Appendix 2: Proven Safety Countermeasures for VRU's

A. Crosswalk Visibility Enhancements (Tech Sheet)
B. Pedestrian Hybrid Beacon (Tech Sheet)
C. Raised Crosswalk (Tech Sheet)
D. Road Diet (Tech Sheet)
E. Rectangular Rapid-Flashing Beacon (Tech Sheet)

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.

June 2018, Updated | *FHWA-SA-18-061*

U.S. Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
Investment in roadway safety saves lives

EDC

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 speed 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

Harkey, D.L., R. Srinivasan, J. Baek, F. Council, K. Eccles, N. Lefler, F. Gross, B. Persaud, C. Lyon, E. Hauer, and J. Bonneson. (2008). NCHRP Report 617: Crash Reduction Factors for Traffic Engineering and ITS Improvements. Transportation Research Board, Washington, D.C.

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.

Gibbons, R. B., Edwards, C., Williams, B., & Andersen, C. K. (2008). Informational Report on Lighting Design for Midblock Crosswalks. Report No. FHWA-HRT-08-053. Federal Highway Administration.

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.

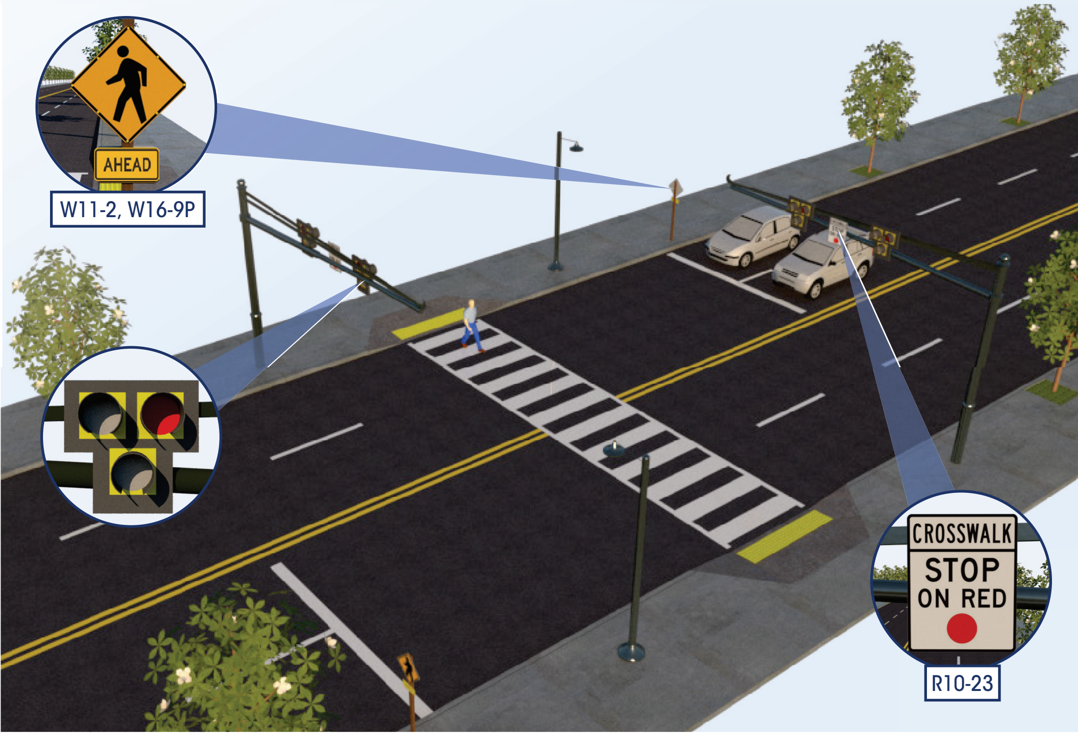
Federal Highway Administration. (2013). Multiple webpages in PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System:

- 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 Hybrid Beacon (PHB)

SAFE TRANSPORTATION FOR EVERY PEDESTRIAN

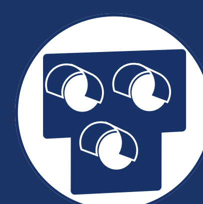
COUNTERMEASURE TECH SHEET



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%**



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.

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

U.S. Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
Investment in roadway safety saves lives

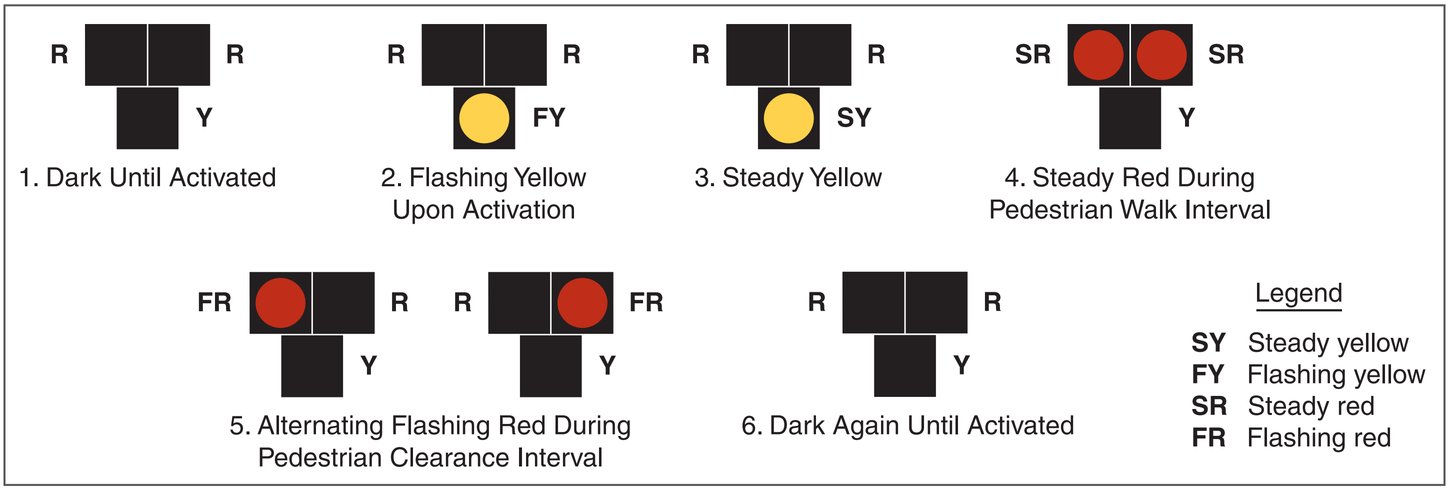
EDC

June 2018, Updated | *FHWA-SA-18-064*

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.

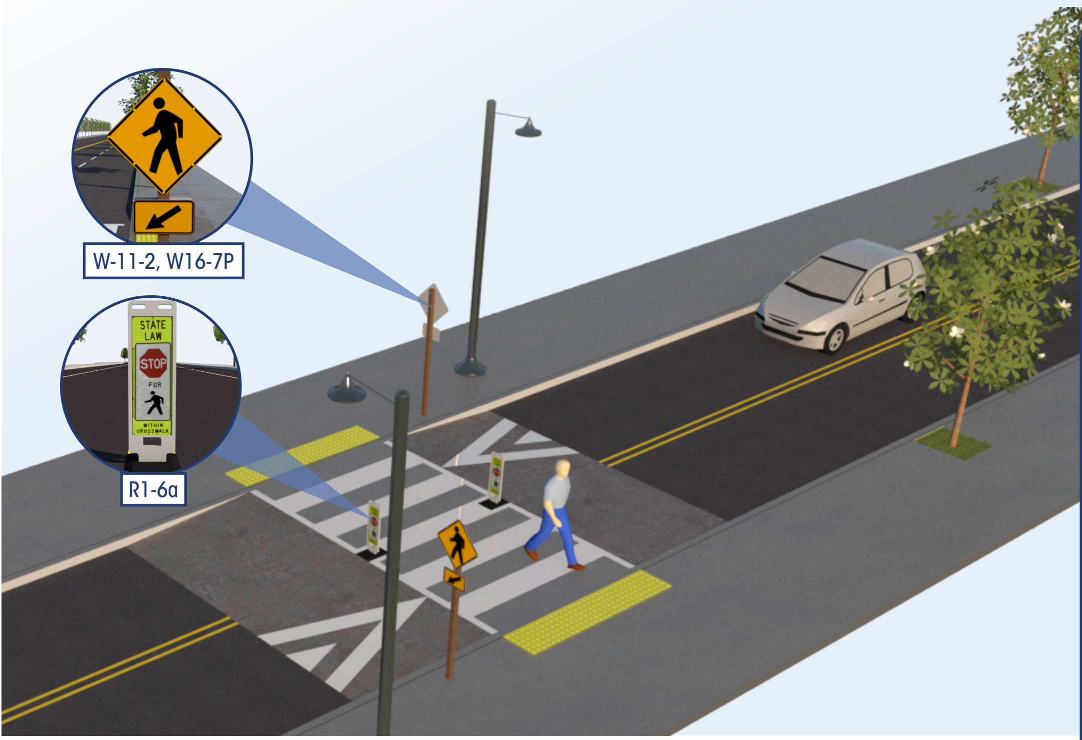
Federal Highway Administration. (2013). "Pedestrian Hybrid Beacon" in PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System. Available: http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=53

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.*

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

Safe Roads for a Safer Future
Investment in roadway safety saves lives

EDC

June 2018, Updated | *FHWA-SA-18-063*

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

Thomas, L., Thirsk, N. J., & Zegeer, C. (2016). NCHRP Synthesis 498: Application of Pedestrian Crossing Treatments for Streets and Highways. Transportation Research Board, Washington D.C.

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.

Elvik, R., Christensen, P., and Amundsen, A. (2004). "Speed and Road Accidents An Evaluation of the Power Model." Transportokonomisk Institutt, Oslo, Norway.

Appendix 2D

Road Diet

SAFE TRANSPORTATION FOR EVERY PEDESTRIAN

COUNTERMEASURE TECH SHEET

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.

U.S. Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
Investment in roadway safety saves lives

EDC

June 2018, Updated | *FHWA-SA-18-066*

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.

Persaud, B., B. Lan, C. Lyon, and R. Bhim. "Comparison of empirical Bayes and full Bayes approaches for before–after road safety evaluations." Accident Analysis & Prevention, Volume 42, Issue 1, 2010, pp. 38-43.

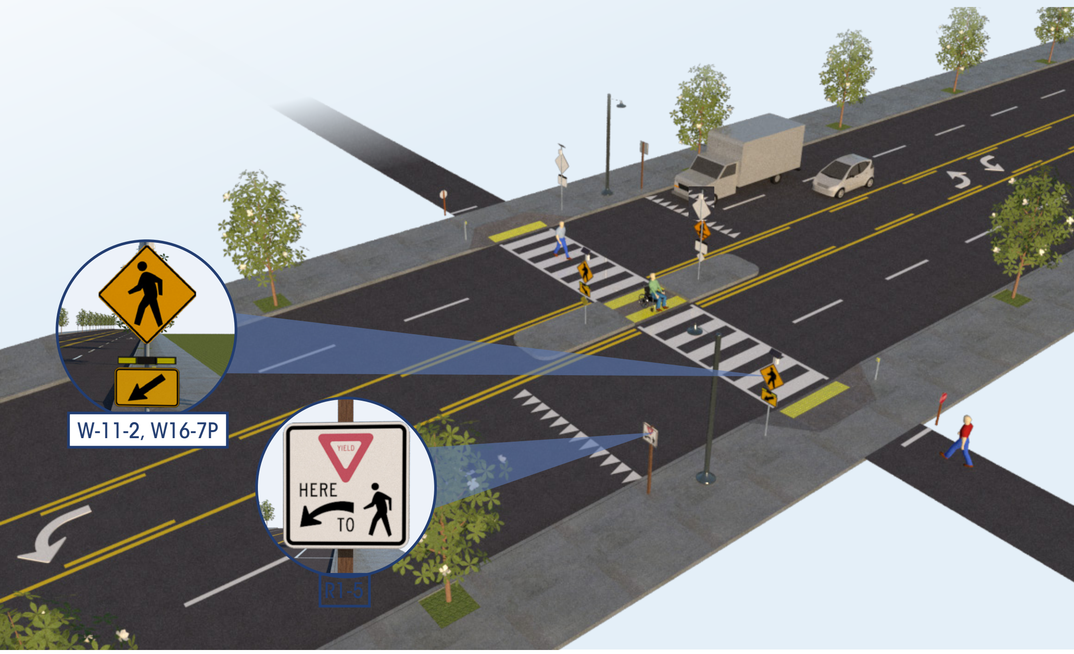
Knapp, K., B. Chandler, J. Atkinson, T. Welch, H. Rigdon, R. Retting, S. Meekins, E. Widstrand, and R.J. Porter. (2014). Road Diet Informational Guide. FHWA-SA-14-028, Federal Highway Administration Office of Safety, Washington, D.C. Available: https://safety.fhwa.dot.gov/road_diets/guidance/info_guide/form.cfm

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)

SAFE TRANSPORTATION FOR EVERY PEDESTRIAN

COUNTERMEASURE TECH SHEET



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%**

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.

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

Safe Roads for a Safer Future
Investment in roadway safety saves lives

EDC

June 2018, Updated | *FHWA-SA-18-065*

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.

Federal Highway Administration. (2013). "Rectangular Rapid Flash Beacon" in PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System. Available: http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=54

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.