers to see the crosswalk – not just the pedestrian - than traditional parallel line markings. Parallel lines indicating a marked crosswalk can be nearly invisible to the motorist at uncontrolled locations. High-visibility crosswalks come in a variety of striping designs, such as ladder ("piano keys"), continental, zebra, or bar pairs. KDOT currently recommends the use of high-visibility crosswalk markings whenever a crosswalk marking is installed on its highways.

FEATURES OF HIGH-VISIBILITY MARKED CROSSWALKS:

» Marked crosswalks should be at least 8 feet wide or the width of the approaching sidewalk, whichever is greater. In areas of heavy pedestrian volumes, crosswalks can be up to 25 feet wide.

» Crosswalks should provide a slip-resistant, level, and accessible surface, and should not include stamped pavements or pavers.

» Crosswalks should directly connect the approaching sidewalks and should be located to maximize the visibility of pedestrians.

» Perpendicular crosswalks minimize crossing distances and therefore limit pedestrian exposure to motorists.

» ADA-compliant curb ramps should align directly with the crosswalk. The bottom of the ramp should lie within the crosswalk to make them accessible.

» Stop lines at stop-controlled and signalized intersections should be located at least 8 feet in advance of crosswalks.

CONSIDERATIONS FOR MARKED CROSSWALKS AND HIGH-VISIBILITY MARKINGS

» While marked crosswalks are important to establish yielding expectations for motorists, they also make it easier for pedestrians with vision loss.

» Crosswalk markings should only be used where there is adequate visibility for motorists. Stopping sight distances are used to determine adequate sight-lines for crossings.

» Crosswalks should also be accompanied with parking restrictions on the crosswalk approach at all established pedestrian crossings (both approaches) so there is adequate sight distance for motorists on the approaches to the crossings and ample sight distance for pedestrians attempting to cross.

» High-visibility markings are especially appropriate for midblock crossings, uncontrolled intersections near schools, parks, or for uncontrolled crossings of arterial and collector streets near major pedestrian generators.

» New marked crosswalks on streets with multiple lanes in each direction, higher speeds, or higher volumes are likely to include additional visibility treatments such as refuge islands, raised crossings, or beacons to create an enhanced crossing.

ADDITIONAL RESOURCES:

» Federal Highway Administration (2013), PEDSAFE-Marked Crosswalks and Enhancements: *HTTP://WWW.PEDBIKESAFE.ORG/PEDSAFE/COUNTERMEASURES_DETAIL.CFM?CM_NUM=4*

» MUTCD Section 3B.18 Crosswalk Markings: *HTTPS://MUTCD.FHWA.DOT.GOV/HTM/2009/PART3/PART3B.HTM AND SECTION 7C.03 CROSSWALK MARKINGS: HTTPS://MUTCD.FHWA.DOT.GOV/HTM/2003/PART7/PART7C.HTM*

Kansas
Department of Transportation