SAFE SYSTEM ROADWAY DESIGN HIERARCHY

ENGINEERING AND INFRASTRUCTURE-RELATED COUNTERMEASURES TO EFFECTIVELY REDUCE ROADWAY FATALITIES AND SERIOUS INJURIES

U.S. Department of Transportation
Federal Highway Administration

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

Notice

An important Note on the Allowable Use of Treatments and Countermeasures

All traffic control devices installed by an agency must be compliant with FHWA's Manual on Traffic Control Devices (MUTCD). For certain treatments which are not MUTCD-compliant, an agency may request an experimentation waiver from FHWA to allow its installation. Only after this waiver is obtained should a non-compliant treatment be installed. For full information on the experimentation waiver request process, please refer to the relevant page on the MUTCD website here (https://mutcd.fhwa.dot.gov/condexper.htm).

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16. Abstract Widespread implementation of safety countermeasures supports the Safe System Approach and can accelerate achieving local, State, and National safety goals. This document introduces the Safe System Roadway Design Hierarchy as a tool to characterize engineering and infrastructure-based countermeasures and strategies relative to their alignment with the goal of eliminating fatalities and serious injuries to support implementation of a Safe System Approach. The Safe System Roadway Design Hierarchy will also result in a greater understanding of Safe System principles and increased application of the Safe System Approach.		
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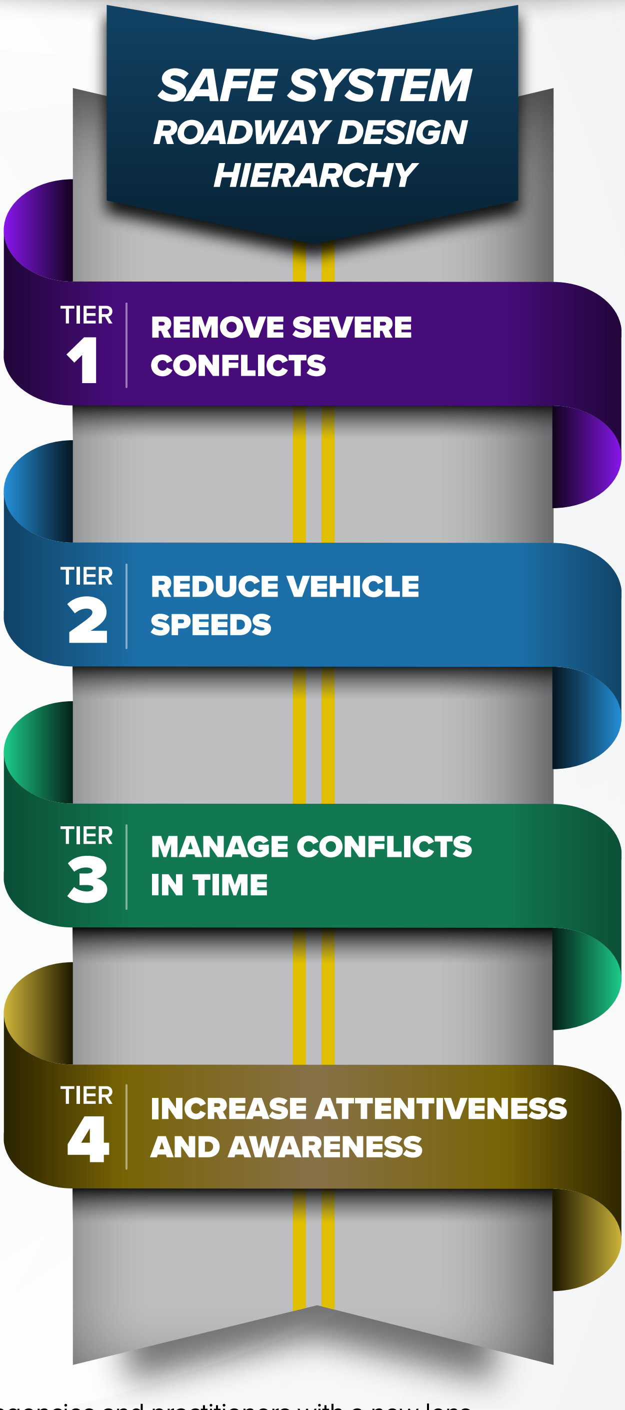
SAFE SYSTEM ROADWAY DESIGN HIERARCHY

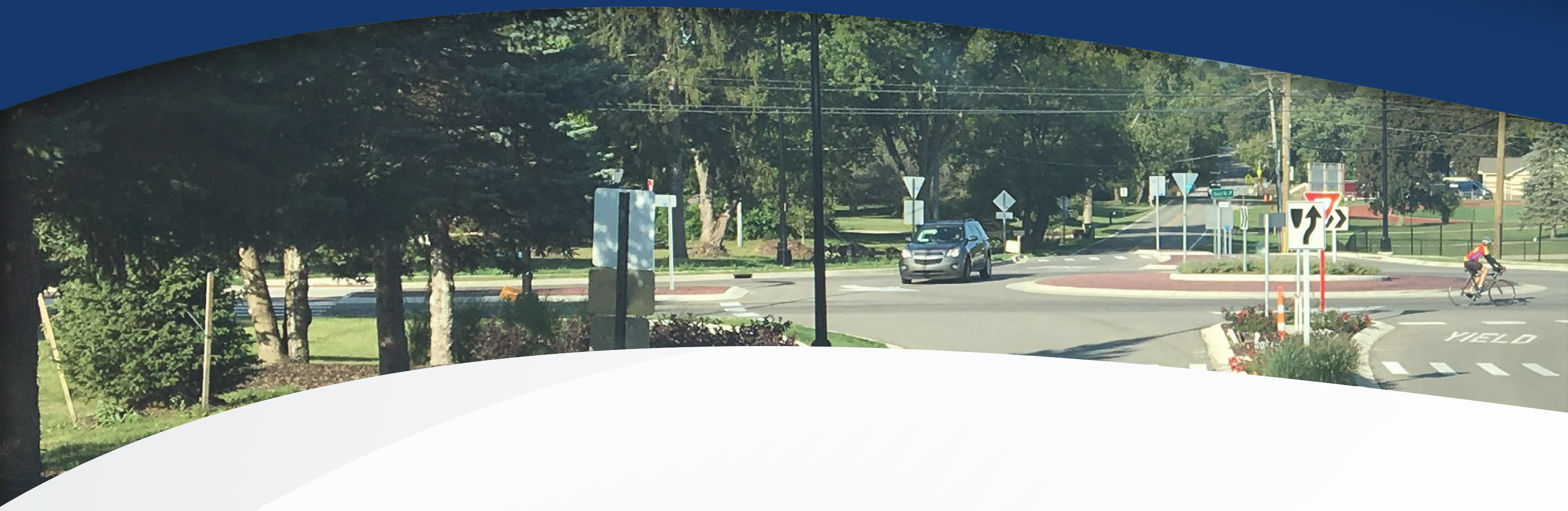


The Safe System Roadway Design Hierarchy is a tool that characterizes engineering and infrastructure-based countermeasures and strategies relative to their alignment with the Safe System Approach (SSA), toward the goal of eliminating traffic-related fatalities and serious injuries. The purpose of the hierarchy is to help transportation agencies and practitioners identify and prioritize countermeasures and strategies when developing transportation projects. The Safe System Roadway Design Hierarchy will facilitate greater understanding and increased application of Safe System principles. FHWA developed the Safe System Roadway Design Hierarchy in response to a recommendation from the informational report on *Integrating the Safe System Approach into the HSIP*. The Safe System Roadway Design Hierarchy is emulated from the hierarchy of controls for workplace safety[1] and previous work by Austroads,[2] and is consistent with the Safe System Pyramid.[3]

The Safe System Roadway Design Hierarchy includes four tiers that are arranged from most to least aligned with the Safe System principles. Tiers 1 through 3 include solutions to remove potential roadway conflicts and separate vulnerable road users from traveling vehicles, with the goal of reducing crash kinetic energy if a crash does occur, whereas Tier 4 countermeasures and strategies provide critical information to the road user so they can take appropriate action. In the Safe System Roadway Design Hierarchy, physical changes to the system are more effective than changes that rely on road users to make safe decisions. While the focus of this publication is on design improvements, agencies should consider all elements of the Safe System Approach when developing projects.

This document introduces the Safe System Roadway Design Hierarchy and describes how various countermeasures and strategies align with each tier; explains how transportation agencies and practitioners can use the hierarchy; demonstrates how Complete Streets and FHWA's Proven Safety Countermeasures support the SSA and align with the Safe System Roadway Design Hierarchy; and presents new or novel uses of countermeasures and strategies in each tier. Widespread implementation of safety countermeasures supports the SSA and can accelerate achieving local, State, and national safety goals. This document is illustrative, and is not inclusive of all strategies that could support implementation of the SSA but is intended to provide transportation agencies and practitioners with a new lens to consider how Safe System solutions can be implemented through example case studies and applications.

The methods, solutions, and considerations presented in this document are current as of the time of this report. As we continue to integrate Safe System principles into our safety programs and advance infrastructure countermeasures and strategies that anticipate human error and accommodate human injury tolerances, new knowledge may result in future updates. Zero deaths and serious injuries on the Nation's roadways is our goal. A Safe System is how we get there.



DESCRIPTION OF SAFE SYSTEM ROADWAY DESIGN HIERARCHY TIERS

TIER 1: REMOVE SEVERE CONFLICTS

Removing severe conflicts involves the elimination of specific high-risk conditions. This involves separating road users moving at different speeds or different directions in space to minimize conflicts with other road users. This tier includes strategies that remove conflicts such as intersection crossing conflicts, removing fixed objects along the roadside, or eliminating railway-highway crossings. Strategies in this tier may also include providing physical separation between motorized and non-motorized users to remove conflicts or providing varying degrees of buffered separation to reduce risk of collisions. These countermeasures support both the Safe Roads and Safe Road Users elements of the SSA.

TIER 2: REDUCE VEHICLE SPEEDS

Implementing design features and speed management strategies to reduce vehicle speeds effectively reduces the kinetic energy involved in a crash should it occur. 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. To achieve desired speeds, agencies often implement other speed management strategies concurrently with setting speed limits, such as self-enforcing roadways, traffic calming measures, and speed safety cameras. Self-enforcing roads involve the use of road and roadside design elements, such as lane narrowing, intersection channelization, and horizontal and vertical deflection, to elicit lower travel speeds of motor vehicles along the roadway. This also includes features for pedestrians and bicyclists, such as median islands, raised crosswalks, and buffered bicycle lanes. These countermeasures support the Safe Roads, Safe Speeds, and Safe Road Users elements of the SSA.


Source: FHWA.

TIER 3: MANAGE CONFLICTS IN TIME

Managing conflicts in time assumes that users will need to occupy the same physical space on the roadway but creates a safer environment by separating the users in time using traffic control devices, such as traffic signals or hybrid beacons, to minimize vehicle conflicts. Providing discrete and alternating opportunities for users to navigate the roadway environment is not only a safety strategy, but also one that relates to user comfort and convenience, especially for non-motorized users. These solutions support the Safe Roads, Safe Speeds, and Safe Road Users elements of the SSA.

TIER 4: INCREASE ATTENTIVENESS AND AWARENESS

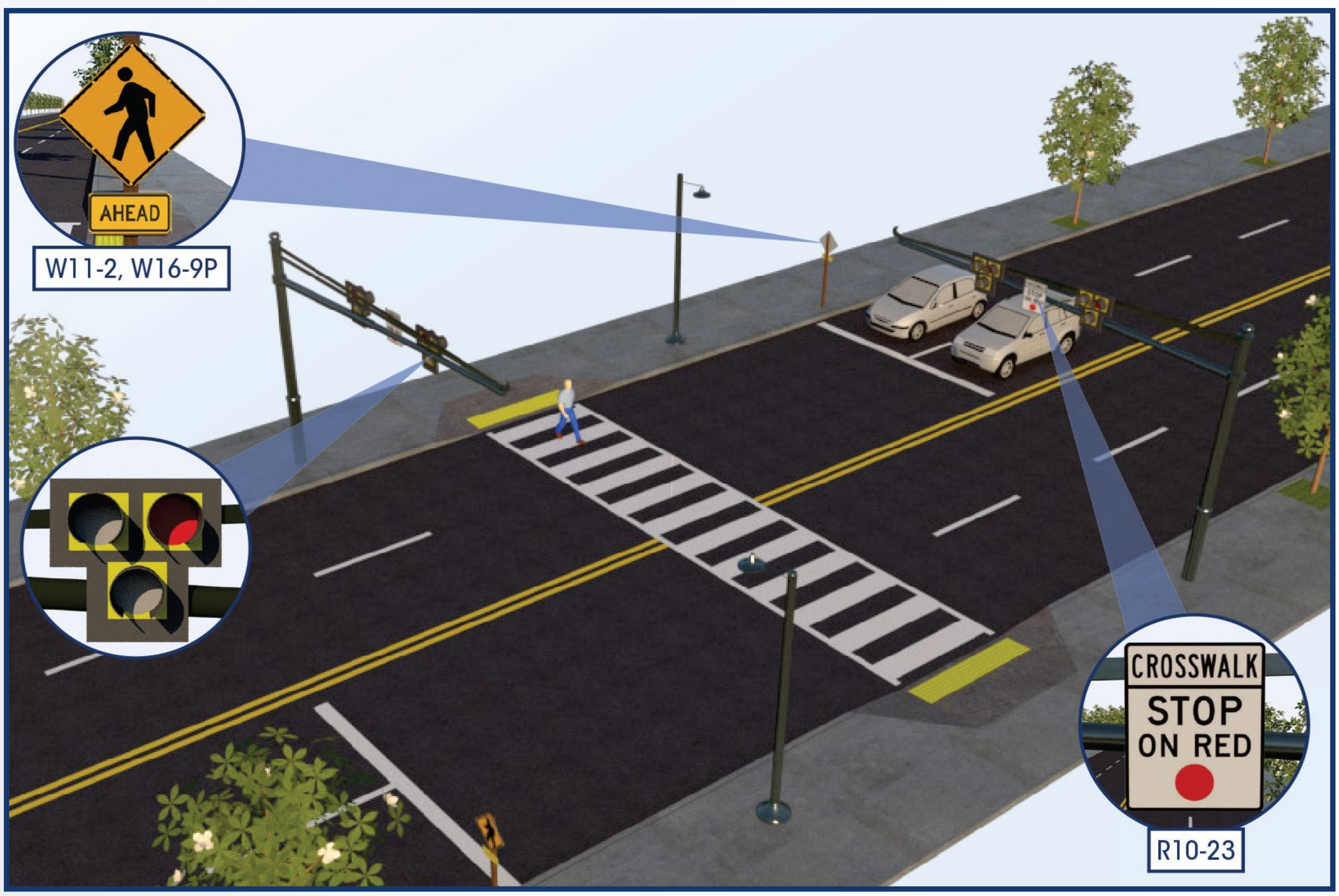
Increasing attentiveness and awareness involves alerting roadway users to certain types of conflicts so that appropriate action can be taken consistent with the SSA. Examples that fall into this category include crossing visibility enhancements, backplates with retroreflective borders, and rumble strips/stripes. These countermeasures support the Safe Roads, Safe Speeds, and Safe Road Users elements of the SSA.

Transportation agencies and practitioners can use the Safe System Roadway Design Hierarchy as a framework for evaluating countermeasures or strategies based on their alignment with the Safe System principle that deaths and serious injuries are unacceptable. It is important to recognize that Safe System alignment is one of many factors that agencies or practitioners may consider when selecting possible countermeasures or strategies to address an identified safety problem. Other factors include but are not limited to community input, feasibility, extent of potential crash reduction, cost, project readiness and funding availability. The Safe System Roadway Design Hierarchy is intended to supplement other tools and information agencies use to identify, select, and prioritize countermeasures.

HOW TO USE THE SAFE SYSTEM ROADWAY DESIGN HIERARCHY

The Safe System Roadway Design Hierarchy is a project-based, site assessment tool. The application of countermeasures and strategies that align with the SSA is dependent on the context, classification, location, and users of the facility. An interstate freeway and a city street can both apply countermeasures and strategies that align with the SSA but applied in very different ways. The four tiers within the Safe System Roadway Design Hierarchy are general in nature and applicable to any scenario.

When applying the hierarchy, agencies should consider countermeasures and strategies under Tier 1 first, as physical separation can permanently eliminate conflicts that lead to severe crashes. If that is not feasible, solutions from the subsequent tiers can then be selected, alone or in combination, to further enhance safety and move toward a Safe System. For example, the Pedestrian Hybrid Beacon is a countermeasure that cross-cuts among multiple tiers; specifically, it manages conflicts in time (Tier 3), increases attentiveness and awareness (Tier 4), and in combination with a raised crosswalk can reduce vehicular speeds (Tier 2).



Source: Pedestrian Hybrid Beacon (PHB), FHWA.

Often, agencies and practitioners will need to combine countermeasures and strategies from multiple tiers to be most effective. This approach reinforces the Safe System principle that redundancy is critical to reduce fatal and serious injury crashes. Complete Streets is a great example of applying a combination of countermeasures and strategies to support implementation of the SSA and improve safety for all users (further described on page 6). As another example, variable speed limits in combination with speed safety cameras on non-freeways at night can reduce speeding and related crashes. This is also an example of how agencies can use Proven Safety Countermeasures in a new or novel way.

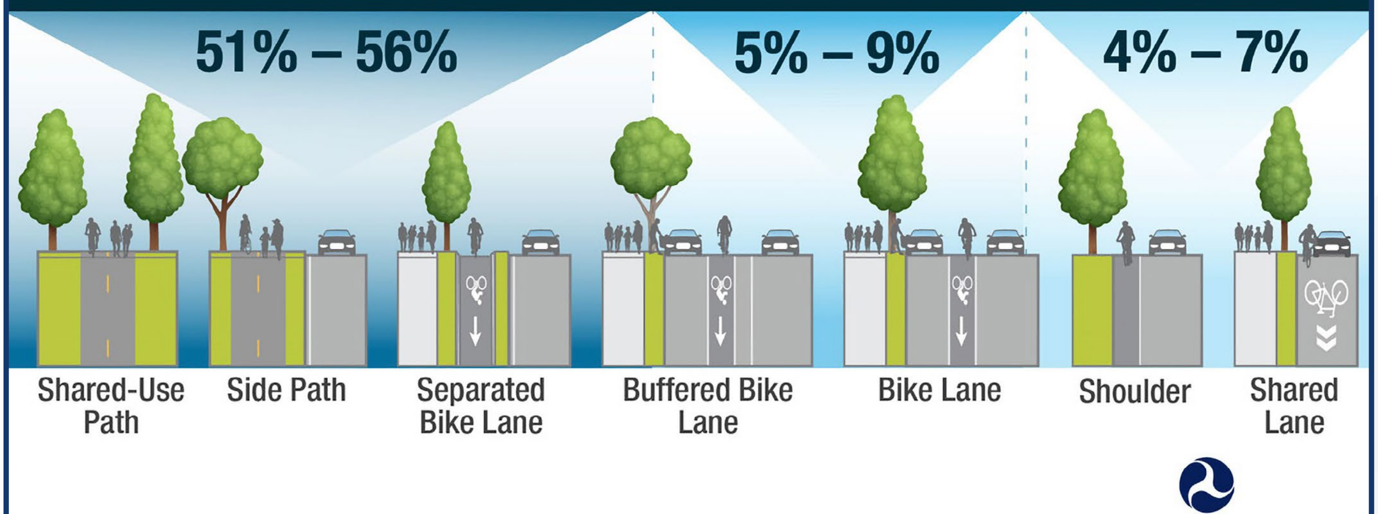
In other cases, an incremental approach to achieving a Safe System may be more feasible. If time or resources are a challenge, agencies can use one or more of the lower tier options as interim solutions until a permanent solution is in place. For example, an agency may install a centerline buffer area today, and then when funding is available in the future, they can implement a median barrier to remove the severe conflict.

Some strategies within Tier 1 may involve providing physical space to separate conflicts between motorized and non-motorized users. The degree of separation provided should be considered when assessing alignment with the SSA. An example is the varying degrees of buffered separation for a bicycle lane as shown in the figure below. Each design option shown has a differing amount of physical separation that can influence the risk of a collision with a motorized vehicle.

The Safe System Roadway Design Hierarchy can also be used to prioritize in the planning phase through a Safe System lens. Agencies could integrate Safe System Roadway Design Hierarchy tiers into project prioritization rating criteria. For instance, agencies can assign each project points based on their alignment with SSA allowing those projects with greatest alignment to be prioritized for implementation.

While the Safe System Roadway Design Hierarchy is a useful design strategy and countermeasure selection tool, agencies should continue to advance policy level strategies that support the SSA, including speed management and equity considerations for all road users. Transportation practitioners will make more rapid progress toward the goal of zero deaths and serious injuries on our Nation's roadways by implementing effective speed management strategies at the agency level and addressing disparate traffic safety outcomes for underserved communities in all projects and programs.

WHICH FACILITIES MAKE RIDERS FEEL SAFER?



Note: Percentages represent the level of comfort that people feel bicycling from 2016 peer-reviewed survey.
Source: NHSTA FARS, https://safety.fhwa.dot.gov/ped_bike/tools_solve/docs/fhwasa18077.pdf
For More Information: https://www.fhwa.dot.gov/environment/bicycle_pedestrian/

COMPLETE STREETS

WHAT IS IT?

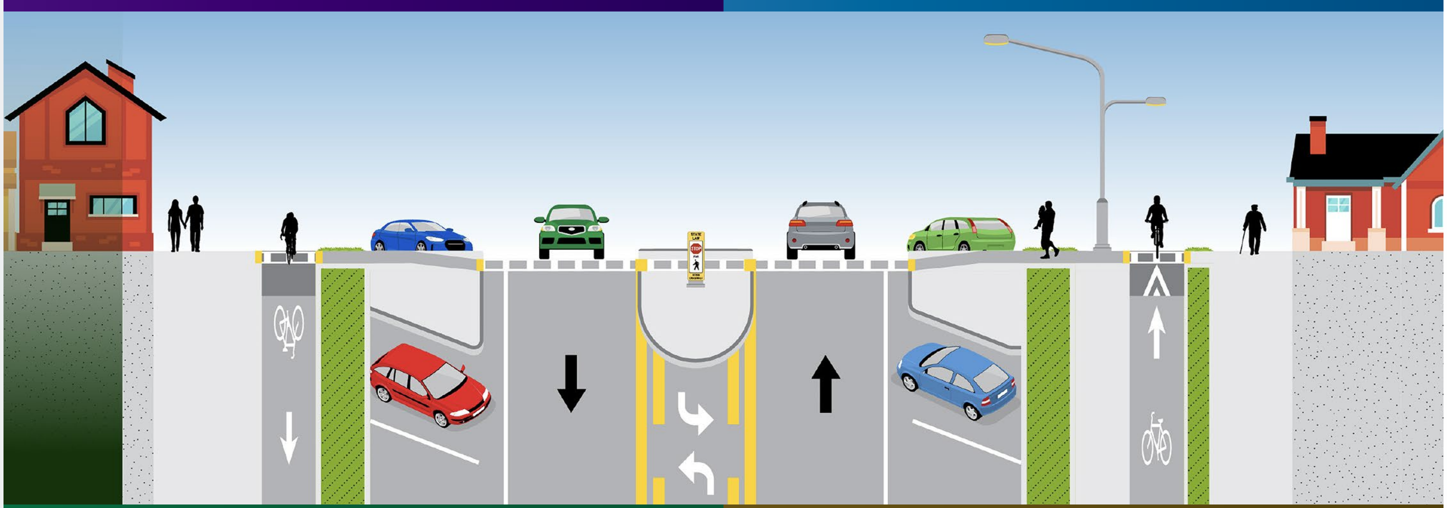
A Complete Street ensures the safe and adequate accommodation of all transportation system users, including pedestrians, bicyclists, public transportation users, children, older individuals, individuals with disabilities, motorists, and operators of transit and freight vehicles. As an implementation strategy of the SSA, Complete Streets focuses on creating safe, connected, and equitable networks that fit community needs and context. Two-thirds of the States have adopted Complete Street policies encompassing planning, design, construction, operations, and maintenance to improve network safety.

HOW DOES IT ALIGN WITH THE SAFE SYSTEM DESIGN HIERARCHY?

Complete Streets approaches vary depending on community context. Complete Streets may apply a wide range of integrated safety elements to develop a system that is safe for all users, such as sidewalks, bicycle lanes, curb extensions, gateway treatments, median refuge islands, road diets, and modified vehicle lanes. Complete Streets implementation may apply the Safe System Roadway Design Hierarchy to identify safety improvement projects. The figure below shows an example of a Complete Street using a road diet to reconfigure a four-lane highway, aligning the safety improvements within the Safe System Roadway Design Hierarchy.

TIER 1: REMOVE SEVERE CONFLICTS
The roadway design provides separation in space to protect all roadway users.

TIER 2: REDUCE VEHICLE SPEEDS
Self-enforcing road design and gateway treatments provide contextual encouragement for motorists to drive at safer speeds.



TIER 3: MANAGE CONFLICTS IN TIME
A Pedestrian Hybrid Beacon (PHB) can assist pedestrians crossing at the uncontrolled intersection.

TIER 4: INCREASE ATTENTIVENESS AND AWARENESS
Bicycle treatments and pedestrian signage make motorists aware of crossing cyclists and pedestrians.

Image source: Complete Streets Transformations, FHWA: Complete Streets Transformations (dot.gov).

COMPLETE STREETS CASE STUDY

The Minnesota Department of Transportation (MnDOT) implemented a Complete Streets redesign and road diet along a section of Highway 24 in St. James, Minnesota. Highway 24 accommodates an average daily traffic of 5,000 to 7,000 vehicles, with heavy commercial vehicles representing ten percent of the traffic. MnDOT replaced traffic signals at two intersections with mini roundabouts, removed one travel lane, reduced lane widths, and replaced parallel parking with back-in angle parking. In addition, the project added improved sidewalks, crosswalks, and curb extensions to make walking and biking more comfortable. These improvements reduced vehicle travel speeds and improved visibility of people walking and biking.

To increase public familiarity of the redesign, MnDOT conducted public events and targeted engagement to reach senior and Latino communities in the area, such as distributing project briefings in Spanish. In addition, the project team conducted driving simulations with freight trucks and school buses to demonstrate how roundabouts do not limit access for large vehicles. Residents had the opportunity to learn about mini-roundabouts and practice back-angle parking at public events. The corridor redesign reduced crossing distances for people walking and biking, calmed traffic, and improved visibility.[4]

BEFORE (2015)

Highway 24 in St. James before construction

AFTER (2021)

Highway 24 in St. James after construction, showing mini-roundabout, back-in angle parking, and improved crosswalks

Source: Complete Streets Case Studies (Highway 24 in St. James), Minnesota Department of Transportation: https://www.dot.state.mn.us/complete-streets/examples.html.

PROVEN SAFETY COUNTERMEASURES (PSC)

Many agencies already implement one or more of FHWA's Proven Safety Countermeasures (PSC) that support a SSA, such as road diets, rectangular rapid flashing beacons, and longitudinal rumble strips. The table below shows how the PSCs align with each tier in the Safe System Roadway Design Hierarchy. Some PSCs align with one tier, whereas other PSCs support multiple tiers. For example, roundabouts align with both Tier 1 (Remove Severe Conflicts) and Tier 2 (Reduce Vehicle Speeds); leading pedestrian intervals aligns with Tier 3 (Manage Conflicts in Time); and variable speed limits align with both Tier 2 (Reduce Vehicle Speeds) and Tier 4 (Increase Attentiveness and Awareness).

Proven Safety Countermeasure	*Tier 1 Remove Severe Conflicts*	*Tier 2 Reduce Vehicle Speeds*	*Tier 3 Manage Conflicts in Time*	*Tier 4 Increase Attentiveness and Awareness*
Speed Management				
Appropriate Speed Limits for All Road Users		✓		
Speed Safety Cameras		✓		
Variable Speed Limits		✓		✓
Pedestrian/Bicyclist				
Bicycle Lanes	✓			
Crosswalk Visibility Enhancements				✓
Leading Pedestrian Interval			✓	
Medians and Pedestrian Refuge Islands	✓	✓		
Pedestrian Hybrid Beacons			✓	
Rectangular Flashing Beacons (RRFB)				✓
Road Diets	✓	✓		
Walkways	✓			
Roadway Departure				
Enhanced Delineation for Horizontal Curves				✓
Longitudinal Rumble Strips and Stripes				✓
Median Barriers	✓			

Proven Safety Countermeasure	Tier 1 Remove Severe Conflicts	Tier 2 Reduce Vehicle Speeds	Tier 3 Manage Conflicts in Time	Tier 4 Increase Attentiveness and Awareness
Roadway Departure (continued)				
Roadside Design Improvements at Curves	✓			
SafetyEdge[SM]	✓			
Wider Edge Lines				✓
Intersections				
Backplates with Reflective 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			✓	
Crosscutting				
Lighting				✓
Local Road Safety Plans	✓	✓	✓	✓
Pavement Friction Management	✓	✓		
Road Safety Audit	✓	✓	✓	✓

CHARACTERIZING SAFE SYSTEM SOLUTIONS

The following section characterizes Safe System countermeasures and strategies based on their alignment with the Safe System Roadway Design Hierarchy. Multiple countermeasures or strategies are presented for each tier, including a description of what the countermeasure is, how it aligns with the SSA, potential benefits and risk factors the countermeasure may address, and an example of the countermeasure in practice. The countermeasures and strategies may be an existing PSC, an existing PSC implemented in a different way, or a new and emerging countermeasure or strategy. Each tier section concludes with a list of resources to support the implementation of countermeasures and strategies.

TIER 1: REMOVE SEVERE CONFLICTS

Removing severe conflicts involves the elimination of specific high-risk conditions. These countermeasures separate road users moving at different speeds or different directions in space to minimize their conflicts with other road users.

ROUNDABOUTS

Source: Turbo Roundabout (Jacksonville, Florida), FHWA.

WHAT IS IT?

Roundabouts are intersections with a circular configuration that use channelized, curved approaches to reduce vehicle speeds and minimize conflict points. Roundabouts direct the flow of traffic counterclockwise around a central island to efficiently move all road users through the intersection while calming traffic.

Roundabouts are highly adaptable, and can range from "mini" roundabouts to multilane roundabouts, and can be used in both high speed rural and low speed urban contexts, and even for interchanges. An emerging form of the roundabout is known as a "turbo", which is a multilane design with additional and more robust channelization.

HOW DOES IT ALIGN WITH THE SSA?

Roundabouts eliminate intersection crossing conflict points, slow down vehicle speeds, and manipulate crash angles to reduce the kinetic energy involved in a vehicle crash. In addition, roundabouts limit pedestrian exposure to oncoming traffic by allowing pedestrians to cross one direction of traffic at a time and may include pedestrian refuge areas.

WHAT ARE THE BENEFITS OF ROUNDABOUTS?

Roundabouts are safer alternatives to traditional intersections and can reduce injury and fatal crashes by 78 to 82 percent when replacing traffic signals or stop signs in the United States.[5] Converting signalized intersections into a two lane roundabout at 16 sites in 10 States indicated a 71 percent reduction in fatal and serious injury crashes when applied in urban or suburban areas with a minimum of 5,300 Annual Average Daily Traffic (AADT) and maximum of 52,000 AADT, and speed setting of a minimum of 15mph and maximum of 35mph.[6]

ROUNDABOUTS MAY ADDRESS THE FOLLOWING RISK FACTORS:
Lack of Pedestrian/Cyclist Space Separation, Undivided Roadway, Permissive Left Turn Conflicts, Intersection Crossing Conflict, and High/Excessive Vehicle Speeds.

Based on studies in Europe, roundabouts may also reduce pedestrian crashes by 75 percent.[7] In Belgium, traditional signalized intersections were replaced by roundabouts with separated bicycle pathways, reducing vehicle/bicycle fatal and serious injury crashes by 44 percent.[8]

THIS COUNTERMEASURE IN PRACTICE

The intersection of Frankford Avenue, Trenton Avenue, and York Street in Philadelphia, Pennsylvania implemented a low-cost compact roundabout to reduce vehicle speeds and provide accommodations for pedestrians, trucks, and buses. The roundabout design included ADA compliant curb ramps and sidewalks, splitter islands, enhanced LED lighting, signage, pavement markings, truck aprons, and a main central island designed to let large trucks traverse the island if needed.

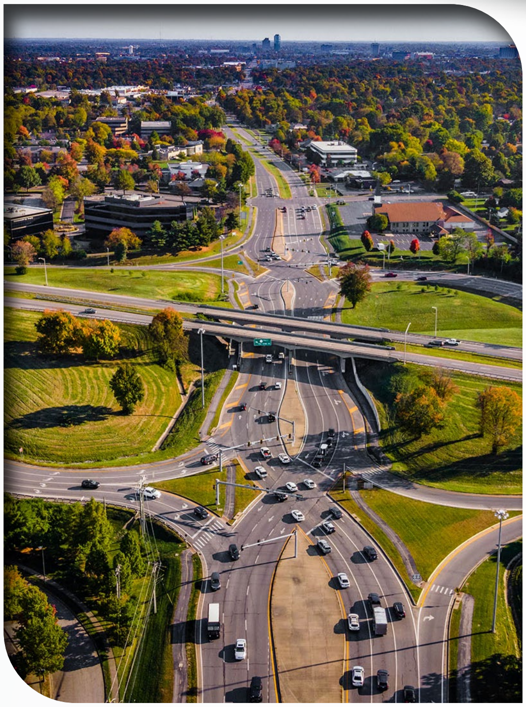
Source: Compact Roundabout (Washentaw County, Michigan), FHWA.

DIVERGING DIAMOND INTERCHANGE

WHAT IS IT?

A Diverging Diamond Interchange (DDI) is an innovative design solution that improves safety and mobility for motorists, pedestrians, and bicyclists by creating intuitive crossovers that transition traffic from the right side of the road and then back again. This design eliminates the need for left turns across opposing traffic and simplifies pedestrian crossing movements.

DDIs are best utilized in locations with high volumes of left turns, unbalanced crossroad traffic volumes, and where there is a need for additional capacity without widening the roadway. DDI's typically have improved operational efficiency and fewer conflict points in comparison to conventional diamond interchanges.



Source: Getty Images.

HOW DOES IT ALIGN WITH THE SSA?

DDIs reduce potential areas of conflict for those biking, walking, and driving. This design may provide bicycle lanes located to the right of traffic to protect people biking, and may be paired with roadway signs or pavement markings to support safe travel for all roadway users.

WHAT ARE THE BENEFITS OF DIVERGING DIAMOND INTERCHANGES?

Compared to the conventional diamond interchange, which is the most common form in the United States, the DDI reduces vehicle-to-vehicle conflict points by nearly 50 percent and eliminates most severe crash types.[9] Converting traditional diamond interchanges to DDIs at 80 locations in 24 States resulted in a 44 percent reduction in fatal and serious injury crashes when applied in urban or suburban areas with a minimum of 1,295 AADT and maximum of 76,100 AADT on arterial roadways.[10]

DDIS MAY ADDRESS THE FOLLOWING RISK FACTORS:
Permissive Left Turn Conflicts, Intersection Crossing Conflict, and Lack of Pedestrian/ Cyclists Space Separation.

THIS COUNTERMEASURE IN PRACTICE

The Minnesota Department of Transportation converted two signalized diamond interchanges, with a minimum of 28,000 AADT to a maximum of 40,000 AADT on major roads and minimum of 3,000 AADT to a maximum of 18,000 AADT on minor roads, to DDIs. According to a before and after safety evaluation conducted between 2006 to 2015, the signalized intersections resulted in an estimated 304 crashes, whereas 37 crashes were recorded after the DDI redesign.[11]

Source: Raised Separated Bike Lane (Fremont, California), FHWA.

SEPARATED BIKE LANES

WHAT IS IT?

Separated bike lanes, also known as protected bicycle lanes, segregate bicyclists from motor vehicles by incorporating a buffer space and vertical element between vehicle travel lanes and the bicycle lane.

HOW DOES IT ALIGN WITH THE SSA?

Separated bike lanes provide a dedicated pathway for cyclists, which reduces the distance and time in which cyclists are exposed to conflicts with motorists.

WHAT ARE THE BENEFITS OF SEPARATED BIKE LANES?

Separated bike lanes improve visibility between people biking and driving, increase the degree of comfort and safety for all bicyclists regardless of their abilities, and support a network of predictable movements across all road users. Converting a traditional bicycle lane to a separated bike lane using vertical flexible delineator posts resulted in a 50 percent decrease in fatal and serious injury crashes when applied to urban areas in Cambridge (MA), San Francisco (CA), and Seattle (WA).[12]

SEPARATED BIKE LANES MAY ADDRESS THE FOLLOWING RISK FACTORS:
Lack of Pedestrian/Cyclists Space Separation and Undivided Roadway.

THIS COUNTERMEASURE IN PRACTICE

The New York City Department of Transportation implemented separated bicycle lanes to separate passing motor vehicle traffic by a parking lane and buffer. This design used striping, markings, signage, vertical elements, and intersection treatments to achieve a 75 percent risk reduction with respect to bicyclist serious injuries.[13]

Source: Making Safer Streets, New York City Department of Transportation: dot-making-safer-streets.pdf (nacto.org).

PROTECTED INTERSECTION

WHAT IS IT?

Protected intersections use a setback or offset design to reduce conflict points and increase visibility between drivers and those bicycling or walking. Protected intersection features may include pedestrian refuge islands, bicycle queuing areas, corner islands, and intersection crossing markings to protect all road users and enhance system predictability. Implementation of a protected intersection should consider a variety of factors, such as accessibility needs and trip purposes, to develop comprehensive solutions that align with the surrounding roadway context.

HOW DOES IT ALIGN WITH THE SAFE SYSTEM APPROACH?

Protected intersections reduce certain conflicts and enhance the physical separation between people walking and biking and vehicles. Protected intersection features may reduce the speed of vehicle turning movements, thus reducing the kinetic energy if a crash does occur. Therefore, protected intersection features can also be considered a Tier 2 countermeasure. Intersection enhancement projects are opportunities to provide safe, more equitable, and accessible facilities for all road users regardless of age or abilities.

WHAT ARE THE BENEFITS OF PROTECTED INTERSECTION FEATURES?

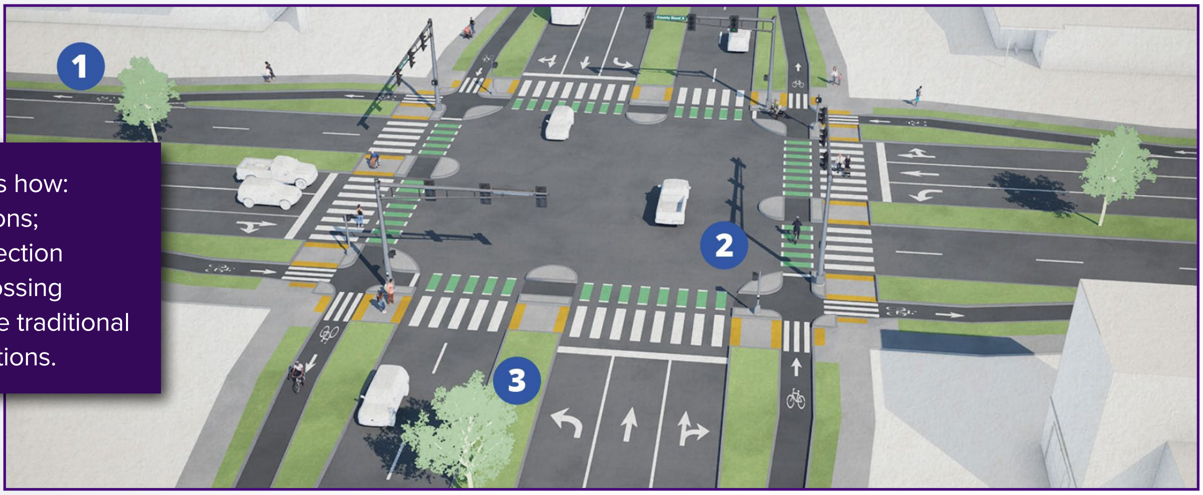
Protected intersection features improve crossing visibility and sight distance to reduce potential conflicts. For example, medians with marked cross walks can reduce pedestrian crashes by 26 percent, and pedestrian refuge islands can reduce pedestrian crashes by 56 percent.[14]

PROTECTED INTERSECTION FEATURES MAY ADDRESS THE FOLLOWING RISK FACTORS:
Lack of Pedestrian/Cyclists Space Separation, Obstructed Sight Distance, and Intersection Crossing Conflict.

THIS COUNTERMEASURE IN PRACTICE

The New York City Department of Transportation implemented various protected intersection features including pedestrian ramps, safety islands, and bicycle facilities along Columbus Ave, W 96th St to W 77th St, resulting in a 25 percent reduction in injury crashes.[15]

The diagram shows how:
1) bike lane transitions;
2) protected intersection features; and 3) crossing islands can improve traditional signalized intersections.



Source: Improving Intersections for Pedestrians and Bicyclists, FHWA: https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/fhwasa22041.pdf

CABLE MEDIAN BARRIERS

WHAT IS IT?

As opposed to rigid concrete barriers, cable barriers are mode from steel cables mounted on weak steel posts that remain flexible. These barriers absorb energy from a crash by capturing or redirecting the vehicle.

HOW DOES IT ALIGN WITH THE SSA?

Cable barriers can be used as a strategy to reduce the number of cross-median crashes or be implemented as a flexible guardrail to reduce crash severity. This countermeasure reduces impact forces to the motor vehicle and in turn reduces impacts to the human body during a crash.

WHAT ARE THE BENEFITS OF CABLE BARRIERS?

Median barriers are typically implemented on high-speed, fully controlled access roadways; however, the flexibility and design of cable barriers allows for a wide variety of unique applications to support the SSA. For example, installing wire guardrails between lanes of opposing traffic resulted in a 26 percent decrease in fatal and serious injury crashes when applied on principle arterial roadways with three travel lanes.[16]

Source: Cable Barrier (Oregon Mount Hood Highway US-26), K. Burns and Katherine E Bell: https://www.semanticscholar.org/paper/Performance-Evaluation-of-a-Cable-Median-Barrier-on-Burns-Bell/3b556bdc0762981e9f88612a1247d0d9e91f5591

CABLE BARRIERS MAY ADDRESS THE FOLLOWING RISK FACTORS:
Undivided Roadway and Vertical and Horizontal Curvature.

THIS COUNTERMEASURE IN PRACTICE

The Oregon Department of Transportation implemented cable barriers along narrow medians (less than 8 feet wide) to reduce crossover crashes on Mount Hood Highway (US-26) resulting in a 29 percent reduction in fatal and serious injury crash rates.[17]

Source: Cable Barrier (1-70 near Friendship, Maryland), Wikipedia Commons: https://commons.wikimedia.org/wiki/File:2008_03_28_-_I70_Cable_Barrier.JPG.

SUPER 2 DESIGN

WHAT IS IT?

A Super 2 design adds a periodic passing lane to a two-lane rural highway to allow for the passing of slower vehicles. A Super 2 design may be introduced on an existing two-lane roadway with a significant amount of slow-moving traffic, limited sight distance for passing, or when the existing traffic volume has exceeded the two-lane highway capacity, creating the need for vehicles to pass on a more frequent basis.

Source: Super 2 Design, Texas A&M Institute (TTI): https://tti.tamu.edu/researcher/two-decades-of-super-2-research-and-implementation-for-txdot-continues-to-produce-benefits/.

HOW DOES IT ALIGN WITH THE SSA?

The Super 2 highway network design reduces conflict points by providing a designated travel lane for motor vehicles to pass slower-moving vehicles. This design reduces risky driver behaviors by improving visibility and protecting drivers from potential severe head-on crashes.

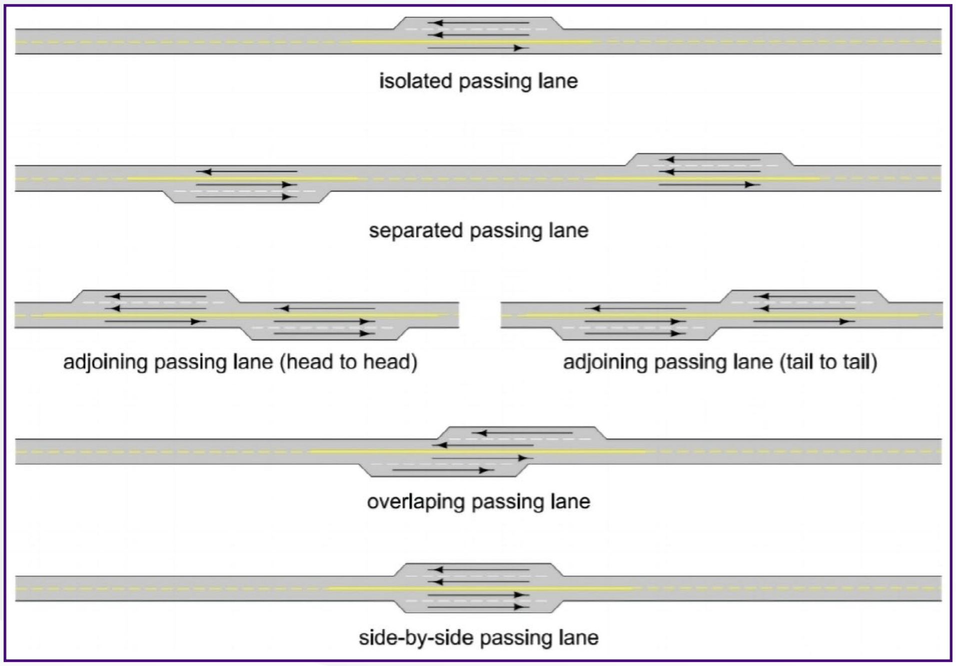
WHAT ARE THE BENEFITS OF SUPER 2 DESIGN?

The Super 2 design has been adopted as a safety strategy in Texas and Kentucky. Super 2 designs have also been implemented in countries such as Spain, Ireland, New Zealand, Germany, Finland, and Sweden. In Sweden, the Super 2 design resulted in a 55 percent reduction in fatal and serious injury crashes.[18]

A SUPER 2 DESIGN MAY ADDRESS THE FOLLOWING RISK FACTORS:
Obstructed Sight Distance, Vertical and Horizontal Curvature, and High/Excessive Vehicle Speeds.

THIS COUNTERMEASURE IN PRACTICE

The Texas Department of Transportation analyzed the operational and safety benefits of the Super 2 design on two-lane roads with traffic volumes between 5,000 and 15,000 vehicles per day, finding that the design resulted in a 35 percent reduction in expected non-intersection injury crashes and a 42 percent reduction for segments with intersections.[19]



Source: Iowa Design Manual.

CENTERLINE BUFFER AREAS

WHAT IS IT?

Centerline buffer areas provides additional space between the two solid centerline markings, creating further separation between opposing directions of traffic.

HOW DOES IT ALIGN WITH THE SAFE SYSTEM APPROACH?

Centerline buffer areas reduce vehicle conflict points and potential head-on crashes through roadway design.

WHAT ARE THE BENEFITS OF CENTERLINE BUFFER AREAS?

Centerline buffer areas were evaluated based on their effectiveness to reduce head-on crashes on rural two-lane roadways. Implementing a two-foot buffer area reduced crashes by 35 percent; a four-foot buffer area reduced crashes by 64 percent; and a 10-foot buffer area reduced crashes by 90 percent.[20]

Source: Centerline Buffer Area with yellow strips and centerline rumble strips (Highway 14), Minnesota Department of Transportation:

CENTERLINE BUFFER AREAS MAY ADDRESS THE FOLLOWING RISK FACTOR:
Undivided Roadway.

THIS COUNTERMEASURE IN PRACTICE

The Minnesota Department of Transportation conducted a road audit on Highway 14, finding that 70 percent of fatal and serious injury crashes were a result of a vehicle crossing the centerline. The Minnesota Department of Transportation then converted the highway into a no-passing zone, implemented an eight-foot centerline buffer area using double yellow striping, installed rumble strips on each side, and installed delineators every 50 feet within the buffer area to reinforce the presence of the no-passing zone. These improvements reduced fatal and serious injury crashes by 100 percent and cross centerline crashes by almost 50 percent.[21]

RESOURCES:

Additional information to support Tier 1 – Remove Severe Conflicts:

- Bikeway Selection Guide
- Separated Bike Lane Planning and Design Guide
- State Best Practice Policy for Medians
- Intersections
- Super 2 Research TxDOT
- Primer on Safe System Approach for Pedestrians and Bicyclists

TIER 2: REDUCE VEHICLE SPEEDS

Implementing design features and speed management strategies to reduce vehicle speeds effectively reduces the kinetic energy involved in a crash should it occur. 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.

Source: South Golden Road before and after improvements (City of Golden, Colorado), Dan Hartman: https://highways.dot.gov/safety/speed-management/noteworthy-practice-booklet-speed-management/case-study-2-noteworthy-speed.

SELF-ENFORCING ROADS

WHAT IS IT?

A self-enforcing or self-explaining roadway is planned, designed, and operated to offer contextual encouragement for motorists to drive at safer speeds in alignment with the roadway purpose and adjacent land uses. These roadways are generally guided by six concepts to encourage effective and safe decision making to reduce severe crashes. These concepts include applying the speed feedback loop process; using the inferred design speed approach; applying operating speed models; utilizing existing geometric design criteria; using a combination of signs and pavement marking; and setting rational speed limits.

Self-enforcing roads may also integrate mechanisms such as Transportation Systems Management and Operations (TSMO) strategies to develop a proactive and predictive transportation network, and Intelligent Transportation Systems (ITS) to improve mobility and safety through technology advancements.

HOW DOES IT ALIGN WITH THE SSA?

Self-enforcing roads support the Safe System principle that humans make mistakes by communicating contextual clues and driver expectations through design and operations, thus resulting in fewer human errors. These roadways encourage drivers to reduce travel speeds, thereby limiting the kinetic energy associated with high-speed traffic crashes, and simultaneously improving roadway safety for all users. Self-enforcing roads may be supplemented with other safety countermeasures such as roundabouts, pedestrian refuge islands, and raised crosswalks to support a Safe System.

SELF-ENFORCING ROADS MAY ADDRESS THE FOLLOWING RISK FACTORS:
Obstructed Sight Distance, High/Excessive Vehicle Speeds, Vertical and Horizontal Curvature, Crossing Conflict Intersections, Driveway Density, Undivided Roadway, and Lack of Pedestrian/Cyclist Space Separation.

WHAT ARE THE BENEFITS OF SELF-ENFORCING OR SELF-EXPLAINING ROADS?

An analysis on speed management research conducted on New Zealand roads showed that speed change thresholds and speed treatments (such as reducing roadway widths and the number of lanes and the installation of rumble stripes, landscaping, speed humps, side barriers, center medians, centerline treatments, and signage) reduced vehicle speeds by 27 percent and reduced the number of serious injury crashes by 15 percent.[22]

THIS COUNTERMEASURE IN PRACTICE

The City of Golden, Colorado rebuilt the South Golden Road corridor using a self-enforcing design to reduce vehicle speeds, improve vulnerable road user safety, and develop a pedestrian and bicycle friendly environment. The design included replacing traffic signals with roundabouts, narrowing roads using center medians, and restricting left turns to improve access to businesses and protect vulnerable road users. The enhancements reduced total crashes per month by 36 percent, injuries per month by 97 percent, and bike-related crashes from 78 crashes recorded over the five years before the improvements to just four crashes over the 3.5 years after the corridor was completed.[23]

RAISED CROSSWALKS

WHAT IS IT?

Raised crosswalks are crosswalks that are typically between three and six inches above street level, providing vertical delineation to increase visibility of crossing pedestrians.

HOW DOES IT ALIGN WITH THE SSA?

Raised crosswalks function similarly to speed humps and are effective at reducing motor vehicle speeds while simultaneously encouraging drivers to yield to pedestrians in the crosswalk. Raised crosswalks may also be combined with other pedestrian crossing countermeasures such as overhead flashing beacons to increase pedestrian visibility and allow pedestrians to establish their presence on the roadway.

Source: Raised Crosswalk, City of Cambridge, Massachusetts: https://statics.teams.cdn.office.net/evergreen-assets/safelinks/1/atp-safelinks.html.

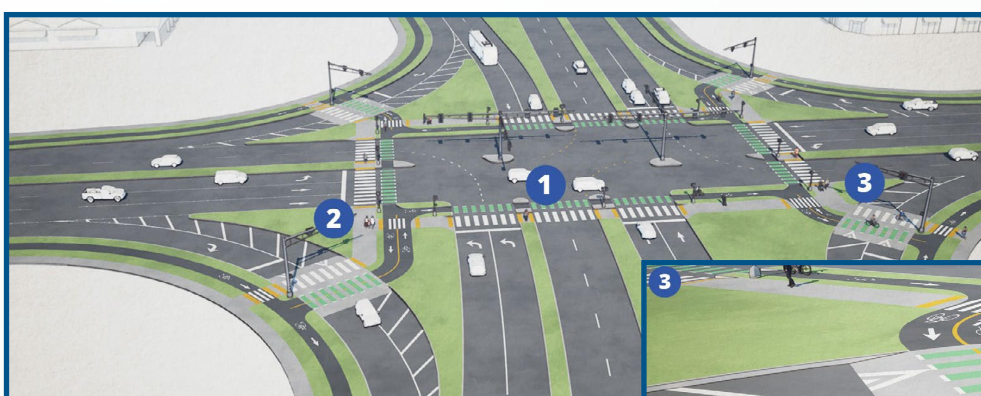
WHAT ARE THE BENEFITS OF RAISED CROSSWALKS?

Raised crosswalks may reduce pedestrian crashes by 45 percent.[24] For example, when applied on local two-lane roadways in urban and suburban areas, raised crosswalks reduced fatal and serious injury crashes by 46 percent.[25]

RAISED CROSSWALKS MAY ADDRESS THE FOLLOWING RISK FACTORS:
Lack of Pedestrian/Cyclist Space Separation, Obstructed Sight Distance, Intersection Crossing Conflict, and High/Excessive Vehicle Speeds.

THIS COUNTERMEASURE IN PRACTICE

Raised crosswalks among other traffic calming improvements were constructed in Cambridge, Massachusetts to improve safety and reduce motor vehicle speeds. For the raised crosswalks, the City used concrete pavers to replicate the look and feel of brick, providing a color contrast to increase effectiveness. Before the improvements, the 85th percentile speed on Granite Street was 28 mph. After the improvements, the speed was reduced to 24 mph.[26]



The diagram shows how: 1) crossing islands; 2) signalized crossings; and 3) raised bike and pedestrian crossings can improve displaced left turn intersections.

Source: Improving Intersections for Pedestrians and Bicyclists, FHWA: https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/fhwasa22041.pdf.

GATEWAYS

WHAT IS IT?

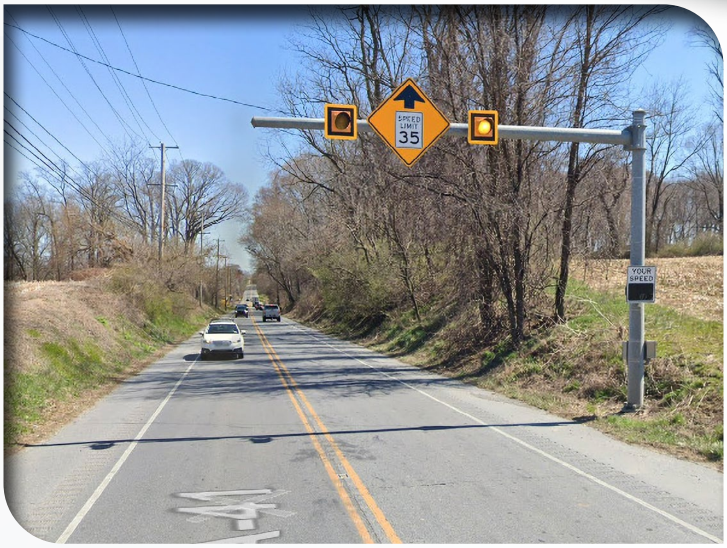
Gateways are physical features or geometric landmarks that are part of a wayfinding system and send a clear message to motorists that the roadway network context is changing. These features may include signage, medians, archways, roundabouts, landscaping, brick paving, decorative fencing, and more. Gateways are often located at key entrance points to neighborhoods or downtowns.

HOW DOES IT ALIGN WITH THE SSA?

Gateways are a form of traffic calming treatments, which aim to reduce travel speeds by creating an expectation for motorists to drive more slowly and to increase awareness of their surroundings.

WHAT ARE THE BENEFITS OF GATEWAYS?

Gateways alert drivers that they are entering an area that may have increased bicycle or pedestrian activity or changing roadway configurations, increasing their awareness of all roadway users. Constructing gateway monuments, roadside structures, and wayfinding signage resulted in a 32 percent reduction in fatal and serious injury crashes when applied on State-owned roadways with a minimum of 3,300 AADT and maximum of 34,000 AADT.[27]



Source: Overhead reduced speed reduction sign leading up to the Village of Chatham gateway sign (Village of Chatham, Pennsylvania), Google Street View.

GATEWAYS MAY ADDRESS THE FOLLOWING RISK FACTORS:
High/Excessive Vehicle Speeds, Proximity to Schools, and Lack of Pedestrian/Cyclist Space.

THIS COUNTERMEASURE IN PRACTICE

The Michigan Department of Transportation developed a highly effective pedestrian gateway treatment to encourage drivers to yield to pedestrians in crosswalks. The pedestrian gateway treatment features RI-6 yield signs at both ends of the crosswalks and a flexible delineator post or yield sign in between travel lanes. According to the Michigan Department of Transportation, this treatment is appropriate for intersections and midblock crosswalks with speed limits of 35 mph or less. The treatment may be used on a variety of roadway configurations including one and two way travel lanes, with or without pedestrian refuge areas, and with or without bike lanes. According to two studies that measured effectiveness, the pedestrian crossing configuration resulted in a 70 to 90 percent vehicle speed compliance rate on roads with posted speeds of 30 mph or lower with up to 25,000 vehicle ADT.[28]

SPEED HUMP/BUMP

WHAT IS IT?

Speed humps, often displayed as speed bumps on signage, are vertical ramps that aim to reduce vehicle speeds by 15 to 20 mph on one-way or two-way roads. Speed humps are commonly two to four inches high and 12 to 14 feet wide, with a ramp length of three to six feet depending on the target speed of the roadway. As recommended by the Manual of Uniform Traffic Control Devices (MUTCD-W17-1), speed humps may be accompanied by a warning sign of the upcoming roadway design feature.

Source: Traffic Calming Speed Hump, Robert Drudi (Creative Commons License).

HOW DOES IT ALIGN WITH THE SSA?

Speed humps are a form of traffic calming treatments which force drivers to travel at reduced, and often safer, speeds.

WHAT ARE THE BENEFITS OF SPEED HUMPS/BUMPS?

Speed humps may be implemented as a strategy to reduce travel speeds at prioritized locations with high volumes of vulnerable road users (e.g., near schools), or implemented consecutively to calm traffic across longer portions of the roadway network. For example, installing speed humps on local 2 lane roadways in both urban and suburban areas resulted in a 50 percent decrease in fatal and serious injury crashes.[29]

SPEED HUMPS MAY ADDRESS THE FOLLOWING RISK FACTOR:
High/Excessive Vehicle Speeds.

THIS COUNTERMEASURE IN PRACTICE

The New York City Department of Transportation designates Neighborhood Slow Zones to reduce crash occurrence and severity. The Neighborhood Slow Zone program integrated gateway signage, 20 mph pavement markings, and speed humps to encourage motorists to drive slowly. These improvements reduced vehicle speeds by 10 to 25 percent, resulting in a 10 percent overall reduction in injury crashes and a 27 percent reduction in vehicle injury crashes.[30]

RESOURCES:

Additional information to support Tier 2 – Reduce Vehicle Speeds:

Evaluation of Lane Reduction "Road Diet" Measures and their Effects on Crashes and Injuries

Pedestrian Gateway Treatment

ITE Traffic Calming Library

Synthesis of Safety Research Related to Speed and Speed Management

Complete Streets Transformations

Complete Streets Best Policy and Implementation Practices

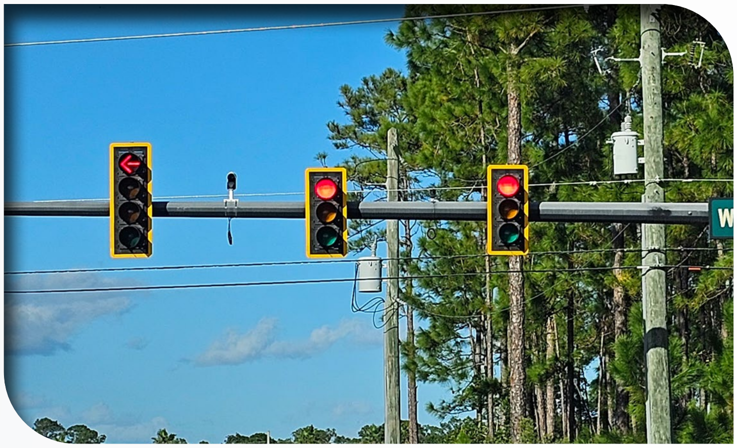
TIER 3:
MANAGE CONFLICTS IN TIME

Managing conflicts in time assumes that users will need to occupy the same physical space on the roadway and creates a safer environment by separating the users in time using traffic control devices, such as traffic signals or hybrid beacons, to minimize vehicle conflicts. Providing discrete and alternating opportunities for users to navigate the roadway environment is not only a safety strategy, but also one that relates to user comfort and convenience, especially for non-motorized users.

LEFT TURN PHASING

WHAT IS IT?

Protected left turn phasing provides a green or yellow arrow for
left-turning vehicles while stopping both on-coming traffic and parallel pedestrian crossings.



Source: Cambridge Systematics, Inc.

HOW DOES IT ALIGN WITH THE SSA?

Protected left turn phasing eliminates conflicts between cross traffic, left-turning vehicles, and pedestrians using the parallel crosswalk. This strategy may also be enhanced with leading pedestrian intervals to clear pedestrians through the crossings and reduce pedestrian and motor vehicle conflict points.

WHAT ARE THE BENEFITS OF LEFT TURN PHASING?

Changing permissive left-turn phasing to protected left-turn phasing in Utah resulted in an 87 percent reduction in fatal and serious injury traffic crashes.[31]

PROTECTED LEFT TURN PHASING MAY ADDRESS THE FOLLOWING RISK FACTORS:
Permissive Left Turn Conflicts and Lack of Pedestrian/Cyclists Time Separation.

THIS COUNTERMEASURE IN PRACTICE

The cities of Detroit and Grand Rapids, Michigan, upgraded permissive left-turn signals to protected left turn phasing at three locations. These improvements reduced total left-turn head-on crashes at the selected intersections by 84 percent, injury crashes by 59 percent, and total crashes by 32 percent per year.[32]

COORDINATED SIGNAL TIMING

WHAT IS IT?

Coordinated signal timing uses synchronized traffic movements to create an uninterrupted flow of traffic along a corridor with frequent intersections. Coordinated signal timing may set desired progression speeds to fit the roadway's surrounding context through platooning. It may also be applied in areas with high pedestrian and bicyclist volumes to achieve desired operating speeds and to prioritize pedestrian and bicyclists travel.

HOW DOES IT ALIGN WITH THE SSA?

Coordinated signal timing reduces potential conflicts associated with interrupted traffic flow for all roadway users, including motorists, transit vehicle operators and passengers, bicyclists, and pedestrians.

WHAT ARE THE BENEFITS OF COORDINATED SIGNAL TIMING?

Coordinated signal timing may reduce the number of stops along a corridor and provide a continuous flow of traffic at the target speed. For example, a 12 intersection corridor on Glades Road in Boca Raton (FL) served as a case study to explore how optimized signal timing could address safety and efficiency, resulting in a 7 percent reduction in traffic conflicts when compared to the initial signal timings.[33]

Source: Urban Street Design Guide, NACTO.

COORDINATED SIGNAL TIMING MAY ADDRESS THE FOLLOWING RISK FACTOR:
High/Excessive Vehicle Speeds.

THIS COUNTERMEASURE IN PRACTICE

As part of Vision Zero, the New York City Department of Transportation implemented the Arterial Slow Zone Program to improve corridor mobility and prevent traffic fatalities. The program utilizes a combination of tools, including setting a lower speed limit, using distinctive blue-and-white roadway signage to make drivers aware of the changing roadway context, and implementing temporary traffic speed enforcement boards at key locations along the corridors to warn motorists of the new speed limit. The Arterial Slow Zone Program retimes traffic signals to ensure consistency with the new speed limit, discourage speeding, and maintain an uninterrupted traffic flow.[34]

PEDESTRIAN SCRAMBLE

WHAT IS IT?

A pedestrian scramble, also known as a Barnes dance or an all-walk phase, is an exclusive signal phase that allows pedestrians to cross an intersection in any direction. Vehicles on all approaches are stopped during the pedestrian scramble. Pedestrian scrambles may be beneficial in locations where other crossing improvement treatments are prohibited by cost or right-of-way concerns.

Source: Pedestrian Scramble, Los Angeles Department of Transportation.

HOW DOES IT ALIGN WITH THE SSA?

A pedestrian scramble removes points of conflict between turning vehicles and crossing pedestrians. This reduces pedestrians' exposure to conflict and overall crossing time while increasing their visibility in the roadway. Pedestrian scrambles are often paired with other pedestrian crossing improvements such as curb extensions, high-visibility crosswalk markings, and "No Turn on Red" restrictions and signage.

WHAT ARE THE BENEFITS OF PEDESTRIAN SCRAMBLES?

A pedestrian scramble gives pedestrians priority in the intersection while removing conflicts with turning vehicles. Implementing a pedestrian scramble on urban roadways in New York City resulted in a 51 percent reduction in vehicle/pedestrian fatal and serious injuries crashes.[35]

PEDESTRIAN SCRAMBLE MAY ADDRESS THE FOLLOWING RISK FACTORS:
Lack of Pedestrian/Cyclists Time Separation, Skewed Geometry, Intersection Density, and Intersection Crossing Conflict.

THIS COUNTERMEASURE IN PRACTICE

A pedestrian scramble was implemented at the intersection of 8th and Webster Streets in the Chinatown neighborhood in Oakland, California. Before the pedestrian scramble was implemented, observations of the intersection revealed vehicle delays and vehicle encroachment in the crosswalk, resulting in a total of 77 conflicts. The implementation process included public outreach efforts such as distributing multilingual brochures and conducting workshops to educate the community on the new intersection design. Following implementation, observers recorded a total of 35 conflicts, noting a significant decrease in pedestrian-vehicle conflicts.[36]

EMERGENCY VEHICLE PREEMPTION

WHAT IS IT?

An emergency vehicle preemption (EVP) system uses ITS technology at signalized intersections to provide a green interval for an emergency vehicle approaching an intersection, and a red interval on all conflicting approaches. This allows emergency vehicles to safely travel through areas with levels of high congestion.

HOW DOES IT ALIGN WITH THE SSA?

EVP systems align with the Post-Crash Care element of the SSA by separating emergency vehicles in time from traveling motorists. EVP systems may improve incident response times by prioritizing the emergency vehicle through an intersection. Similar to yellow change intervals, EVPs also reduce potential conflict points and reduce the likelihood of crashes.

WHAT ARE THE BENEFITS OF EVP?

EVPs increase overall safety at intersections by improving driver awareness of approaching emergency vehicles. EVPs also provide separation in time to facilitate the safe passing of emergency vehicles through roadway traffic. This system may reduce the risk of emergency vehicle crashes with motorists while also improving incident response times, creating a safe and integrated transportation network.

Source: Getty Images.

EMERGENCY VEHICLE PREEMPTION MAY ADDRESS THE FOLLOWING RISK FACTORS:
Intersection Crossing Conflicts and Clearance Times.

THIS COUNTERMEASURE IN PRACTICE

An EVP system in the City of Plano, Texas reduced the number of emergency vehicles crashes from an average of 2.3 intersection crashes per year to less than one intersection crash every five years.[37]

RESOURCES

Additional information to achieve Tier 3 – Manage Conflicts in Time:

Leading Pedestrian Interval

Urban Street Design Guide

Manual on Uniform Traffic Control Devices

TIER 4:
INCREASE ATTENTIVENESS AND AWARENESS

Increasing attentiveness and awareness involves alerting roadway users to certain types of conflicts so that appropriate action can be taken consistent with the SSA principle that responsibility is shared.

ENHANCED PAVEMENT MARKINGS

WHAT IS IT?

Enhanced pavement markings include wider edge lines, retroreflective pavement markings, in-lane pavement markings, in-lane curve warning markings, and more.

Source: Getty Images.

HOW DOES IT ALIGN WITH THE SSA?

Enhanced pavement markings aim to increase driver awareness and attentiveness of the travel lane, surrounding roadway, or upcoming roadway context changes. Increasing awareness of the roadway supports the Safe Roads Element of the Safe System Approach and the principle that redundancy is crucial.

WHAT ARE THE BENEFITS OF ENHANCED PAVEMENT MARKINGS?

Wider edge lines may reduce non-intersection-related fatal and serious injury crashes on rural two-lane roads by up to 37 percent and fatal and serious injury crashes on rural freeways by up to 22 percent.[38]

Providing “Stop Ahead” pavement markings at stop-controlled intersections at forty-one sites in four States resulted in a 66 percent reduction in all traffic crash types and severity when applied on rural two-lane roadways with a minimum of 105 AADT to a maximum of 4,800 AADT on major roadways, and a minimum of 25 AADT to a maximum of 1,770 AADT on minor roadways.[39]

ENHANCED PAVEMENT MARKINGS MAY ADDRESS THE FOLLOWING RISK FACTORS:

High/Excessive Vehicle Speeds, No Lighting, Undivided Roadway, and Curvature.

In-lane curve warning pavement markings may reduce all crashes by 35 to 38 percent.[40]

THIS COUNTERMEASURE IN PRACTICE

The adoption of wider edge lines was evaluated on rural, two-lane roadways in Kansas, Michigan, and Illinois. The study indicated a 15 to 30 percent reduction in total crashes.[41]

INTERSECTION CONFLICT WARNING SYSTEMS

WHAT IS IT?

Intersection conflict warning systems (ICWS) use a vehicle sensor to detect the presence of vehicles approaching the intersecting roadway. The sensor triggers a warning message (such as "Vehicle Entering When Flashing" or "Crossing Traffic When Flashing") and flashing light beacons to warn drivers of the potentially conflicting vehicle approaching the intersection. ICWS are often implemented in rural areas at non-signalized, stop-controlled intersections.

HOW DOES IT ALIGN WITH THE SSA?

ICWS provide drivers with a warning in real-time of potential crossing conflicts. These systems are intended to reduce crash frequency by increasing driver attentiveness and awareness of potential roadway conflicts.

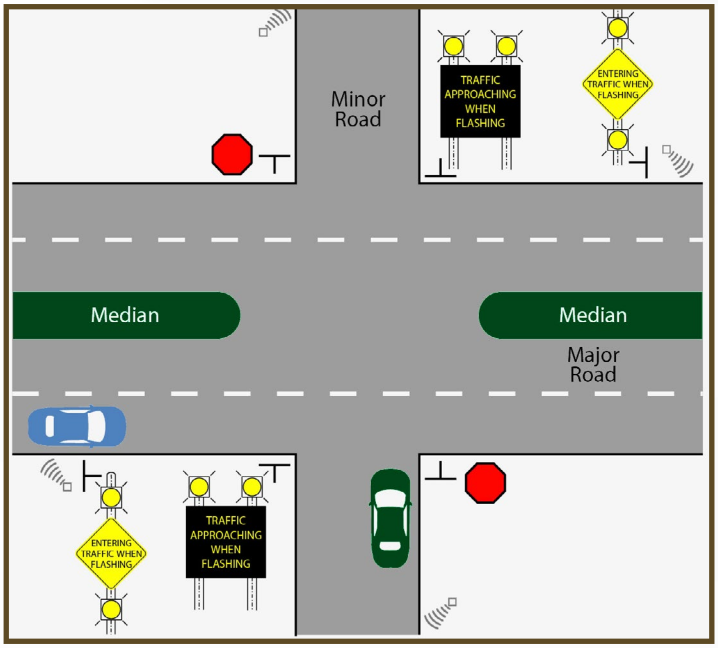
WHAT ARE THE BENEFITS OF INTERSECTION CONFLICT WARNING SYSTEMS?

Installing an ICWS with a combination of overhead and advanced post-mounted signs and flashers at four sites in three States resulted in a 30 percent reduction in all traffic crash types and severity applied at rural two-lane, stop-controlled intersections.[42]

INTERSECTION CONFLICT WARNING SYSTEMS MAY ADDRESS THE FOLLOWING RISK FACTORS:
Obstructed Sight Distance and High/Excessive Vehicle Speeds.

THIS COUNTERMEASURE IN PRACTICE

Since 2020, the Indiana Department of Transportation has implemented ICWS at non-signalized, stop-controlled highway intersections statewide to reduce the likelihood of severe traffic crashes. Drivers traveling on the major road will see a static ENTERING TRAFFIC WHEN FLASHING sign and flashing warning lights when a vehicle is waiting on the intersecting minor road. Drivers traveling on the minor road, in addition to the stop sign, will see a constantly illuminated TRAFFIC APPROACHING WHEN FLASHING sign and flashing warning lights when a vehicle is approaching the intersection on the major road.[43]



Source: ICWS Highway Roadway Diagram and Signage, Indiana Department of Transportation: https://www.in.gov/indot/traffic-engineering/intersection-conflict-warning-systems/
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WRONG WAY DRIVING COUNTERMEASURES

WHAT IS IT?

Wrong way driving crashes occur when a vehicle travels in a direction opposing the legal flow of traffic and collides with a vehicle traveling in the proper direction. Several countermeasures may deter or prevent wrong way driving behavior, such as static signage and pavement markings (e.g., “Wrong Way” signs), dynamic alert systems (e.g., illuminated “Wrong Way’ signs providing flashing warnings when a vehicle traveling the wrong way is detected), or in-vehicle alert systems connected via vehicle-to-infrastructure (V2I) or vehicle-to-vehicle (V2V) technologies.

HOW DOES IT ALIGN WITH THE SAFE SYSTEM APPROACH?

Countermeasures may increase driver awareness and attentiveness by providing visual warnings to deter and prevent wrong way driving, which reduces potential crash conflicts with vehicles traveling in the right direction.

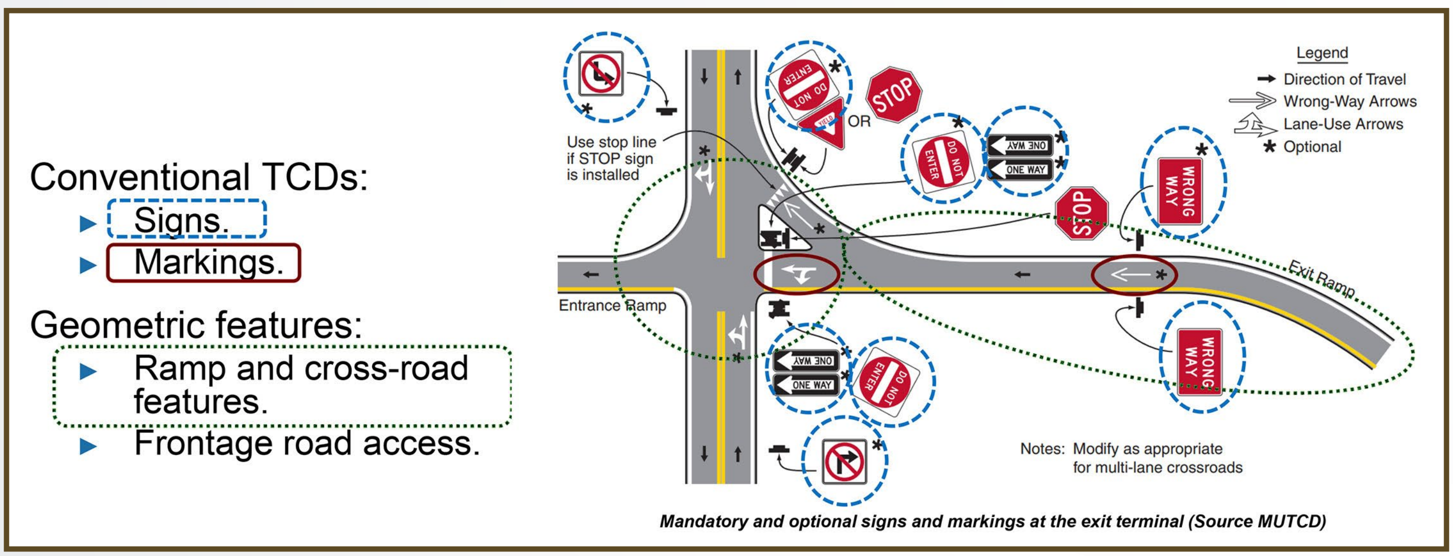
WHAT ARE THE BENEFITS OF WRONG WAY DRIVING COUNTERMEASURES?

Wrong way driving crashes are one of the most severe crash types, typically occurring on high-speed divided highways or access ramps. Wrong way driving countermeasures aim to reduce both crash occurrence and severity, while limiting illegal driving behaviors.

WRONG WAY DRIVING COUNTERMEASURES MAY ADDRESS THE FOLLOWING RISK FACTORS:
Obstructed Sight Distance, Ramp Geometry, and Driver Uncertainty and Confusion

THIS COUNTERMEASURE IN PRACTICE

To combat wrong way driving, the Texas Department of Transportation implemented enhanced LED wrong way signs at 28 exit ramps along Highway 281, resulting in a 35 percent reduction in the average monthly rate of logged wrong way driving events between 2012 to 2016. In addition, the Texas Department of Transportation implemented radar detection devices on overhead sign bridges along I-10 and I-35 to detect wrong way driving vehicles, which trigger a wrong way warning sign and flashing LED lights to catch the driver’s attention, while also providing a warning message to on-coming drivers that a vehicle is traveling in the wrong direction.[44]



Mandatory and optional signs and markings at the exit terminal (Source MUTCD)

Source: Wrong Way Driving Countermeasures, FHWA:
https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-07/WWD%20National%20Workshop%20Presentation.pdf

BICYCLE TREATMENTS

WHAT IS IT?

Bicycle treatments include intersection bicycle boxes, bicycle signal heads and phases, and green colored pavement markings that aim to enhance the visibility of bicyclists on the roadway. The context of the roadway, including the composition and volumes of roadway users, vehicle speeds, and surrounding land uses will determine which bicycle treatments are most appropriate.

Source: Green Colored Paint, FHWA: Improving Intersections for Pedestrians and Bicyclists: Informational Guide (dot.gov).

HOW DOES IT ALIGN WITH THE SSA?

Bicycle treatments increase driver awareness and attentiveness of bicyclists, promote bicyclist visibility and priority in the roadway, reduce potential conflict points, and provide designated routes for bicycle movements. For example, green colored pavement markings remind motor vehicles that space on the roadway is shared with bicyclists, which may encourage drivers to reduce their travel speeds. Bicycle signal heads can also be considered a Tier 3 countermeasure to separate conflicts in time if a separate bicycle phase is provided or if the bike signals provide for a longer intersection clearance interval for cyclists

BICYCLE TREATMENTS MAY ADDRESS THE FOLLOWING RISK FACTORS:
Lack of Pedestrian/Cyclists Space Separation, Obstructed Sight Distance, and Intersection Crossing Conflict.

WHAT ARE THE BENEFITS OF BICYCLE TREATMENTS?

By making drivers more aware of bicycle movements, they are more likely to avoid crashes. For example, colored bicycle treatments were installed at signalized intersections in New Zealand and Australia at locations where bicyclists previously shared the roadway with motor vehicles, resulting in a 39 percent reduction in vehicle/bicycle crash types.[45]

THIS COUNTERMEASURE IN PRACTICE

According to an evaluation of 12 bike boxes implemented at signalized intersections in Portland, Oregon, the bike boxes reduced bicycle-motor vehicle conflicts at all improved intersections. Additionally, 77 percent of bicyclists felt that traveling through the intersection was safer after instillation of a bicycle treatment.[46]

Source: Getty Images.

TRANSVERSE RUMBLE STRIPS

WHAT IS IT?

Transverse rumble strips are placed perpendicularly across the travel lane to warn drivers when approaching upcoming roadway changes that may not be anticipated by the driver. Transverse rumble strips are low-cost roadway improvements that may be used in both urban and rural areas to warn drivers of changing conditions, such as approaching minor stop-controlled intersections, horizontal curves, or work zones.

HOW DOES IT ALIGN WITH THE SAFE SYSTEM APPROACH?

Transverse rumble strips provide a tactile and audible warning for drivers to alert them of upcoming traffic approaches while encouraging speed reduction through roadway design.

WHAT ARE THE BENEFITS OF TRANSVERSE RUMBLE STRIPS?

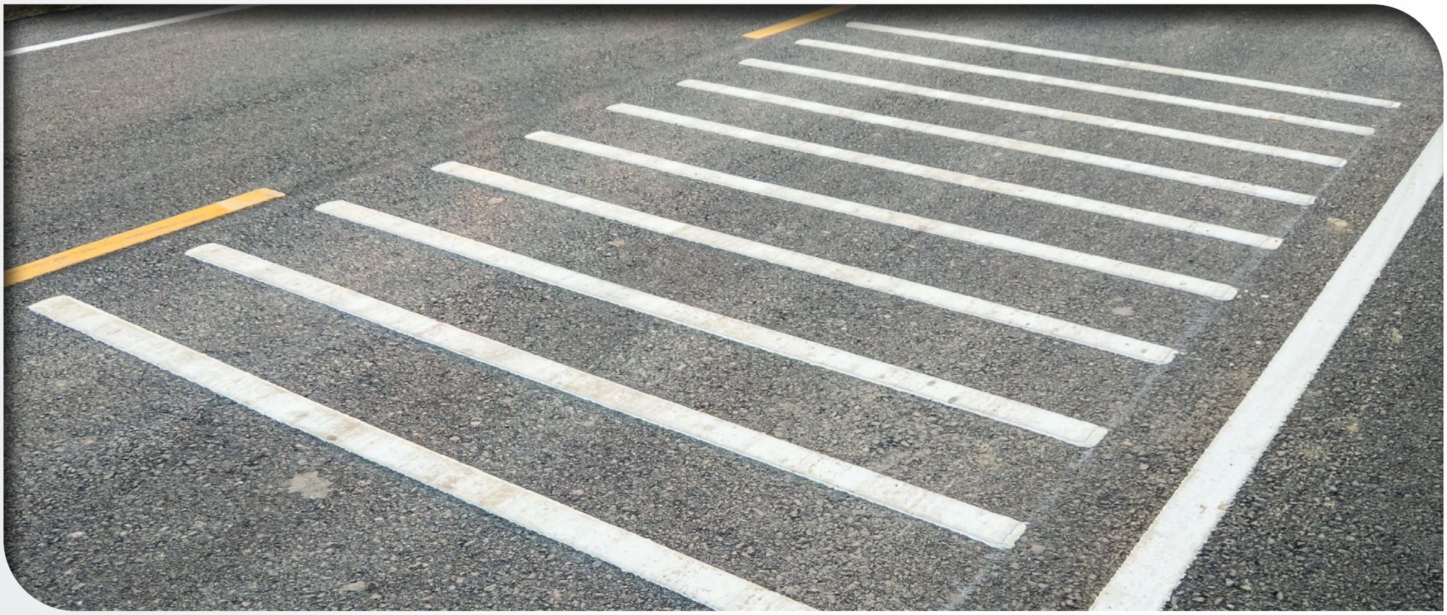
Transverse rumble strips are a low-cost strategy with proven applications for stop-controlled intersections, approaches to horizontal curves, or in advance of work zones. In addition, transverse rumble strips resulted in a 36 percent reduction in fatal and serious injury crashes when applied as a traffic calming device on local roadways in both urban and suburban areas.[47]

TRANSVERSE RUMBLE STRIPS MAY ADDRESS THE FOLLOWING RISK FACTORS:

Horizontal Curvature and High/ Excessive Vehicle Speeds.

THIS COUNTERMEASURE IN PRACTICE

Transverse rumble strips were evaluated on rural roadways in Iowa and Minnesota to examine their impacts on both total crashes and specific crash types such as right angle and run stop sign crashes. The analysis indicated a 23 percent reduction in fatal and serious injury crashes.[48]



Source: Getty Images.

DYNAMIC SPEED FEEDBACK SIGNS

WHAT IS IT?

Dynamic speed feedback signs (DSFS) are traffic control devices that provide a message to drivers when they exceed a certain speed threshold. A DSFS system typically uses a speed measuring device and a message sign to display feedback to drivers. DSFSs may be used in various applications such as school zones, work zones, and community entrances.

HOW DOES IT ALIGN WITH THE SSA?

A DSFS alerts drivers when they are speeding and creates a sense of being monitored, reminding drivers of their shared responsibility to drive safely. A DSFS acts as a traffic calming device and encourages drivers to reduce speeds.

WHAT ARE THE BENEFITS OF DYNAMIC SPEED FEEDBACK SIGNS?

Applying dynamic speed feedback signs on rural two-lane curves may result in traffic crash reductions from 5 to 7 percent.[49]

DYNAMIC FEEDBACK SIGNS MAY ADDRESS THE FOLLOWING RISK FACTORS:
Travel Speeds.

Source: Cambridge Systematics, Inc.

THIS COUNTERMEASURE IN PRACTICE

The City of Bellevue (WA) evaluated two DSFS systems on urban two-lane roads with 25 to 35 mph speed limits. The first system implemented a “your speed” sign and the second system displayed the vehicle speed for vehicles traveling over the posted speed limit. An average speed reduction of 4.2 mph was documented after the first year of implementation, while an average speed reduction of 6.2 mph was documented four to eight years after installment.[50]

RESOURCES

Additional information to support Tier 4 – Increase Attentiveness and Awareness:

Guidance for the Design and Application of Shoulder and Centerline Rumble Strips

MUTCD Interim Approval 21 – RRFBs at Crosswalks

Manual for Uniform Traffic Control Devices

BIKESAFE Intersection Markings

NACTO Transit Street Design Guide

Self-Enforcing Roadways: A Guidance Report

Endnotes

1 OSHA, Practices for Safety and Health Programs: Identifying Hazard Control Options: The Hierarchy of Controls (osha.gov)

2 D. McTiernan and A. Rensen. “The Safe System Hierarchy of Control Framework for Local Roads,“ in Australasian Road Safety Conference (Canberra, ACT, Australia: September 2016).

3 Ederer et al. The Safe Systems Pyramid: A new framework for traffic safety, Transportation Research Interdisciplinary Perspectives, Volume 21, 2023: https://www.sciencedirect.com/science/article/pii/S2590198223001525

4 Minnesota Department of Transportation, Complete Streets Case Studies: https://www.dot.state.mn.us/complete-streets/examples.html

5 Insurance Institute for Highway Safety (IIHS), Roundabouts: https://www.iihs.org/topics/roundabouts

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ZERO IS OUR GOAL

A SAFE SYSTEM IS HOW WE GET THERE

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