

MAKING OUR ROADS SAFER

One Countermeasure at a Time

28 Proven Safety Countermeasures that offer significant and measurable impacts to improving safety

U.S. Department of Transportation
Federal Highway Administration

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16. ABSTRACT

The Proven Safety Countermeasure Initiative (PSCi) is a collection of 28 countermeasures and strategieseffective in reducing roadway fatalities and serious injuries on our Nation's highways. Transportationagencies are strongly encouraged to consider widespread implementation of PSCs to accelerate theachievement of local, State, and National safety goals. This booklet provides 1-page handouts for all 28PSCs, broken into the focus areas of speed management, roadway departure, intersections,pedestrians/bicyclists, and crosscutting for countermeasures that apply across categories.

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OFFICE OF SAFETY

Proven Safety Countermeasures

SPEED MANAGEMENT


Speed Safety Cameras



Variable Speed Limits



Appropriate Speed Limits for All Road Users

ROADWAY DEPARTURE


Wider Edge Lines


Enhanced Delineation for Horizontal Curves


Longitudinal Rumble Strips and Stripes on Two-Lane Roads


SafetyEdge℠


Roadside Design Improvements at Curves


Median Barriers

INTERSECTIONS


Backplates with Retroreflective Borders


Corridor Access Management


Dedicated Left- and Right-Turn Lanes at Intersections


Reduced Left-Turn Conflict Intersections


Roundabouts


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


Yellow Change Intervals

PEDESTRIANS/BICYCLES


Crosswalk Visibility Enhancements


Bicycle Lanes


Rectangular Rapid Flashing Beacons (RRFB)


Leading Pedestrian Interval


Medians and Pedestrian Refuge Islands in Urban and Suburban Areas


Pedestrian Hybrid Beacons


Road Diets (Roadway Reconfiguration)


Walkways

Crosscutting


Pavement Friction Management


Lighting


Local Road Safety Plans


Road Safety Audit

Introduction

Widespread use of the 28 Proven Safety Countermeasures (PSCs) identified in this booklet can offer significant, measurable impacts as part of any agency's approach to improving safety. These strategies are designed for all road users and all kinds of roads—from rural to urban, from high-volume freeways to less traveled two-lane State and county roads, from signalized crossings to horizontal curves, and everything in between. Each countermeasure addresses at least one safety focus area – speed management, intersections, roadway departures, or pedestrians/bicyclists – while others are crosscutting strategies that address multiple safety focus areas.

Between 2016 and 2020, 85 percent[1] of all public highway fatalities occurred on Federal-aid highways, which represent 25 percent[2] of the entire public highway network. FHWA's partner agencies have invested in highway safety through the Highway Safety Improvement Program (HSIP), which provides targeted safety funding that is eligible for use on all public roads. However, this dedicated funding source represents only about 6 percent of the total Federal-aid program.[3] Every transportation project, whether or not the specific project purpose is safety related, is a new opportunity to save lives on our roadways. The FHWA's Proven Safety Countermeasures are eligible under most Federal-aid highway funding programs, and can support state, local, and tribal agency efforts to effectively accomplish goals to reduce fatalities and serious injuries. These countermeasures should serve as the basis for what agencies consider and implement when designing any highway project to improve safety.

To assist practitioners with determining the most appropriate PSC for their location of interest, the PSC webpage includes a filter tool that allows users to obtain a tailored listing of potential PSCs. Users answer questions regarding area types, functional classification, traffic volumes, issue identified, targeted crash types, and other information to receive a list of PSCs meeting thecriteria. This search function is intended to better serve practitioners, including those with limited safety background, when identifying and considering treatments and strategies that can improve safety as part of their program or project.

The PSCs can support agencies with implementation of the Safe System Approach, which seeks to build and reinforce multiple layers of protection to both prevent crashes from happening and minimize the harm caused to those involved when crashes do occur. Implementing a Safe System Approach requires collaborative engagement among a diverse group of stakeholders to increase safety for all road users. Accordingly, agencies should consider how the PSCs and National Highway Traffic Safety Administration's (NHTSA) Countermeasures That Work[4] can create a system with redundancies in place to protect all road users. Reaching our goal of zero deaths and serious injuries requires all of us to take ownership in safety. Together, we can consider the safety needs at every stage of the project development process, the safety impact of every investment decision, and the appropriate safety countermeasures for every Federal-aid project.

1 NHTSA Fatality Analysis Reporting System (FARS) 2016-2020 Final
2 FHWA Highway Statistics 2022 (https://www.fhwa.dot.gov/policyinformation/statistics/2022/hm16.cfm)
3 Federal-aid apportioned programs under the Infrastructure Investment and Jobs Act (IIJA) (https://www.fhwa.dot.gov/bipartisan-infrastructure-law/funding.cfm)
4 Countermeasures That Work (https://www.nhtsa.gov/book/countermeasures/countermeasures-that-work)

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Speed Safety Cameras

Safe Speeds is a core principle of the Safe System Approach since humans are less likely to survive high-speed crashes. Enforcing safe speeds has been challenging; however, with more information and tools communities can make progress in reducing speeds. Agencies can use speed safety cameras (SSCs) as an effective and reliable technology to supplement more traditional methods of enforcement, engineering measures, and education to alter the social norms of speeding. SSCs use speed measurement devices to detect speeding and capture photographic or video evidence of vehicles that are violating a set speed threshold.



Safety Benefits:

Fixed units can reduce crashes on urban principal arterials up to:

54% for all crashes.[4]

48% for injury crashes.[4]

P2P units can reduce crashes on urban expressways, freeways, and principal arterials up to:

37% for fatal and injury crashes.[2]

Mobile units can reduce crashes on urban principal arterials up to:

20% for fatal and injury crashes.[5]

In New York City, fixed units reduced speeding in school zones up to 63% during school hours.[6]

For more information on this and other FHWA Proven Safety Countermeasures, please reference the: Speed Safety Camera Program Planning and Operations Guide.

The contents of this Fact Sheet do not have the force and effect of law and are not meant to bind the public in any way. This Fact Sheet is intended only to provide clarity regarding existing requirements under the law or agency policies.

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Applications

Agencies should conduct a network analysis of speeding-related crashes to identify locations to implement SSCs. The analysis can include scope (e.g., widespread, localized), location types (e.g., urban/suburban/rural, work zones, residential, school zones), roadway types (e.g., expressways, arterials, local streets), times of day, and road users most affected by speed-related crashes (e.g., pedestrians, bicyclists).

SSCs can be deployed as:

- **Fixed units**—a single, stationary camera targeting one location.
- **Point-to-Point (P2P) units**—multiple cameras to capture average speed over a certain distance.
- **Mobile units**—a portable camera, generally in a vehicle or trailer.

The table below describes suitable circumstances for SSC deployment.[1]

Considerations

- SSCs can produce a crash reduction upstream and downstream, thus generating a spillover effect.[2]
- Public trust is essential for any type of enforcement. With proper controls in place, SSCs can offer fair and equitable enforcement of speeding, regardless of driver age, race, gender, or socio-economic status. SSCs should be planned with community input and equity impacts in mind.
- Using both overt (i.e., highly visible) and covert (i.e., hidden) enforcement may encourage drivers to comply with limits everywhere, not only at sites they are aware are enforced.
- Agencies should conduct evaluations regularly to determine if SSCs are accomplishing safety goals and whether changes in strategy, scheduling, communications, or public engagement are necessary.
- Agencies should conduct a legal and policy review to determine if SSCs are authorized within a jurisdiction and how the authorization and other traffic laws will affect a SSC program.
- Agencies should develop an SSC program plan with consideration of the USDOT SSC guidelines for planning, public involvement, stakeholder coordination, implementation, maintenance, evaluation, etc.[3]

Considerations for Selection	Fixed	P2P	Mobile
Problems are long-term and site-specific.	X	X	—
Problems are network-wide, and shift based on enforcement efforts.	—	—	X
Speeds at enforcement site vary largely from downstream sites.	—	X	X
Overt enforcement is legally required.	X	X	X
Sight distance for the enforcement unit is limited.	X	X	—
Enforcement sites are multilane facilities.	X	X	—

1 Speed Safety Camera Program Planning and Operations Guide. FHWA, (2023).
2 (CMF ID: 7718) Montella et al. "Effects on speed and safety of point-to-point speed enforcement systems". Accident Analysis and Prevention, Vol. 75, (2015). Note that this is an international study.
3 Speed Enforcement Camera Systems Operational Guidelines. NHTSA, (2008).
4 (CMF ID: 2915,2921) Shin et al. "Evaluation of the Scottsdale Loop 101 automated speed enforcement demonstration program." Accident Analysis and Prevention, Vol. 41, (2009).
5 (CMF ID: 7582) Li et al. "A Before-and-After Empirical Bayes Evaluation of Automated Mobile Speed Enforcement on Urban Arterial Roads." Presented at the 94th Annual Meeting of the Transportation Research Board, Paper No. 15-1563, Washington, D.C., (2015). Note that this is an international study.
6 Automated Speed Enforcement Program Report 2014-2017. New York City DOT, (2018).

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Variable Speed Limits

Selecting appropriate speed limits on roadways is important in maintaining a safe and efficient transportation network. Speed limits are established with an engineering study based on inputs like traffic volumes, operating speeds, roadway characteristics, and crash history. However, conditions on the roadway are susceptible to change in a short amount of time (e.g., congestion, crashes, weather). Drivers typically determine their operating speeds under normal weather conditions on a straight roadway section with good pavement quality and adequate sight distances. If ideal conditions do not exist and the roadway does not meet the driver's expectations, there is a greater chance that a driver error could result in a crash. Providing variable speeds limits (VSLs) capable of adapting to changing circumstances could reduce crash frequency and severity.

Speed management strategies, including VSLs, are integral to the Safe Speeds element of the Safe System Approach. Because humans are unlikely to survive high-speed crashes, VSLs reduce speeds so that human injury tolerances are accommodated in three ways: improving visibility, providing additional time for drivers to stop, and reducing impact forces.

Safety Benefits:

VSLs can reduce crashes on freeways up to:

34%
for total crashes.[1]

65%
for rear-end crashes.[1]

51%
for fatal and injury crashes.[1]

Benefit/Cost Ratios range between[1]

9:1 - 40:1

Applications

VSLs use prevailing information on the roadway, like traffic speed, volumes, weather, and road surface conditions, to determine appropriate speeds and display them to drivers. This strategy improves safety performance and traffic flow by reducing speed variance (i.e., improving speed harmonization). VSLs may also improve driver expectation by providing information in advance of slowdowns and potential lane closures, which could reduce the probability for secondary crashes. VSLs can mitigate adverse weather conditions or to slow faster-moving traffic as it approaches a queue or bottleneck.

Agencies can implement VSLs for the following applications:


CONGESTION


INCIDENTS


WORK ZONES


INCLEMENT WEATHER

Considerations

- Particularly effective on urban and rural freeways and high-speed arterials with posted speed limits greater than 40 mph.
- Often implemented as part of Active Traffic Management (ATM) plans or incorporated into existing Road Weather Information Systems.
- When used with ATM, VSLs can mitigate rear-end, sideswipe, and other crashes on high-speed roadways.
- May be implemented as a regulatory and/or an advisory system.
- Can be applied to an entire roadway segment or individual lanes.



Source: WSDOT

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/speed-management/reference-materials.

1 (CMF ID: 11002,11005,11003) Avelar et al. Developing Crash Modification Factors for Variable Speed Limit. FHWA, (2020).

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Appropriate Speed Limits for All Road Users

There is broad consensus among global roadway safety experts that speed control is one of the most important methods for reducing fatalities and serious injuries. Speed is an especially important factor on non-limited access roadways where vehicles and vulnerable road users mix.

A driver may not see or be aware of the conditions within a corridor, and may drive at a speed that feels reasonable for themselves but may not be for all users of the system, especially vulnerable road users, including children and seniors. A driver traveling at 30 miles per hour who hits a pedestrian has a 45 percent chance of killing or seriously injuring them.[1] At 20 miles per hour, that percentage drops to 5 percent.[1] A number of cities across the United States, including New York, Washington, Seattle and Minneapolis, have reduced their local speed limits in recent years in an effort to reduce fatalities and serious injuries, with most having to secure State legislative authorization to do so.

States and local jurisdictions should set appropriate speed limits to reduce the significant risks drivers impose on others—especially vulnerable road users—and on themselves. Addressing speed is fundamental to the Safe System Approach to making streets safer, and a growing body of research shows that speed limit changes alone can lead to measurable declines in speeds and crashes.[2]

Safety Benefits:

Traffic fatalities in the City of Seattle decreased 26 percent after the city implemented comprehensive, city-wide speed management strategies and countermeasures inspired by Vision Zero. This included setting speed limits on all non-arterial streets at 20 mph and 200 miles of arterial streets at 25 mph.[5]

One study found that on rural roads, when considering other relevant factors in the engineering study along with the speed distribution, setting a speed limit no more than 5 mph below the 85th-percentile speed may result in fewer total and fatal plus injury crashes, and lead to drivers complying closely with the posted speed limit.[6]

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/speed-management/reference-materials.

Applications

Posted speed limits are often the same as the legislative statutory speed limit. Agencies with designated authorities to set speed limits, which include States, and sometimes local jurisdictions, can establish non-statutory speed limits or designate reduced speed zones, and a growing number are doing so. While non-statutory speed limits must be based on an engineering study, conducted in accordance with the *Manual on Uniform Traffic Control Devices* (MUTCD) involving multiple factors and engineering judgment, FHWA is also encouraging agencies to use the following:[3]

- Expert Systems tools.
  - USLIMITS2.
  - NCHRP 966: Posted Speed Limit Setting Procedure and Tool.
- Safe System approach.

Based on international experience and implementation in the United States, the use of 20 mph speed zones or speed limits in urban core areas where vulnerable users share the road environment with motorists may result in further safety benefits.[4]

Considerations

When setting a speed limit, agencies should consider a range of factors such as pedestrian and bicyclist activity, crash history, land use context, intersection spacing, driveway density, roadway geometry, roadside conditions, roadway functional classification, traffic volume, and observed speeds.

To achieve desired speeds, agencies often implement other speed management strategies concurrently with setting speed limits, such as self-enforcing roadways, traffic calming, and speed safety cameras. Additional information is in the following FHWA resources:

- FHWA Speed Management website.
- Self-Enforcing Roadways: A Guidance Report.
- Noteworthy Speed Management Practices.
- Jurisdiction Speed Management Action Plan Development Package.
- Traffic Calming ePrimer.

1 Reducing the speed limit to 20 mph in urban areas: Child deaths and injuries would be decreased.
2 Lowering the speed limit from 30 to 25 mph in Boston: effects on vehicle speeds.
3 FHWA's Methods and Practices for Setting Speed Limits: An Informational Report, (2012).
4 Recommendations of the Academic Expert Group for the 3rd Global Ministerial Conference on Road Safety.
5 https://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa20047/sec8.cfm#foot813
6 Safety and Operational Impacts of Setting Speed Limits below Engineering Recommendations.

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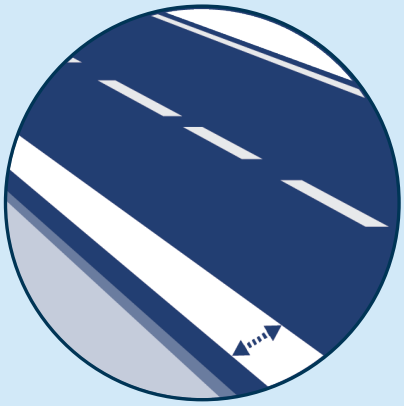

Wider Edge Lines

Roadway departures account for over half of all traffic fatalities in the United States. If drivers cannot clearly identify the edge of the travel lanes and see the road alignment ahead, the risk of roadway departure may be greater. Wider edge lines enhance the visibility of travel lane boundaries compared to traditional edge lines. Edge lines are considered "wider" when the marking width is increased from the minimum normal line width of 4 inches to the maximum normal line width of 6 inches.[1]

Safety Benefits:

Wider edge lines can reduce crashes up to:

37%
for non-intersection, fatal and injury crashes on rural, two-lane roads.[2]

22%
for fatal and injury crashes on rural freeways.[3]

Benefit Cost Ratio
25:1
for fatal and serious injury crashes on two-lane rural roads.[4]

Applications

Wider edge lines increase drivers' perception of the edge of the travel lane and can provide a safety benefit to all facility types (e.g., freeways, multilane divided and undivided highways, two-lane highways) in both urban and rural areas.[2] Wider edge lines are most effective in reducing crashes on rural two-lane highways, especially for single-vehicle crashes.[3] Agencies should also consider implementing a systemic approach to wider edge line installation based roadway departure crash risk factors. Potential risk factors for two-lane rural roads include:

- Pavement and shoulder widths.
- Presence of curves.
- Traffic volumes.
- History of nighttime crashes.

Considerations

- Wider edge lines are relatively low cost.
- Wider edge lines can be implemented using existing equipment during maintenance procedures like re-striping and resurfacing, with the only cost increase being the additional material.
- Paint may have a lower initial cost, but more durable materials (e.g., thermoplastic) may result in a lower life cycle cost based on their longer service life.
- As the number of automated vehicles increases on roadways, wider edge lines may provide better guidance for these vehicles' sensors.



Source: Texas Transportation Institute

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/other/visibility/pavement-markings.

1 Manual on Uniform Traffic Control Devices (MUTCD), Section 3A.04. FHWA, (2023).
2 (CMF ID: 4737) Park et al. "Safety effects of wider edge lines on rural, two-lane highways." Accident Analysis and Prevention Vol. 48, pp.317-325, (2012).
3 Potts et al. Benefit/Cost Evaluation of MoDOT's Total Striping and Delineation Program: Phase II. Missouri Department of Transportation, (2011).
4 Abdel-Rahim et al. Safety Impacts of Using Wider Pavement Markings on Two-Lane Rural Highways in Idaho. Idaho Transportation Department, (2018).

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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.[4]

In-Lane Curve Warning Pavement Markings

35 - 38% reduction in all crashes.[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://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/rwd/keep-vehicles-road/horizontal-curve-safety.

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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 (CMF ID: 2439,2431,2432) Albin et al. Low-Cost Treatments for Horizontal Curve Safety 2016. FHWA-SA-15-084, (2016).
2 (CMF ID: 2438) Srinivasan et al. Safety Evaluation of Improved Curve Delineation. FHWA-HRT-09-045, (2009).
3 (CMF ID: 8978) 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 (CMF ID: 10362) Hallmark, S. Evaluation of Sequential Dynamic Chevrons on Rural Two-lane Highways. FHWA, (2017).
5 (CMF ID: 10312,9167) Donnell et al. Reducing Roadway Departure Crashes at Horizontal Curve Sections on Two-lane Rural Highways. FHWA-SA-19-005, (2019).

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Longitudinal Rumble Strips and Stripes

Longitudinal rumble strips are milled or raised elements on the pavement intended to alert drivers through vibration and sound that their vehicle has left the travel lane. They can be installed on the shoulder, edge line, or at or near the center line of an undivided roadway.

Rumble stripes are edge line or center line rumble strips where the pavement marking is placed over the rumble strip. This can increase the visibility and durability of the pavement marking during wet, nighttime conditions, and can improve the durability of the marking on roads with snowplowing operations.

Safety Benefits:

Center Line Rumble Strips

44-64%

reduction in head-on fatal and injury crashes on two-lane rural roads.[4]

Shoulder Rumble Strips

13-51%

reduction in single vehicle, run-off-road fatal and injury crashes on two-lane rural roads.[4]

With roadway departure crashes accounting for more than half of the fatal roadway crashes annually in the United States, rumble strips and stripes are designed to address these crashes by alerting distracted, drowsy, or otherwise inattentive drivers who drift from their lane. They are most effective when deployed systemically.

Transportation agencies should consider milled center line rumble strips (including in passing zone areas) and milled edge line or shoulder rumble strips with bicycle gaps for systemic safety projects, location-specific corridor safety improvements, as well as reconstruction or resurfacing projects.

Considerations

- Rumble strips are relatively low-cost, and economic analyses have indicated benefit/cost ratios that exceed 100.[1]
- Where rumble strips cannot be placed due to noise concerns, agencies may consider a design using an oscillating sine wave pattern (also known as "mumble strips") that reduces noise outside of the vehicle. However, the safety benefits of this design need more study.[2]
- Maintenance concerns:
  - Where rumble strips are placed along a pavement joint, there are typically no issues with joint stability if the pavement structure and joint was already in good condition.
  - Studies have shown no evidence of issues related to snow, ice, or rain build-up in the rumble strip.[3]



Shoulder rumble strips and center line rumble stripes are installed on this roadway. Source: FHWA



Example of an edge line rumble stripe. Source: Missouri DOT

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/rwd/keep-vehicles-road/rumble-strips.

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1 Himes, S., and McGee, H. Decision Support Guide for the Installation of Shoulder and Center Line Rumble Strips on Non-Freeways. Federal Highway Administration Report No. FHWA-SA-16-115. (August 2016).
2 Bedsole et al. *Did You Hear That?* Public Roads Magazine, Volume 80, No. 4. FHWA Publication No. FHWA-HRT-17-002, (2017).
3 NCHRP Synthesis 339: Centerline Rumble Strips – A Synthesis of Highway Practices, (2005
4 (CMF ID: 3358, 3356, 3425, 3648) NCHRP Report 641: Guidance for the Design and Application of Shoulder and Centerline Rumble Strips, (2009).

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SafetyEdge℠

The SafetyEdge℠ technology shapes the edge of the pavement at approximately 30 degrees from the pavement cross slope during the paving process. This safety practice eliminates the potential for vertical drop-off at the pavement edge, has minimal effect on project cost, and can improve pavement durability by reducing edge raveling of asphalt.

Safety Benefits:

11%
reduction in fatal and injury crashes.[2]

21%
reduction in run-off-road crashes.[2]

19%
reduction in head-on crashes.[2]

Benefit-Cost Ratio Range[3]

700:1 to 1,500:1

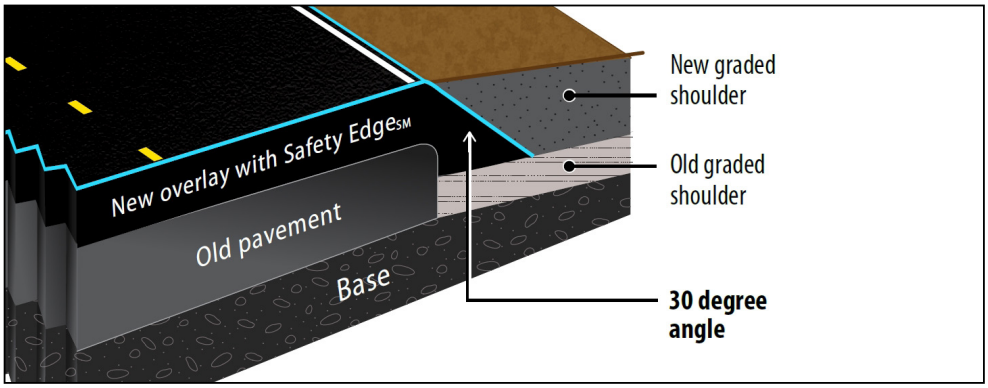
Rural road crashes involving edge drop-offs are 2-4 times more likely to include a fatality than other crashes on similar roads.[1] Vehicles may leave the roadway for various reasons ranging from distracted driver errors to low visibility, or to the presence of an animal on the road. Exposed vertical pavement edges can cause vehicles to become unstable and prevent their safe return to the roadway. The SafetyEdge℠ gives drivers the opportunity to return to their travel lane while maintaining control of their vehicle.

The SafetyEdge℠ technology only requires adding one of several commercially available devices to the screed or endgate when placing hot-mix asphalt. Forms for shaping the edge of concrete pavement are simpler and can be made on site by the contractor. Some agencies allow the SafetyEdge℠ to remain exposed while a segment is under construction, unlike conventional pavement edges. However, before construction ends, agencies should bring the adjacent roadside flush with the top of the pavement for both the SafetyEdge℠ and traditional pavement edge. Over time, regardless of the edge type, the edge may become exposed due to settling, erosion, and tire wear. When this occurs, the gentle slope provided by the SafetyEdge℠ is preferred versus the traditional vertical pavement edge.

Transportation agencies should develop standards for implementing the SafetyEdge℠ systemwide on all new asphalt paving and resurfacing projects where curbs and/or guardrail are not present, while also encouraging standard application for concrete pavements.



Example of the SafetyEdge℠ after backfill material settles or erodes. Source: FHWA



Cross-section view of an overlay with the SafetyEdge℠. Source: FHWA-SA-17-044

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/rwd/provide-safe-recovery/safetyedge.

FHWA-SA-21-038

1 Hallmark et al. Safety Impacts of Pavement Edge Drop-offs, (Washington, DC: AAA Foundation for Traffic Safety: 2006), p 93.
2 (CMF ID: 9205, 9211, 9217) Donnell et al. Development of Crash Modification Factors for the Application of the SafetyEdge℠ on Two-Lane Rural Roads. FHWA-HRT-17-081, (2017).
3 Safety Effects of the SafetyEdge℠, FHWA-SA-17-044, (2017).

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Safety Benefits:

Flatten sideslope from 1V:3H to 1V:4H:

8%

reduction for single-vehicle crashes.[2]

Flatten sideslope from 1V:4H to 1V:6H:

12%

reduction for single-vehicle crashes.[2]

Increase the distance to roadside features from 3.3 ft to 16.7 ft:

22%

reduction for all crashes.[3]

Increase the distance to roadside features from 16.7 ft to 30 ft:

44%

reduction for all crashes.[3]

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/rwd/provide-safe-recovery/clear-zones/clear-zones.

FHWA-SA-21-029

Roadside Design Improvements at Curves

Horizontal curves account for 27 percent of all fatal crashes and 80 percent of all fatal crashes at curves are roadway departure crashes.[1] Roadside design improvements at curves is a strategy encompassing several treatments that target the high-risk roadside environment along the outside of horizontal curves. These treatments can reduce roadway departure fatalities and serious injuries by giving vehicles the opportunity to recover safely and by reducing crash severity.

Roadside design improvements can be implemented alone or in combination, and are particularly recommended at horizontal curves—where data indicates a higher risk for roadway departure fatalities and serious injuries.

Roadside Design Improvements to Provide for a Safe Recovery

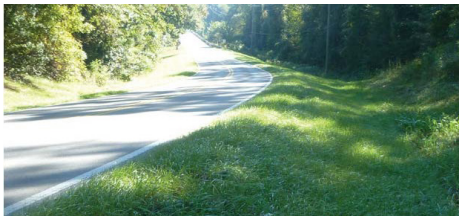
In cases where a vehicle leaves the roadway, having strategic roadside design elements, including an added or widened shoulder, flattened sideslopes, or a widened clear zone can provide drivers with an opportunity to regain control and re-enter the roadway in their lane or come to a safe stop before rolling over or encountering a fixed object.

- A **clear zone** is an unobstructed, traversable roadside area that allows a driver to stop safely or regain control of a vehicle that has left the roadway. Agencies should avoid adding new fixed objects such as trees and utility cabinets or poles in the clear zone. AASHTO's *Roadside Design Guide* details the clear zone width adjustment factors to be applied at horizontal curves.
- **Slope flattening** reduces the steepness of the sideslope to increase drivers' ability to keep the vehicle stable, regain control of the vehicle, and avoid obstacles. Slopes of 1V:4H or flatter are considered recoverable (i.e., drivers can retain control of a vehicle by slowing or stopping). Slopes between 1V:3H and 1V:4H are generally considered traversable, but non-recoverable (i.e., errant vehicle will continue to the bottom of the slope).
- **Adding or widening shoulders** gives drivers more recovery area to regain control in the event of a roadway departure.

Roadside Design Improvements to Reduce Crash Severity

Since not all roadside hazards can be removed, relocated, or redesigned at curves, installing roadside barriers to shield unmovable objects or steep embankments may be an appropriate treatment. Three common types of roadside barriers are:

- **Cable barrier** is a flexible barrier made from steel cables mounted on weak steel posts. Flexible barriers are more forgiving and have the most deflection.
- **Metal-beam guardrail** is a semi-rigid barrier where a W-beam or box-beam is mounted on steel or timber posts. These deflect less than cable barriers, so they can be located closer to objects where space is limited.
- **Concrete barrier** is a rigid barrier that has little to no deflection.



Clear zone provided on the outside of the curve. Source: FHWA.

1 Fatality Analysis Reporting System.
2 (CMF ID: 4627,4632) NCHRP Report 617: Accident Modification Factors for Traffic Engineering and ITS Improvements, (2008).
3 (CMF ID: 35,36) Elvik, R., and Vaa, T. Handbook of Road Safety Measures, (2004).

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8%

of all fatalities on divided highways are due to head-on crashes.[1]

Safety Benefits:

Median Barriers Installed on Rural Four-Lane Freeways

97%

reduction in cross-median crashes.[2]

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/rwd/reduce-crash-severity.

FHWA-SA-21-037

Median Barriers

Median barriers are longitudinal barriers that separate opposing traffic on a divided highway and are designed to redirect vehicles striking either side of the barrier. Median barriers significantly reduce the number of cross-median crashes, which are attributed to the relatively high speeds that are typical on divided highways. AASHTO's ***Roadside Design Guide*** (RDG) recommends guidelines for the use of median barriers on high-speed, fully controlled-access roadways for locations where the median is 30 ft in width or less and the average daily traffic (ADT) is greater than 20,000 vehicles per day (vpd). For locations with median widths greater than 50 ft and where the ADT is less than 20,000 vpd, a median barrier is optional. For locations where the median is between 30 and 50 feet, the RDG suggests an analysis to determine the cost effectiveness of median barrier installation. Median barriers can be cable, metal-beam, or concrete.

- **Cable barriers** are flexible barriers, made from steel cables mounted on weak steel posts, resulting in less occupant impact force as it absorbs energy from the crash, capturing or redirecting the vehicle. Due to larger deflection, median width is an important consideration. These barriers are more adaptable to slopes typically found in medians. Cable barriers tend to require more frequent maintenance and repair than other barrier types.
- **Metal-beam guardrails** are considered semi-rigid barriers, where the W-beam or box-beam is mounted to steel or timber posts. When impacted, they are designed to deform and deflect, absorbing some of the crash energy and redirecting the vehicle. Metal-beam guardrails often do not require maintenance after minor impacts. They deflect less than cable barriers, so they can be located closer to objects where space is limited.
- **Concrete barriers** are usually rigid and result in little to no deflection. They redirect rather than absorb energy from the impact. Rigid concrete barriers seldom require repair or maintenance. Some agencies have used portable concrete barriers as median barriers. These barriers require repositioning after an impact but are typically less maintenance than a post mounted barrier.

To reduce cross-median crashes, transportation agencies should review their head-on crash history on divided highways to identify hot spots. Agencies should also consider implementing a systemic approach to median barrier placement based on cross-median crash risk factors. Potential risk factors include:

- Traffic volumes.
- Vehicle classifications.
- Median crossover history.
- Crash incidents.
- Vertical and horizontal alignment.
- Median terrain configurations.



Median cable barrier prevents a potential head-on crash.
Source: Washington State DOT

1 Fatality Analysis Reporting System.
2 (CMF ID: 7040) NCHRP Report 794: Median Cross-Section Design for Rural Divided Highways, (2011).

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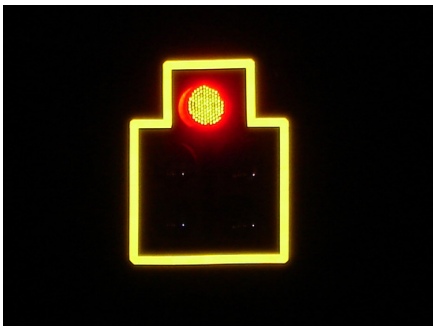
Backplates with Retroreflective Borders

Backplates added to a traffic signal head improve the visibility of the illuminated face of the signal by introducing a controlled-contrast background. The improved visibility of a signal head with a backplate is made even more conspicuous by framing it with a 1- to 3-inch yellow retroreflective border. Signal heads that have backplates equipped with retroreflective borders are more visible and conspicuous in both daytime and nighttime conditions.

Safety Benefits:

15%
reduction in total crashes.[1]

This treatment is recognized as a human factors enhancement of traffic signal visibility, conspicuity, and orientation for both older and color vision deficient drivers. This countermeasure is also advantageous during periods of power outages when the signals would otherwise be dark, providing a visible cue for motorists to stop at the intersection ahead.



Retroreflective borders are highly visible during the night. Source: South Carolina DOT

Considerations

Transportation agencies should consider backplates with retroreflective borders as part of their efforts to systematically improve safety performance at signalized intersections. Adding a retroreflective border to an existing signal backplate is a very low-cost safety treatment. This can be done by either adding retroreflective tape to an existing backplate or purchasing a new backplate with a retroreflective border already incorporated. The most efficient means of implementing this proven safety countermeasure is to adopt it as a standard treatment for signalized intersections across a jurisdiction or State.

Implementation challenges include minimizing installation time, accessing existing signal heads, and structural limitations due to added wind load in instances where an entire backplate is added. Agencies should consider the design of the existing signal support structure to determine if the design is sufficient to support the added wind load.



Signal backplate framed with a retroreflective border. Source: FHWA

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://rosap.ntl.bts.gov/view/dot/42807.

1 (CMF ID: 1410) Sayed, T., Leur, P., and Pump, J., "Safety Impact of Increased Traffic Signal Backboards Conspicuity." 2005 TRB 84th Annual Meeting: Compendium of Papers CD-ROM, Vol. TRB#05-16, Washington, D.C., (2005).

FHWA-SA-21-039

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Safety Benefits:

Reducing driveway density

5-23%
reduction in total crashes along 2-lane rural roads.[3]

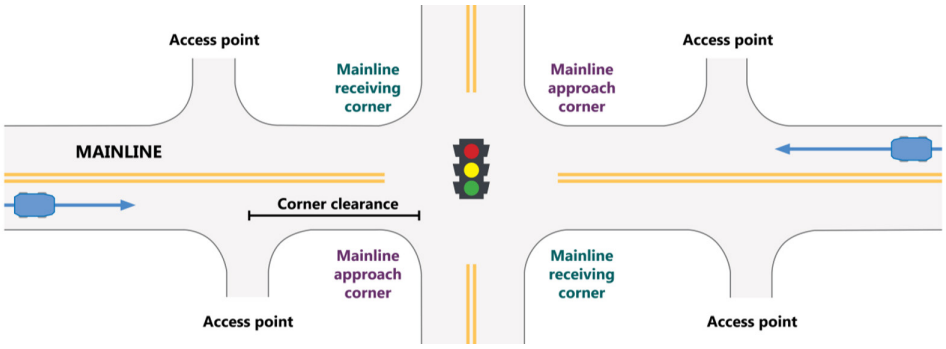
25-31%
reduction in fatal and injury crashes along urban/ suburban arterials.[4]

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/intersection-safety/cam.

FHWA-SA-21-040

Corridor Access Management

Access management refers to the design, application, and control of entry and exit points along a roadway. This includes intersections with other roads and driveways that serve adjacent properties. Thoughtful access management along a corridor can simultaneously enhance safety for all modes, facilitate walking and biking, and reduce trip delay and congestion.



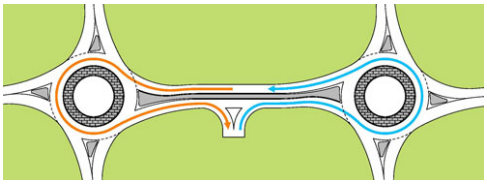
Schematic of an intersection and adjacent access points. Source: FHWA

Every intersection, from a signalized intersection to an unpaved driveway, has the potential for conflicts between vehicles, pedestrians, and bicyclists. The number and types of conflict points—locations where the travel paths of two users intersect—influence the safety performance of the intersection or driveway. FHWA developed corridor-level crash prediction models to estimate and analyze the safety effects of selected access management techniques for different area types, land uses, roadway variables, and traffic volumes.[1]

The following access management strategies can be used individually or in combination with one another:

- Reduce density through driveway closure, consolidation, or relocation.
- Manage spacing of intersection and access points.
- Limit allowable movements at driveways (such as right-in/ right-out only).
- Place driveways on an intersection approach corner rather than a receiving corner, which is expected to have fewer total crashes.[2]
- Implement raised medians that preclude across-roadway movements.
- Utilize designs such as roundabouts or reduced left-turn conflicts (such as restricted crossing U-turn, median U-turns, etc.).
- Provide turn lanes (i.e., left-only, right-only, or interior two-way left).
- Use lower speed one-way or two-way off-arterial circulation roads.

Successful corridor access management involves balancing overall safety and mobility for all users along with the needs of adjacent land uses.



Tandem roundabouts with a continuous raised median eliminates left-turn and across-roadway conflicts. Source: FHWA

1 Gross et al. Safety Evaluation of Access Management Policies and Techniques. FHWA-HRT-14-057, (2018).
2 Le et al. Safety Evaluation of Corner Clearance at Signalized Intersections. FHWA-HRT-17-084, (2018).
3 Harwood et al. Prediction of the Expected Safety Performance of Rural Two-Lane Highways. FHWA-RD-99-207, (2000).
4 (CMF ID: 179,178) Elvik, R. and Vaa, T., Handbook of Road Safety Measures. Oxford, United Kingdom, Elsevier, (2004).

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Dedicated Left- and Right-Turn Lanes at Intersections

Auxiliary turn lanes—either for left turns or right turns—provide physical separation between turning traffic that is slowing or stopped and adjacent through traffic at approaches to intersections. Turn lanes can be designed to provide for deceleration prior to a turn, as well as for storage of vehicles that are stopped and waiting for the opportunity to complete a turn.

Safety Benefits:

Left-Turn Lanes

28-48%

reduction in total crashes.[1]

Positive Offset Left-Turn Lanes

36%

reduction in fatal and injury crashes.[2]

Right-Turn Lanes

14-26%

reduction in total crashes.[1]



Left- and right-turn lanes at a two-way stop-controlled intersection. Source: City of Greeley, CO

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://www.fhwa.dot.gov/publications/research/safety/02103/02103techbrief.pdf.

FHWA-SA-21-041

While turn lanes provide measurable safety and operational benefits at many types of intersections, they are particularly helpful at two-way stop-controlled intersections. Crashes occurring at these intersections are often related to turning maneuvers. Since the major route traffic is free flowing and typically travels at higher speeds, crashes that do occur are often severe. The main crash types include collisions of vehicles turning left across opposing through traffic and rear-end collisions of vehicles turning left or right with other vehicles following closely behind. Turn lanes reduce the potential for these types of crashes.

Installing left-turn lanes and/or right-turn lanes should be considered for the major road approaches for improving safety at both three- and four-leg intersections with stop control on the minor road, where significant turning volumes exist, or where there is a history of turn-related crashes. Pedestrian and bicyclist safety and convenience should also be considered when adding turn lanes at an intersection. Specifically, offset left- and right-turn lanes will lengthen crossing distances for pedestrians.

Offset Turn Lanes

Providing offset of left- and right-turn lanes to increase visibility can provide added safety benefits, and is preferable in many situations, particularly at locations with higher speeds, or where free-flow or permissive movements are possible.

At turn lanes with zero or negative offset, turning vehicles can block sightlines. For left-turn lanes, this usually involves opposing left-turning vehicles occupying the turn lanes at the same time. For right-turn lanes, this typically involves right-turning vehicles from the major road and vehicles entering the intersection from the minor road. In both scenarios, adding positive offset to turn lanes enhances the sight distance to approaching vehicles that conflict with the turning movement. Offset turn lanes should be considered when there is a high frequency of these types of conflicts in order to reduce the likelihood of a severe crash.

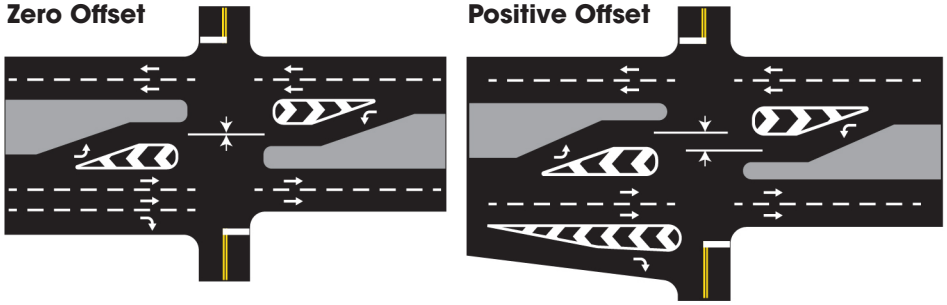

Illustration comparing zero offset to positive offset of left- and right-turn lanes. Source: FHWA

1 (CMF ID: 260, 268, 285, 289) Harwood et al. Safety Effectiveness of Intersection Left- and Right-Turn Lanes. FHWA-HRD-02-089, (2002).
2 (CMF ID: 6096) Persaud et al. Safety Evaluation of Offset Improvements for Left-Turn Lanes. FHWA-HRT-09-035, (2009).

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Safety Benefits:

RCUT

Two-Way Stop-Controlled to RCUT:

54%

reduction in fatal and injury crashes.[2]

Signalized Intersection to Signalized RCUT:

22%

reduction in fatal and injury crashes.[3]

Unsignalized Intersection to Unsignalized RCUT:

63%

reduction in fatal and injury crashes. [4]

MUT

30%

reduction in intersection-related injury crash rate.[5]

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/intersection-safety/intersection-types/reduced-left-turn-conflict-intersections.

FHWA-SA-21-030

Reduced Left-Turn Conflict Intersections

Reduced left-turn conflict intersections are geometric designs that alter how left-turn movements occur. These intersections simplify decision-making for drivers and minimize the potential for higher severity crash types, such as head-on and angle. Two highly effective designs that rely on U-turns to complete certain left-turn movements are known as the Restricted Crossing U-turn (RCUT) and the Median U-turn (MUT).

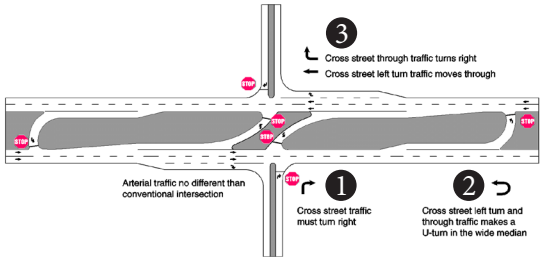
Restricted Crossing U-turn

The RCUT intersection, also known as a J-Turn, Superstreet, or Reduced Conflict Intersection, modifies the direct left-turn and through movements from cross-street approaches. Minor road traffic makes a right turn followed by a U-turn at a designated location—either signalized or unsignalized—to continue in the desired direction. The RCUT is suitable for and adaptable to a wide variety of circumstances, ranging from isolated rural, high-speed locations to urban and suburban high-volume, multimodal corridors. It is a competitive and less costly alternative to constructing an interchange. RCUTs work well when consistently used along a corridor, but also can be used effectively at individual intersections. Studies have shown that installing an RCUT can result in a 30-percent increase in throughput and a 40-percent reduction in network intersection travel time.[1]

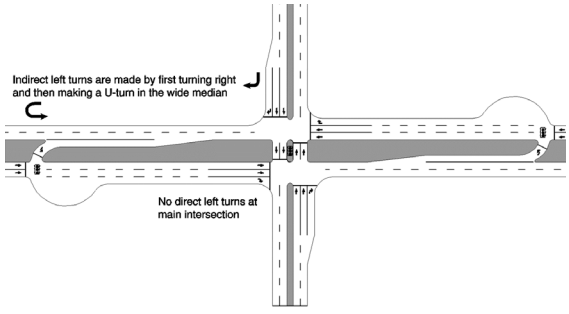
Median U-turn

The MUT intersection modifies direct left turns from the major approaches. Vehicles proceed through the main intersection, make a U-turn a short distance downstream, followed by a right turn at the main intersection. The U-turns can also be used for modifying the cross-street left turns, similar to the RCUT.

The MUT is an excellent choice for intersections with heavy through traffic and moderate left-turn volumes. Studies have shown a 20- to 50-percent improvement in intersection throughput for various lane configurations as a result of implementing the MUT design. When implemented at multiple intersections along a corridor, the efficient two-phase signal operation of the MUT can reduce delay, improve travel times, and create more crossing opportunities for pedestrians and bicyclists.



Example of a unsignalized RCUT intersection. Source: FHWA



Example of a MUT intersection. Source: FHWA

1 Hugher and Jagannathan. Restricted Crossing U-Turn Intersection. FHWA-HRT-09-059, (2009).
2 (CMF ID: 5556) Edara et al. Evaluation of J-turn Intersection Design Performance in Missouri. MoDOT, (2013).
3 (CMF ID: 9985) Hummer and Rao. Safety Evaluation of a Signalized Restricted Crossing U-Turn. FHWA-HRT-17-082, (2017).
4 (CMF ID: 4884) Hummer et al. Superstreet Benefits and Capacities. FHWA/NC/2009-06, NC State University, (2010).
5 (CMF ID: 10867) Synthesis of the Median U-Turn Treatment, Safety, and Operational Benefits, FHWA-HRT-07-033, (2007).

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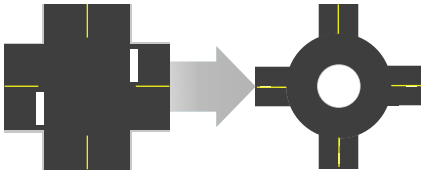
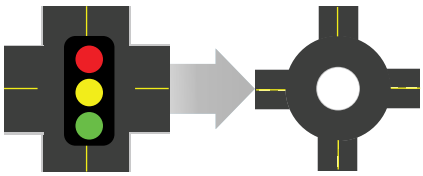
Safety Benefits:

Two-Way Stop-Controlled Intersection to a Roundabout



82%
reduction in fatal and injury crashes.[1]

Signalized Intersection to a Roundabout



78%
reduction in fatal and injury crashes.[1]

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/intersection-safety/intersection-types/roundabouts.

FHWA-SA-21-042

Roundabouts

The modern roundabout is an intersection with a circular configuration that safely and efficiently moves traffic. Roundabouts feature channelized, curved approaches that reduce vehicle speed, entry yield control that gives right-of-way to circulating traffic, and counterclockwise flow around a central island that minimizes conflict points. The net result of lower speeds and reduced conflicts at roundabouts is an environment where crashes that cause injury or fatality are substantially reduced.

Roundabouts are not only a safer type of intersection; they are also efficient in terms of keeping people moving. Even while calming traffic, they can reduce delay and queuing when compared to other intersection alternatives. Furthermore, the lower vehicular speeds and reduced conflict environment can create a more suitable environment for walking and bicycling.

Roundabouts can be implemented in both urban and rural areas under a wide range of traffic conditions. They can replace signals, two-way stop controls, and all-way stop controls. Roundabouts are an effective option for managing speed and transitioning traffic from high-speed to low-speed environments, such as freeway interchange ramp terminals, and rural intersections along high-speed roads.



Illustration of a multilane roundabout. Source: FHWA



Example of a single-lane roundabout. Source: FHWA

1 (CMF ID: 211,226) AASHTO. The Highway Safety Manual, American Association of State Highway Transportation Professionals, Washington, D.C., (2010).

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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.

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://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/fhwasa18047.pdf.

FHWA-SA-21-031

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.

Source: (CMF ID: 8867, 8870, 8874, 8893) T. Le et al. "Safety Effects of Low-Cost Systemic Safety Improvements at Signalized and Stop-Controlled Intersections," 96th Annual Meeting of the Transportation Research Board, Paper Number 17-05379, January 2017.

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Safety Benefits:

36-50%
reduction in red light running.[3]

8-14%
reduction in total crashes.[3]

12%
reduction in injury crashes.[3]

Yellow Change Intervals

At a signalized intersection, the yellow change interval is the length of time that the yellow signal indication is displayed following a green signal indication. The yellow signal confirms to motorists that the green has ended and that a red will soon follow.

Since red-light running is a leading cause of severe crashes at signalized intersections, it is imperative that the yellow change interval be appropriately timed. Too brief an interval may result in drivers being unable to stop safely and cause unintentional red-light running. Too long of an interval may result in drivers treating the yellow as an extension of the green phase and invite intentional red-light running. Factors such as the speed of approaching and turning vehicles, driver perception-reaction time, vehicle deceleration, and intersection geometry should all be considered in the timing calculation.

Transportation agencies can improve signalized intersection safety and reduce red-light running by reviewing and updating their traffic signal timing policies and procedures concerning the yellow change interval. Agencies should institute regular evaluation and adjustment protocols for existing traffic signal timing. Refer to the *Manual on Uniform Traffic Control Devices* for basic requirements and further recommendations about yellow change interval timing.[1] As part of strategic signal system modernization and updates, incorporating automated traffic signal performance measures (ATSPMs) is a proven approach to improve on traditional retiming processes. ATSPMs provide continuous performance monitoring capability and the ability to modify timing based on actual performance, without requiring expensive modeling or data collection.[2]



Appropriately timed yellow change intervals can reduce red-light running and improve overall intersection safety. Source: FHWA

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/fhwasa13027.pdf.

1 Manual on Uniform Traffic Control Devices (MUTCD), Section 4F.17. FHWA, (2023).
2 Federal Highway Administration. "Automated Traffic Signal Performance," (2020).
3 (CMF ID: 380,384) NCHRP Report 731: Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections, (2011).

FHWA-SA-21-043

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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.

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]

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 inlay 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 for 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

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/techSheetVizEnhancemt2018.pdf.

1 (CMF ID: 4123) 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 (CMF ID: 436) Elvik, R. and Vaa, T. Handbook of Road Safety Measures. Oxford, United Kingdom, Elsevier, (2004).
3 (CMF ID: 9017) Zeeger et al. Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments, FHWA, (2017).

Transportation agencies should refer to the Manual on Uniform Traffic Control Devices (MUTCD) for information on crosswalk markings (Chapter 3C) and in-street signing (Sections 2B.19 and 2B.20).

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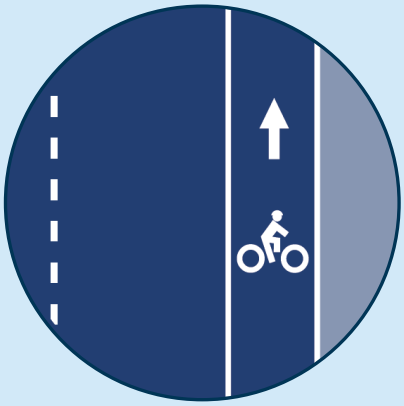

Bicycle Lanes

Most fatal and serious injury bicyclist crashes occur at non-intersection locations. Nearly one-third of these crashes occur when motorists are overtaking bicyclists[1] because the speed and size differential between vehicles and bicycles can lead to severe injury. Many people are not comfortable riding a bicycle because of their fear that this type of crash may occur. To make bicycling safer and more comfortable for most types of bicyclists, State and local agencies should consider installing bicycle lanes. Providing bicycle facilities can mitigate or prevent interactions, conflicts, and crashes between bicyclists and motor vehicles, and create a network of safer roadways for bicycling. Bicycle Lanes align with the Safe System Approach principle of recognizing human vulnerability—where separating users in space can enhance safety for all road users.

Safety Benefits:

Converting traditional or flush buffered bicycle lanes to a separated bicycle lane with flexible delineator posts can reduce crashes up to:

53%

for bicycle/vehicle crashes.[3]

Bicycle Lane Additions can reduce crashes up to:

49%

for total crashes on urban 4-lane undivided collectors and local roads.[7]

30%

for total crashes on urban 2-lane undivided collectors and local roads.[7]



Bicycle lane in Washington, DC. Source: Alex Baca, Washington Area Bicyclist Association.

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-07/fhwasa18077.pdf.

Applications

The FHWA's *Bikeway Selection Guide* and *Incorporating On-Road Bicycle Networks into Resurfacing Projects* assist agencies in determining which facilities provide the most benefit in various contexts. Bicycle lanes can be included on new roadways or created on existing roads by reallocating space in the right-of-way through *Road Diets*. Separated bicycle lanes, which use vertical elements—such as flexible delineator posts, curbs, or vegetation—between the bicycle lane and motorized traffic lanes provide additional safety benefits.[2,3] For a marked bike lane without vertical elements, a lateral offset with marked buffer can help to further separate bicyclists from vehicle traffic.

Considerations

- In order to maximize a roadway's suitability for riders of all ages and abilities, bicycle lane design should vary according to roadway characteristics (number of lanes, motor vehicle and truck volumes, speed, presence of transit), user needs (current and forecasted ridership, types of bicycles and micromobility devices in use within the community, role within the bicycling network), and land-use context (adjacent land uses, types and intensity of conflicting uses, demands from other users for curbside access). Separated bicycle lanes are recommended on roadways with higher vehicle volumes and speeds, such as arterials.
- City and State policies may require minimum bicycle lane widths, although desirable bicycle lane widths can differ by agency and functional classification of the road, current and forecasted bicycle volumes, and contextual attributes such as topography.
- Studies have found that roadways did not experience an increase in crashes or congestion when travel lane widths were decreased to add a bicycle lane.[4]
- Studies and experience in U.S. cities show that bicycle lanes increase ridership and may help jurisdictions better manage roadway capacity.
- In rural areas, rumble strips can negatively impact bicyclists' ability to ride if not properly installed. Agencies should consider the dimensions, placement, and offset of rumble strips when adding a bicycle lane.[5]
- Bicycle lanes should be considered on roadways where adjacent land use suggests that trips could be served by varied modes, particularly to meet the safety and travel needs of low-income populations likely to use bicycles to reach essential destinations.[6]

1 Thomas et al. *Bicyclist Crash Types on National, State, and Local Levels: A New Look*. Transportation Research Record 673(6), 664-676, (2019).
2 Separated Bike Lane Planning and Design Guide. FHWA-HEP-15-025, (2015).
3 (CMF ID: 11296) Developing CMFs for Separated Bicycle Lanes. FHWA-HRT-23-025, (2023).
4 Park and Abdel-Aty. *Evaluation of safety effectiveness of multiple cross sectional features on urban arterials*. Accident Analysis and Prevention, Vol. 92, pp. 245-255, (2016).
5 FHWA Tech Advisory Shoulder and Edge Line Rumble Strips, (2011).
6 Sandt et al. Pursuing Equity in Pedestrian and Bicycle Planning. FHWA, (2016).
7 (CMF ID: 10738, 10742) Development of Crash Modification Factors for Bicycle Lane Additions While Reducing Lane and Shoulder Widths. FHWA-HRT-21-012, (2021).

FHWA-SA-21-051

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Proven Safety Countermeasures



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://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/techSheet_RRFB_2018.pdf.

FHWA-SA-21-053

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.

Transportation agencies should refer to the *Manual on Uniform Traffic Control Devices (MUTCD)* for information on the application of RRFBs.[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 at 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 Manual on Uniform Traffic Control Devices (MUTCD), Chapter 4L. FHWA, (2023).
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. TTI-CTS-0010. Texas A&M Transportation Institute, (2016).
4 (CMF ID: 9024) NCHRP Research Report 841 Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments, (2017).

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Safety Benefits:

13%

reduction in pedestrian-vehicle crashes at intersections.[2]

Leading Pedestrian Interval

A leading pedestrian interval (LPI) gives pedestrians the opportunity to enter the crosswalk at an intersection 3-7 seconds before vehicles are given a green indication. Pedestrians can better establish their presence in the crosswalk before vehicles have priority to turn right or left.

LPIs provide the following benefits:

- Increased visibility of crossing pedestrians.
- Reduced conflicts between pedestrians and vehicles.
- Increased likelihood of motorists yielding to pedestrians.
- Enhanced safety for pedestrians who may be slower to start into the intersection.

FHWA's Handbook for ***Designing Roadways for the Aging Population*** recommends the use of the LPI at intersections with high turning vehicle volumes. Transportation agencies should refer to the ***Manual on Uniform Traffic Control Devices*** for guidance on LPI timing and ensure that pedestrian signals are accessible for all users.[1] Costs for implementing LPIs are very low when only signal timing alteration is required.



An LPI allows a pedestrian to establish a presence in the crosswalk before vehicles are given a green indication. Source: FHWA



LPIs reduce potential conflicts between pedestrians and turning vehicles. Source: FHWA

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/fhwasa19040.pdf.

1 Manual on Uniform Traffic Control Devices (MUTCD), Section 4I.06. FHWA, (2023).
2 (CMF ID: 9918) Goughnour, E., D. Carter, C. Lyon, B. Persaud, B. Lan, P. Chun, I. Hamilton, and K. Signor. "Safety Evaluation of Protected Left-Turn Phasing and Leading Pedestrian Intervals on Pedestrian Safety." Report No. FHWA-HRT-18-044. Federal Highway Administration. (October 2018)

FHWA-SA-21-032

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Safety Benefits:

Median with Marked Crosswalk

46%

reduction in pedestrian crashes.[2]

Pedestrian Refuge Island

56%

reduction in pedestrian crashes.[2]

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-ft wide, but preferably 8 ft 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.pedbikeimages.org / Dan Burden

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-08/techSheet_PedRefugeIsland2018.pdf.

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

2 (CMF ID: 175) Desktop Reference for Crash Reduction Factors, FHWA-SA-08-011, September 2008, Table 11.

FHWA-SA-21-044

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Safety Benefits:

55%
reduction in pedestrian crashes.[3]

29%
reduction in total crashes.[4]

15%
reduction in fatal and serious injury crashes.[4]



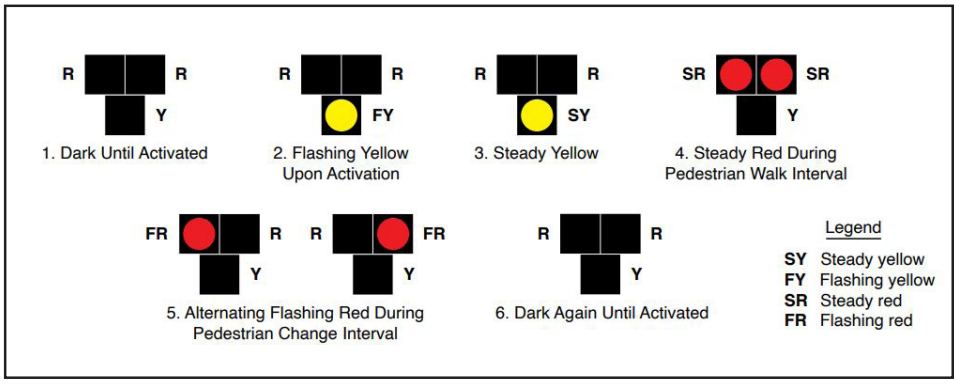
Example of PHBs mounted on a mast arm. Source: FHWA

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/fhwasa18064.pdf.

FHWA-SA-21-045

Pedestrian Hybrid Beacons

The pedestrian hybrid beacon (PHB) is a traffic control device designed to help pedestrians safely cross higher-speed roadways at midblock crossings and uncontrolled intersections. The beacon head consists of two red lenses above a single yellow lens. The lenses remain "dark" until a pedestrian desiring to cross the street pushes the call button to activate the beacon, which then initiates a yellow to red lighting sequence consisting of flashing and steady lights that directs motorists to slow and come to a stop, and provides the right-of-way to the pedestrian to safely cross the roadway before going dark again.



Sequence for a PHB. Source: MUTCD 2023 Edition, Chapter 4J, FHWA

Nearly 74 percent of pedestrian fatalities occur at non-intersection locations, and vehicle speeds are often a major contributing factor.[1] As a safety strategy to address this pedestrian crash risk, the PHB is an intermediate option between a flashing beacon and a full pedestrian signal because it assigns right of way and provides positive stop control. It also allows motorists to proceed once the pedestrian has cleared their side of the travel lane(s), reducing vehicle delay.

Transportation agencies should refer to the *Manual on Uniform Traffic Control Devices* (MUTCD) for information on the application of PHBs.[2] Transportation agencies should locate pedestrian signals to be accessible for all users.

In general, PHBs are used where it is difficult for pedestrians to cross a roadway, such as when gaps in traffic are not sufficient or speed limits exceed 35 miles per hour. They are very effective at locations where three or more lanes will be crossed or traffic volumes are above 9,000 annual average daily traffic. Installation of a PHB must also include a marked crosswalk and pedestrian countdown signal. If PHBs are not already familiar to a community, agencies should conduct appropriate education and outreach as part of implementation.

1 National Center for Statistics and Analysis. (2020, March). Pedestrians: 2018 data (Traffic Safety Facts. Report No. DOT HS 812 850). National Highway Traffic Safety Administration
2 Manual on Uniform Traffic Control Devices, Chapter 4J. FHWA, (2023).
3 (CMF ID: 9020) Zegeer et al. NCHRP Report 841: Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments. TRB, (2017).
4 (CMF ID: 2911,2917) Fitzpatrick, K. and Park, E.S. Safety Effectiveness of the HAWK Pedestrian Crossing Treatment, FHWA-HRT-10-042, (2010).

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Safety Benefits:

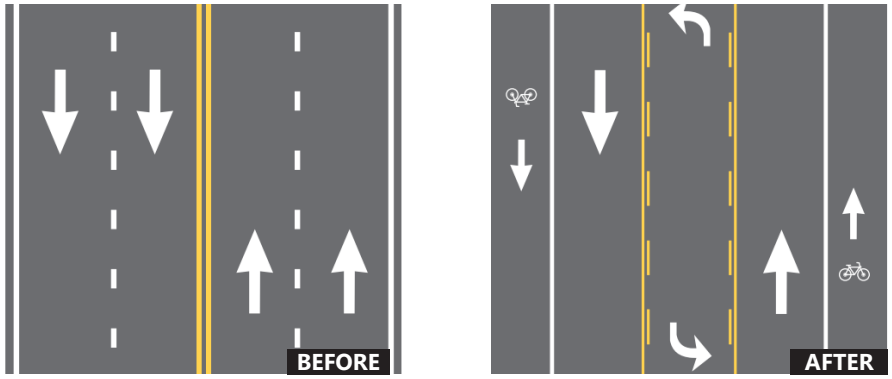
4-Lane to 3-Lane Road Diet Conversions

19-47%

reduction in total crashes.[1]

Road Diets (Roadway Reconfiguration)

A Road Diet, or roadway reconfiguration, can improve safety, calm traffic, provide better mobility and access for all road users, and enhance overall quality of life. A Road Diet typically involves converting an existing four-lane undivided roadway to a three-lane roadway consisting of two through lanes and a center two-way left-turn lane (TWLTL).



Before and after example of a Road Diet. Source: FHWA

Benefits of Road Diet installations may include:

- Reduction of rear-end and left-turn crashes due to the dedicated left-turn lane.
- Reduced right-angle crashes as side street motorists cross three versus four travel lanes.
- Fewer lanes for pedestrians to cross.
- Opportunity to install pedestrian refuge islands, bicycle lanes, on-street parking, or transit stops.
- Traffic calming and more consistent speeds.
- A more community-focused, Complete Streets environment that better accommodates the needs of all road users.

A Road Diet can be a low-cost safety solution when planned in conjunction with a simple pavement overlay, and the reconfiguration can be accomplished at no additional cost. Typically, a Road Diet is implemented on a roadway with a current and future average daily traffic of 25,000 or less.



Road Diet project in Honolulu, Hawaii. Source: Leidos

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/other/road-diets.

1 (CMF ID: 5554,2841) *Evaluation of Lane Reduction "Road Diet" Measures on Crashes*, FHWA-HRT-10-053, (2010).

FHWA-SA-21-046

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Safety Benefits:

Sidewalks

65-89%

reduction in crashes involving pedestrians walking along roadways.[3]

Paved Shoulders

71%

reduction in crashes involving pedestrians walking along roadways.[3]

Walkways

A walkway is any type of defined space or pathway for use by a person traveling by foot or using a wheelchair. These may be pedestrian walkways, shared use paths, sidewalks, or roadway shoulders.

With more than 6,200 pedestrian fatalities and 75,000 pedestrian injuries occurring in roadway crashes annually,[1] it is important for transportation agencies to improve conditions and safety for pedestrians and to integrate walkways more fully into the transportation system. Research shows people living in low-income communities are less likely to encounter walkways and other pedestrian-friendly features.[2]

Well-designed pedestrian walkways, shared use paths, and sidewalks improve the safety and mobility of pedestrians. Pedestrians should have direct and connected network of walking routes to desired destinations without gaps or abrupt changes. In some rural or suburban areas, where these types of walkways are not feasible, roadway shoulders provide an area for pedestrians to walk next to the roadway, although these are not preferable.

Transportation agencies should work towards incorporating pedestrian facilities into all roadway projects unless exceptional circumstances exist. It is important to provide and maintain accessible walkways along both sides of the road in urban areas, particularly near school zones and transit locations, and where there is a large amount of pedestrian activity. Walkable shoulders should also be considered along both sides of rural highways when routinely used by pedestrians.



Example of a sidewalk in a residential area. Source: pedbikeimages.org / Burden



Paved shoulder used as a walkway. Source: pedbikeimages.org / Burden

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=1.

FHWA-SA-21-047

1 National Center for Statistics and Analysis. (2020, March). Pedestrians: 2018 data (Traffic Safety Facts. Report No. DOT HS 812 850). National Highway Traffic Safety Administration.
2 Gibbs, et all. Income Disparities in Street Features that Encourage Walking. Bridging the Gap, (2012, March).
3 Gan et al. Update of Florida Crash Reduction Factors and Countermeasures to Improve the Development of District Safety Improvement Projects. Florida DOT, (2005).

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Safety Benefits:

HFST can reduce crashes up to:

63%
for injury crashes at ramps.[2]

48%
for injury crashes at horizontal curves.[2]

20%
for total crashes at intersections.[3]



Automated application of HFST.
Source: FHWA

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/rwd/keep-vehicles-road/pavement-friction/hfst.

FHWA-SA-21-052

Pavement Friction Management

Friction is a critical characteristic of a pavement that affects how vehicles interact with the roadway, including the frequency of crashes. Measuring, monitoring, and maintaining pavement friction—especially at locations where vehicles are frequently turning, slowing, and stopping—can prevent many roadway departure, intersection, and pedestrian-related crashes.

Pavement friction treatments, such as High Friction Surface Treatment (HFST), can be better targeted and result in more efficient and effective installations when using continuous pavement friction data along with crash and roadway data.

Continuous Pavement Friction Measurement

Friction data for safety performance is best measured with Continuous Pavement Friction Measurement (CPFM) equipment. Spot friction measurement devices, like locked-wheel skid trailers, cannot safely and accurately collect friction data in curves or intersections, where the pavement polishes more quickly and adequate friction is so much more critical. Without CPFM equipment, agencies will assume the same friction over a mile or more.

CPFM technology measures friction continuously at highway speeds and provides both network and segment level data. Practitioners can analyze the friction, crash, and roadway data to better understand and predict where friction-related crashes will occur to better target locations and more effectively install treatments.[1]

High Friction Surface Treatment

HFST consists of a layer of durable, anti-abrasion, and polish-resistant aggregate over a thermosetting polymer resin binder that locks the aggregate in place to restore or enhance friction and skid resistance. Calcined bauxite is the aggregate shown to yield the best results and should be used with HFST applications.

Applications

HFST should be applied in locations with increased friction demand, including:

- Horizontal curves.
- Interchange ramps.
- Intersection approaches.
  - Higher-speed signalized and stop-controlled intersections.
  - Steep downward grades.
- Locations with a history of rear-end, failure to yield, wet-weather, or red-light-running crashes.
- Crosswalk approaches.

Considerations

- HFST is applied on existing pavement, so no new pavement is added.
- If the underlying pavement structure is unstable, then the HFST life cycle may be shortened, resulting in pre-mature failure.
- The automated installation method is preferred as it minimizes issues often associated with manual installation: human error due to fatigue, inadequate binder mixing, improper and uneven binder thickness, delayed aggregate placement, and inadequate aggregate coverage.
- The cost can be reduced when bundling installations at multiple locations.

1 Izeppi et al. Continuous Friction Measurement Equipment as a Tool for Improving Crash Rate Prediction: A Pilot Study. Virginia Department of Transportation, (2016).
2 (CMF ID: 10342, 10333) Merritt et al. Development of Crash Modification Factors for High Friction Surface Treatments. FHWA, (2020).
3 (CMF ID: 2259) NCHRP Report 617: Accident Modification Factors for Traffic Engineering and ITS Improvements, (2008).

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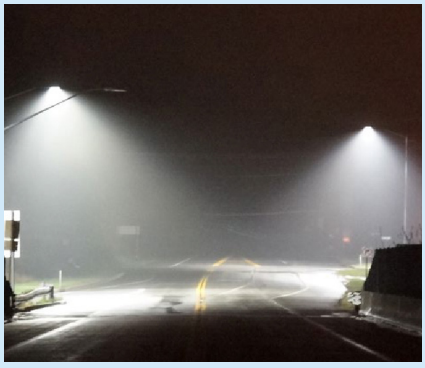
Safety Benefits:

Lighting can reduce crashes up to:

42%
for nighttime injury pedestrian crashes at intersections.[1]

33-38%
for nighttime crashes at rural and urban intersections.[2,1]

28%
for nighttime injury crashes on rural and urban highways.[1]



Source: FHWA

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/other/visibility/roadway-lighting-resources.

FHWA-SA-21-050

Lighting

The number of fatal crashes occurring in daylight is about the same as those that occur in darkness. However, the nighttime fatality rate is three times the daytime rate because only 25 percent of vehicle miles traveled (VMT) occur at night. At nighttime, vehicles traveling at higher speeds may not have the ability to stop once a hazard or change in the road ahead becomes visible by the headlights. Therefore, lighting can be applied continuously along segments and at spot locations such as intersections and pedestrian crossings in order to reduce the chances of a crash.

Adequate lighting (i.e., at or above minimum acceptable standards) is based on research recommending horizontal and vertical illuminance levels to provide safety benefits to all users of the roadway environment. Adequate lighting can also provide benefits in terms of personal security for pedestrians, wheelchair and other mobility device users, bicyclists, and transit users as they travel along and across roadways.

Applications

Roadway Segments

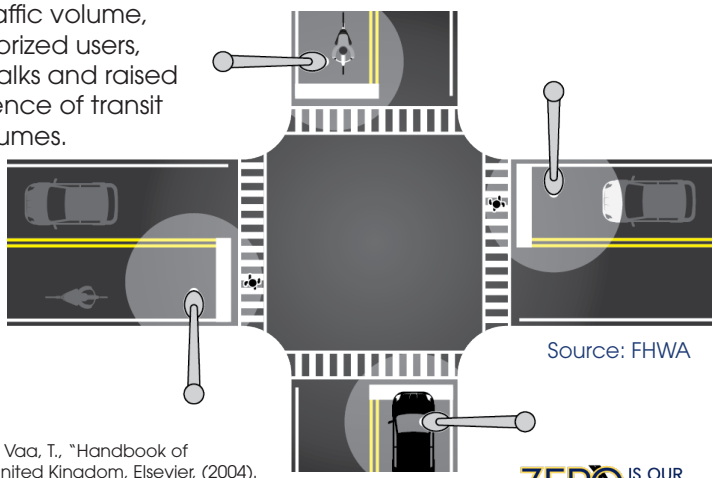
Research indicates that continuous lighting on both rural and urban highways (including freeways) has an established safety benefit for motorized vehicles.[1] Agencies can provide adequate visibility of the roadway and its users through the uniform application of lighting that provides full coverage along the roadway and the strategic placement of lighting where it is needed the most.

Intersections and Pedestrian Crossings

Increased visibility at intersections at nighttime is important since various modes of travel cross paths at these locations. Agencies should consider providing lighting to intersections based on factors such as a history of crashes at nighttime, traffic volume, the volume of non-motorized users, the presence of crosswalks and raised medians, and the presence of transit stops and boarding volumes.

Considerations

Most new lighting installations are made with breakaway features, shielded, or placed far enough from the roadway to reduce the probability and/or severity of fixed-object crashes. Modern lighting technology gives precise control with minimal excessive light affecting the nighttime sky or spilling over to adjacent properties. Agencies can equitably engage with underserved communities to determine where and how new and improved lighting can most benefit the community by considering their priorities, including eliminating crash disparities, connecting to essential neighborhood services, improving active transportation routes, and promoting personal safety.



Source: FHWA

1 (CMF ID: 436,433,192) Elvik, R. and Vaa, T., "Handbook of Road Safety Measures." Oxford, United Kingdom, Elsevier, (2004).
2 (CMF ID: 2376) Ye et al. A Simultaneous Equations Model of Crash Frequency By Collision Type for Rural Intersections, 87th Annual Meeting of the Transportation Research Board, (2008).

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Safety Benefits:

Agencies have experienced the following benefits after LRSP implementation:

25%
reduction in county road fatalities in Minnesota.

17%
reduction in fatal and serious injury crashes on county-owned roads in Washington State.

35%
reduction in severe curve crashes in Thurston County, WA.

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/local-rural/local-road-safety-plans.

FHWA-SA-21-033

Local Road Safety Plans

A local road safety plan (LRSP) provides a framework for identifying, analyzing, and prioritizing roadway safety improvements on local roads. The LRSP development process and content are tailored to local issues and needs. The process results in a prioritized list of issues, risks, actions, and improvements that can be used to reduce fatalities and serious injuries on local roads. FHWA has developed several resources including an LRSP Do-It-Yourself website which further explains the process and includes resources local agencies and their partners need to create and implement an LRSP.[1]

Approximately 75 percent of rural roads are owned by local agencies.[2] While local roads are less traveled than State highways, they have a much higher rate of fatal and serious injury crashes.[2] Developing an LRSP is an effective strategy to improve local road safety for all road users and support the goals of a State's overall Strategic Highway Safety Plan (SHSP).

Although the development process and resulting plan can vary depending on the local agency's needs, available resources, and targeted crash types, aspects common to LRSPs include:

- Stakeholder engagement representing the 4E's: engineering, enforcement, education, and emergency medical services.
- Collaboration among municipal, county, Tribal, State, and/or Federal entities to leverage expertise and resources.
- Identification of target crash types and crash risk with corresponding recommended proven safety countermeasures.
- Timeline and goals for implementation and evaluation.

Local road agencies should consider developing an LRSP to be used as a tool for reducing roadway fatalities, injuries, and crashes.[3] LRSPs can help agencies create a prioritized list of improvements. LRSPs are also a proactive risk management technique to demonstrate an agency's responsiveness. The plan should be viewed as a living document that can be updated to reflect changing local needs and priorities.



Infographic showing the LRSP process. Source: FHWA

1 https://highways.dot.gov/safety/local-rural/local-road-safety-plans
2 Anderson et al. Noteworthy Practices: Addressing Safety on Locally-Owned and Maintained Roads A Domestic Scan, FHWA-SA-09-019, (2010).
3 Developing Safety Plans: A Manual for Local Rural Road Owners, FHWA-SA-12-017, provides guidance on developing an LRSP.

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OFFICE OF SAFETY

Proven Safety Countermeasures



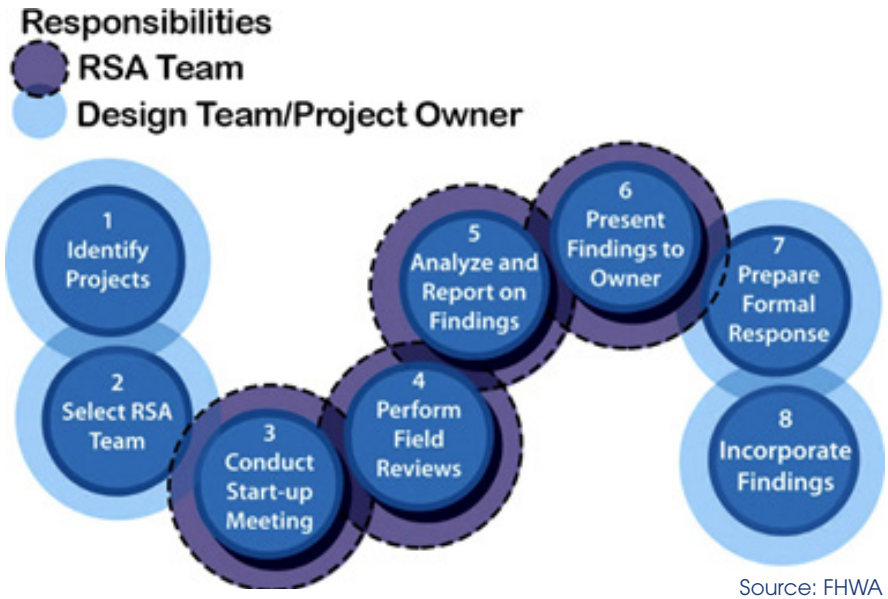
Safety Benefits:

10-60%

reduction in total crashes.[1]

Road Safety Audit

While most transportation agencies have established traditional safety review procedures, a road safety audit (RSA) or assessment is unique. RSAs are performed by a multidisciplinary team independent of the project. RSAs consider all road users, account for human factors and road user capabilities, are documented in a formal report, and require a formal response from the road owner. (See the eight steps for conducting an RSA below.)



Source: FHWA

RSAs provide the following benefits:

- Reduced number and severity of crashes due to safer designs.
- Reduced costs resulting from early identification and mitigation of safety issues before projects are built.
- Increased opportunities to integrate multimodal safety strategies and proven safety countermeasures.
- Expanded ability to consider human factors in all facets of design.
- Increased communication and collaboration among safety stakeholders.
- Objective review by independent multidisciplinary team.

RSAs can be performed in any phase of project development, from planning through construction. Agencies may focus RSAs specifically on motorized vehicles, pedestrians, bicyclists, motorcyclists, or a combination of these roadway users. Agencies are encouraged to conduct an RSA at the earliest stage possible, as all roadway design options and alternatives are being explored.



Multidisciplinary team performs field review during an RSA. Source: FHWA

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/data-analysis-tools/systemic/road-safety-audits-rsa.

1 Road Safety Audits: An Evaluation of RSA Programs and Projects, FHWA-SA-12-037; and FHWA Road Safety Audit Guidelines, FHWA-SA-06-06.

FHWA-SA-21-048

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