

LOW-COST SAFETY IMPROVEMENTS



Safety Improvement Types

- Conflict point management
- Stop-Controlled Intersections
- Enhanced Curve Delineation
- Crosswalk Visibility Enhancements
- Medians and Pedestrian Refuge
- Rapid Rectangular Flashing Beacons



Conflict Point Management

- Provide clear sight triangle
 - remove vegetation and visual obstructions
 - restrict parking
 - reduce sign clutter

- Modify driveway access
 - close or restrict specific movements

continued



Provide Clear Sight Triangle



Remove vegetation

Provide Clear Sight Triangle



Remove parking near intersection



Restrict driveway to right-in/right-out (RIRO)



Driveway curbing with “no left turn” sign





Safety Benefits:

10%

reduction of fatal and injury crashes at all locations/types/areas.

15%

reduction of nighttime crashes at all locations/types/areas.

27%

reduction of fatal and injury crashes at rural intersections.

19%

reduction of fatal and injury crashes at 2-lane by 2-lane intersections.

Average Benefit-Cost Ratio

12:1

For more information on this and other FHWA Proven Safety Countermeasures, please visit <https://safety.fhwa.dot.gov/provencountermeasures/> and <https://safety.fhwa.dot.gov/intersection/stop/fhwasal8047.pdf>.

Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections

This systemic approach to intersection safety involves deploying a package of multiple low-cost countermeasures, including enhanced signing and pavement markings, at a large number of stop-controlled intersections within a jurisdiction. These countermeasures increase driver awareness and recognition of the intersections and potential conflicts.

There are several benefits to systemically applying multiple low-cost countermeasures at stop-controlled intersections, including:

- Resources are maximized because the treatments are low cost.
- A high number of intersections can receive treatment.
- Improvements are highly cost-effective, with an average benefit-cost ratio of 12:1, even assuming a conservative 3-year service life.



Example of countermeasures on the through approach.
Source: South Carolina DOT



Example of countermeasures on the stop approach.
Source: South Carolina DOT

The low-cost countermeasures for stop-controlled intersections generally consist of the following treatments:

On the Through Approach

- Doubled-up (left and right), oversized advance intersection warning signs, with supplemental street name plaques (can also include flashing beacon)
- Retroreflective sheeting on sign posts.

- Enhanced pavement markings that delineate through lane edge lines.

On the Stop Approach

- Doubled-up (left and right), oversized advance "Stop Ahead" intersection warning signs (can also include flashing beacon).
- Doubled-up (left and right), oversized Stop signs.
- Retroreflective sheeting on sign posts.
- Properly placed stop bar.
- Removal of vegetation, parking, or obstructions that limit sight distance.
- Double arrow warning sign at stem of T-intersections.



Systemic Safety

- Applying low-cost safety treatments to large number of locations as “pro-active” measure.
- Not based on “crash history”.
- Doesn’t chase crash “hot spots” (reactive)
- Based on “risk” of similar characteristics - speed, volume, classification, geometry, etc.
- Treatments expected to reduce overall crashes within a jurisdiction.



Stop Sign Enhancements

- Check stop sign placement (height, offset)
- Remove obstructions (vegetation)
- Replace with new sign, enhanced reflectivity
- Larger (oversize) stop sign
- Red retroreflective strip on post

Continued



Oversize Stop Sign



Stop Sign enhancements

Continued

- Mark a stop line
- Add supplement left side stop sign
- Add supplemental overhead stop sign
- Red flashing beacon or blinker
(beacon must supplement the sign -- No isolated beacons)



Provide a marked Stop Line



Enhanced STOP signing

Dual STOP sign, stop line, red flashing beacon, double arrow



Supplemental overhead “Stop” sign



Red Flashing Beacon



“Stop Ahead” Sign Enhancements

- Check stop ahead advance placement (minimum distance in Table 2C-4)
- Replace with new sign, enhanced reflectivity
- Larger (oversize) “stop ahead” sign
- Yellow retroreflective strip on post
- Add supplemental left side “stop ahead” sign
- Yellow flashing beacon or blinker



Left supplemental “stop ahead” sign



"Stop Ahead" with yellow flashing beacon



STOP “rumble strips”

Transverse rumble strips- perpendicular to road

- A. Feel and hear
- B. Grind in
- C. WisDOT strives for 3 sets of rumble arrays.
- D. Place first set 200 ft downstream from “stop ahead” for 55 mph
- E. Noise concerns. Take what you can get



Intersection Warning Sign

On main road. Typically for limited sight, but not always



New intersection warning sign

Enhanced
Retroreflectivity



Crossroad symbol modified for offset intersections



Intersection Warning Sign with Advisory Speed





Safety Benefits:

Chevron Signs

25% reduction in nighttime crashes.¹

16% reduction in non-intersection fatal and injury crashes.²

Oversized Chevron Signs

15% reduction in fatal and injury crashes.³

Sequential Dynamic Chevrons

60% reduction in fatal and injury crashes.³

In-Lane Curve Warning Pavement Markings

35 - 38% reduction in all crashes.^{4,5}

New Fluorescent Curve Signs or Upgrade Existing Curve Signs to Fluorescent Sheeting

18% reduction in non-intersection, head-on, run-off-road, and sideswipe in rural areas.¹

For more information on this and other FHWA Proven Safety Countermeasures, please visit <https://safety.fhwa.dot.gov/provencountermeasures/> and https://safety.fhwa.dot.gov/roadway_dept/countermeasures/horcurves/.

Enhanced Delineation for Horizontal Curves

Enhanced delineation at horizontal curves includes a variety of potential strategies that can be implemented in advance of or within curves, in combination, or individually.

Potential Strategies	In Advance of Curve	Within Curve
Pavement markings (standard width or wider)	✓	✓
In-lane curve warning pavement markings	✓	
Retroreflective strips on sign posts	✓	✓
Delineators		✓
Chevron signs		✓
Enhanced conspicuity (larger, fluorescent, and/or retroreflective signs)	✓	✓
Dynamic curve warning signs (including speed radar feedback signs)	✓	
Sequential dynamic chevrons		✓

Enhanced delineation treatments can alert drivers to upcoming curves, the direction and sharpness of the curve, and appropriate operating speed.

Agencies can take the following steps to implement enhanced delineation strategies:

1. Review signing practices and policies to ensure they comply with the Manual on Uniform Traffic Control Devices (MUTCD) principles of traffic control devices. Consistent practice for similar curves sets the appropriate driver expectancy.
2. Use the [systemic approach](#) to identify and treat problem curves. For example, Minnesota uses risk factors that include curve radii between 500 and 1,200 ft, traffic volumes between 500 and 1,000 vehicles per day, intersection in the curve, and presence of a visual trap.¹
3. Match the appropriate strategy to the identified problem(s), considering the full range of enhanced delineation treatments. Once the MUTCD requirements and recommendations have been met, an incremental approach is often beneficial to avoid excessive cost.



Chevron signs with retroreflective strips on sign posts installed along a curve. Source: FHWA

¹ Albin et al. Low-Cost Treatments for Horizontal Curve Safety 2016. FHWA-SA-15-084. (2016).
² Srinivasan et al. Safety Evaluation of Improved Curve Delineation. FHWA-HRT-09-045. (2009).
³ Lyon et al. Safety Evaluation of Two Curve Warning Treatments: In-Lane Curve Warning Pavement Markings and Oversized Chevron Signs. Presented at the 96th TRB Annual Meeting, Paper No. 17-00432. (2017).
⁴ Hallmark, S. Evaluation of Sequential Dynamic Chevrons on Rural Two-lane Highways. FHWA. (2017).
⁵ Donnell et al. Reducing Roadway Departure Crashes at Horizontal Curve Sections on Two-lane Rural Highways. FHWA-SA-19-005. (2019).



Curves

Chevrons to supplement curve/turn warning signs





Safety Benefits:
High-visibility crosswalks
can reduce pedestrian injury
crashes up to:
40%¹

Intersection lighting can
reduce pedestrian crashes
up to:
42%²

Advance yield or stop
markings and signs can
reduce pedestrian
crashes up to:
25%³

For more information on this
and other FHWA Proven Safety
Countermeasures, please visit
<https://safety.fhwa.dot.gov/provencountermeasures/>
and
https://safety.fhwa.dot.gov/ped_bike/step/docs/tech_sheet_VizEnhancem12018.pdf

Crosswalk Visibility Enhancements

Poor lighting conditions, obstructions such as parked cars, and horizontal or vertical roadway curvature can reduce visibility at crosswalks, contributing to safety issues. For multilane roadway crossings where vehicle volumes are in excess of 10,000 Average Annual Daily Traffic (AADT), a marked crosswalk alone is typically not sufficient. Under such conditions, more substantial crossing improvements could prevent an increase in pedestrian crash potential.

Three main crosswalk visibility enhancements help make crosswalks and the pedestrians, bicyclists, wheelchair and other mobility device users, and transit users using them more visible to drivers. These include high-visibility crosswalks, lighting, and signing and pavement markings. These enhancements can also assist users in deciding where to cross. Agencies can implement these features as standalone or combination enhancements to indicate the preferred location for users to cross.

High-visibility crosswalks

High-visibility crosswalks use patterns (i.e., bar pairs, continental, ladder) that are visible to both the driver and pedestrian from farther away compared to traditional transverse line crosswalks. They should be considered at all midblock pedestrian crossings and uncontrolled intersections. Agencies should use materials such as inklay or thermoplastic tape, instead of paint or brick, for highly reflective crosswalk markings.

Improved Lighting

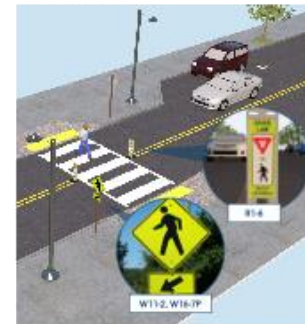
The goal of crosswalk lighting should be to illuminate with positive contrast to make it easier for a driver to visually identify the pedestrian. This involves carefully placing the luminaires in forward locations to avoid a silhouette effect of the pedestrian.

Enhanced Signing and Pavement Markings

On multilane roadways, agencies can use "YIELD Here to Pedestrians" or "STOP Here to Pedestrians" signs 20 to 50 feet in advance of

a marked crosswalk to indicate where a driver should stop or yield to pedestrians, depending on State law. To supplement the signing, agencies can also install a STOP or YIELD bar (commonly referred to as "shark's teeth") pavement markings.

In-street signing, such as "STOP Here for Pedestrians" or "YIELD Here to Pedestrians" may be appropriate on roads with two- or three-lane roads where speed limits are 30 miles per hour or less.



Source: FHWA

1. Chen, L., C. Chen, and R. Ewing. The Relative Effectiveness of Pedestrian Safety Countermeasures at Urban Intersections - Lessons from a New York City Experience. (2012).
2. Eby, R. and Voa, T. Handbook of Road Safety Measures. Oxford, United Kingdom: Elsevier, (2004).
3. Zegeer et al. Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments. FHWA, (2017).





Safety Benefits:

Median with
Marked Crosswalk

46%

reduction in
pedestrian crashes.²

Pedestrian Refuge
Island

56%

reduction in
pedestrian crashes.²

For more information on this and other FHWA Proven Safety Countermeasures, please visit <https://safety.fhwa.dot.gov/provencountermeasures/> and https://safety.fhwa.dot.gov/ped_bike/step/docs/techSheet_PedRefugelsIand2018.pdf.

Medians and Pedestrian Refuge Islands in Urban and Suburban Areas

A **median** is the area between opposing lanes of traffic, excluding turn lanes. Medians in urban and suburban areas can be defined by pavement markings, raised medians, or islands to separate motorized and non-motorized road users.

A **pedestrian refuge island** (or crossing area) is a median with a refuge area that is intended to help protect pedestrians who are crossing a road.

Pedestrian crashes account for approximately 17 percent of all traffic fatalities annually, and 74 percent of these occur at non-intersection locations.¹ For pedestrians to safely cross a roadway, they must estimate vehicle speeds, determine acceptable gaps in traffic based on their walking speed, and predict vehicle paths. Installing a median or pedestrian refuge island can help improve safety by allowing pedestrians to cross one direction of traffic at a time.

Transportation agencies should consider medians or pedestrian refuge islands in curbed sections of urban and suburban multilane

roadways, particularly in areas with a significant mix of pedestrian and vehicle traffic, traffic volumes over 9,000 vehicles per day, and travel speeds 35 mph or greater. Medians/refuge islands should be at least 4-f wide, but preferably 8 f for pedestrian comfort. Some example locations that may benefit from medians or pedestrian refuge islands include:

- Mid-block crossings.
- Approaches to multilane intersections.
- Areas near transit stops or other pedestrian-focused sites.



Example of a road with a median and pedestrian refuge islands. Source: City of Charlotte, NC



Median and pedestrian refuge island near a roundabout. Source: www.pedbikemages.org / Dan Burden

¹ National Center for Statistics and Analysis. (2020, March). Pedestrians: 2018 data (Traffic Safety Facts Report No. DOT HS 812 850).

² National Highway Traffic Safety Administration Desktop Reference for Crash Reduction Factors, FHWA-SA-08-011, September 2008, Table 11.



Pedestrian Refuge Islands

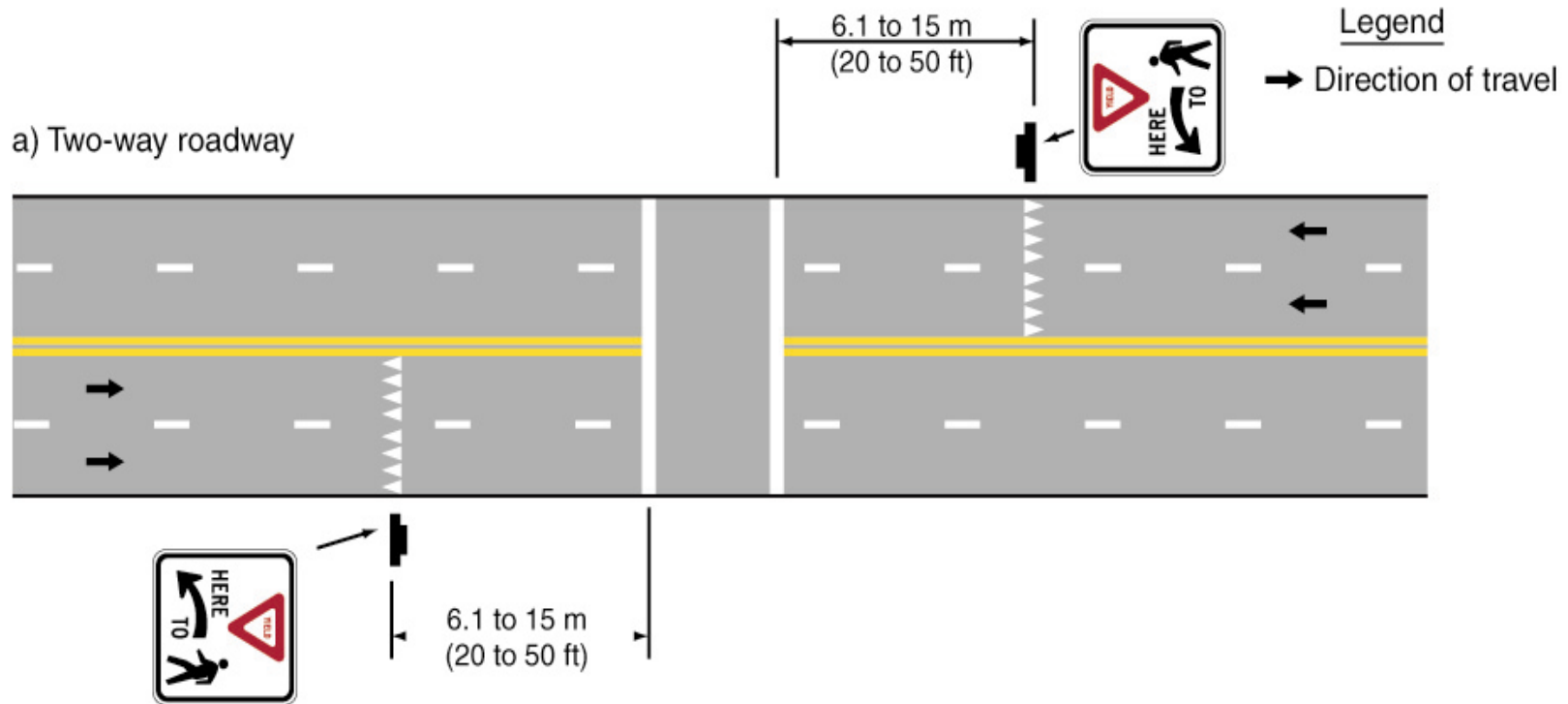
- Place along centerline or median
- Allows for two-stage pedestrian crossing
Easier to find gaps
- Allows place for supplemental left side
ped warning signs and flashers



Pedestrian Refuge Island (with curb extension)



“Yield Here to Pedestrians” sign R1-5



- Option at crosswalk with uncontrolled multi-lane approach (Typically mid-block; not at roundabouts)
- Option at single lane approaches to mid-block xwalk
- Undivided or Divided roadway. Yield line optional



“Yield Here to Pedestrians” sign R1-5



Section 2B.11

Sign shall be used if yield lines are used in advance of a marked crosswalk that crosses an uncontrolled multi-lane approach





Safety Benefits:
RRFBs can reduce
crashes up to:

47%

for pedestrian crashes.⁴

**RRFBs can increase motorist
yielding rates up to:**

98%

(varies by speed limit, number
of lanes, crossing distance,
and time of day).³



RRFBs used at a trail crossing.
Source: LJB

For more information on this
and other FHWA Proven Safety
Countermeasures, please
visit <https://safety.fhwa.dot.gov/provencountermeasures/>
and https://safety.fhwa.dot.gov/ped_bike/step/docs/techSheet_RRFB_2018.pdf.

Rectangular Rapid Flashing Beacons (RRFB)

A marked crosswalk or pedestrian warning sign can improve safety for pedestrians crossing the road, but at times may not be sufficient for drivers to visibly locate crossing locations and yield to pedestrians. To enhance pedestrian conspicuity and increase driver awareness at uncontrolled, marked crosswalks, transportation agencies can install a pedestrian actuated Rectangular Rapid Flashing Beacon (RRFB) to accompany a pedestrian warning sign. RRFBs consist of two, rectangular-shaped yellow indications, each with a light-emitting diode (LED)-array-based light source.¹ RRFBs flash with an alternating high frequency when activated to enhance conspicuity of pedestrians at the crossing to drivers.

For more information on using RRFBs, see the Interim Approval in the *Manual on Uniform Traffic Control Devices (MUTCD)*.¹

Applications

The RRFB is applicable to many types of pedestrian crossings but is particularly effective at multilane crossings with speed limits less than 40 miles per hour.² Research suggests RRFBs can result in motorist yielding rates as high as 98 percent at marked crosswalks, but varies depending on the location, posted speed limit, pedestrian crossing distance, one- versus two-way road, and the number of travel lanes.³ RRFBs can also accompany school or trail crossing warning signs.

RRFBs are placed on both sides of a crosswalk below the pedestrian crossing sign and above the diagonal downward arrow plaque pointing at the crossing.¹ The flashing pattern can be activated with pushbuttons or passive (e.g., video or infrared) pedestrian detection, and should be unlit when not activated.

Considerations

Agencies should:²

- Install RRFBs in the median rather than the far-side of the roadway if there is a pedestrian refuge or other type of median.
- Use solar-power panels to eliminate the need for a power source.
- Reserve the use of RRFBs for locations with significant pedestrian safety issues, as over-use of RRFB treatments may diminish their effectiveness.

Agencies shall not:²

- Use RRFBs without the presence of a pedestrian, school or trail crossing warning sign.
- Use RRFBs for crosswalks across approaches controlled by YIELD signs, STOP signs, traffic control signals, or pedestrian hybrid beacons, except for the approach or egress from a roundabout.

¹ *MUTCD Interim Approval 21 – RRFBs at Crosswalks*.

² "Rectangular Rapid Flash Beacon" in PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System. FHWA, (2013).

³ Fitzpatrick et al. "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. TI-CIS-0010. Texas A&M Transportation Institute, (2016).

⁴ NCHRP Research Report 841 Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments, (2017).



Pedestrians/School



RRFB – Rectangular rapid flashing beacon



Pedestrian Enhancements

- Use Zebra or Ladder markings, especially mid-block
- Use W11-2 Pedestrian warning signs
- Median Refuge Island and curb extensions
- Consider RRFB or flashing beacons. Push-button activated
- Consider “in-street pedestrian” R1-6 sign. Not recommended for 45 mph or greater



Traffic Safety Improvements: FHWA Resources

Federal Highway Administration (FHWA):

- safety.fhwa.dot.gov

Tabs for:

“Intersection Safety”

“Local and Rural Road Safety”

“Pedestrian and Bicycle Safety”



Federal Highway Administration
Proven Safety Countermeasures in
Rural Communities



U.S. Department of Transportation
Federal Highway Administration

ZERO IS OUR GOAL
A SAFE SYSTEM IS HOW WE GET THERE

FHWA-SA-24-005

Traffic Safety Improvements: FHWA Resources

Search: “Proven Safety Countermeasures 2021”

28 countermeasures as of Oct. 2021

“Proven” by in-field before/after crash studies

Descriptions of countermeasures, applications, crash reduction percentages, etc.



THANK YOU!

Questions?

