Safe System Approach

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PM&E

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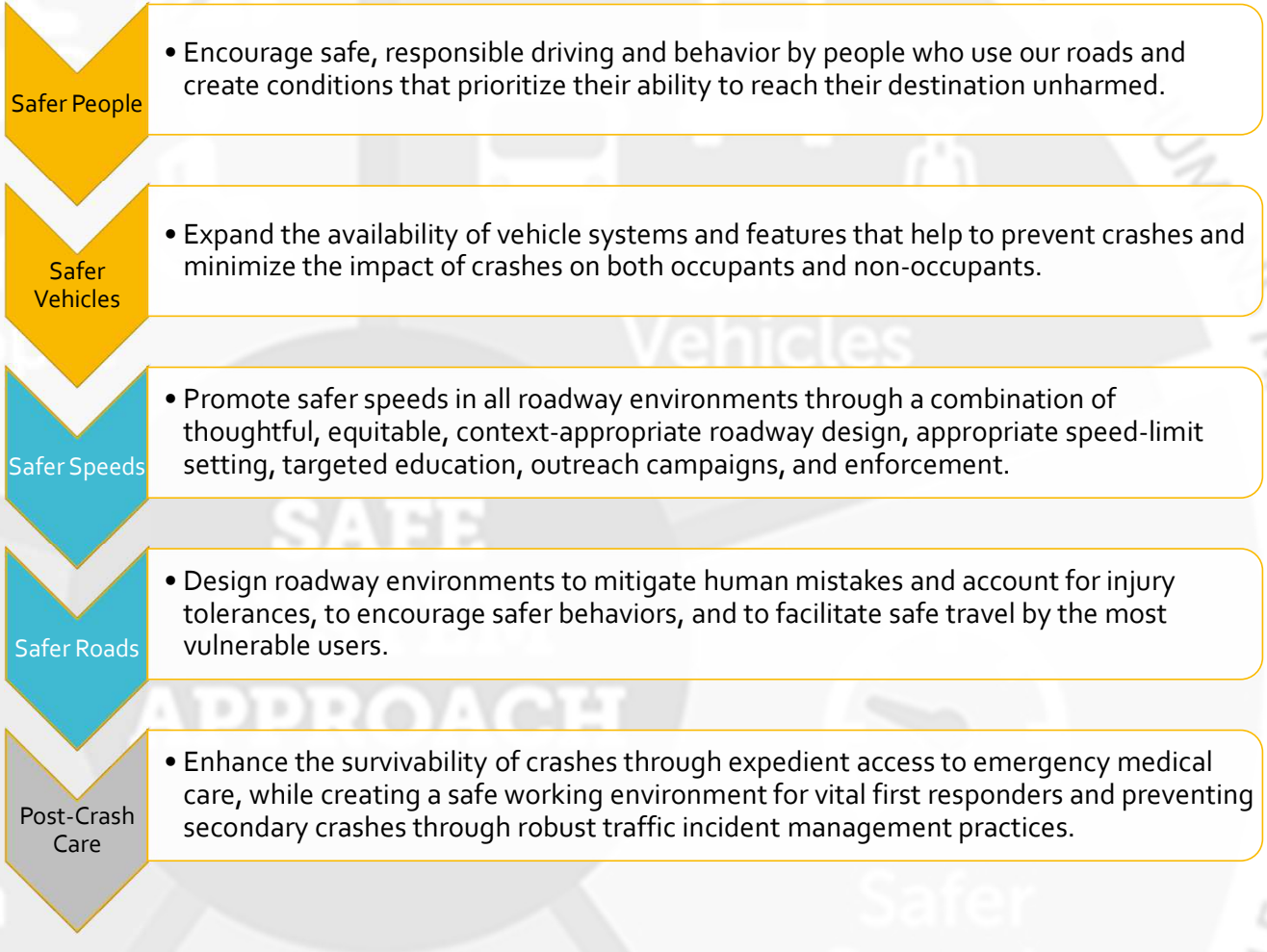
PROJECT MANAGEMENT & ENGINEERING

Safe System Approach

- Safe System Approach
  - Principals of the Safe System Approach
  - Objectives of the Safe System Approach
  - Crash Reduction (Traditional Approach)
  - Safer Speeds
  - Safer Roads
    - Anticipate Human Error
    - Accommodate Human Injury Tolerances
  - Post-Crash Care
- Vision Zero Lesson from Finland

Principals of the Safe System Approach

Objectives of a Safe System Approach

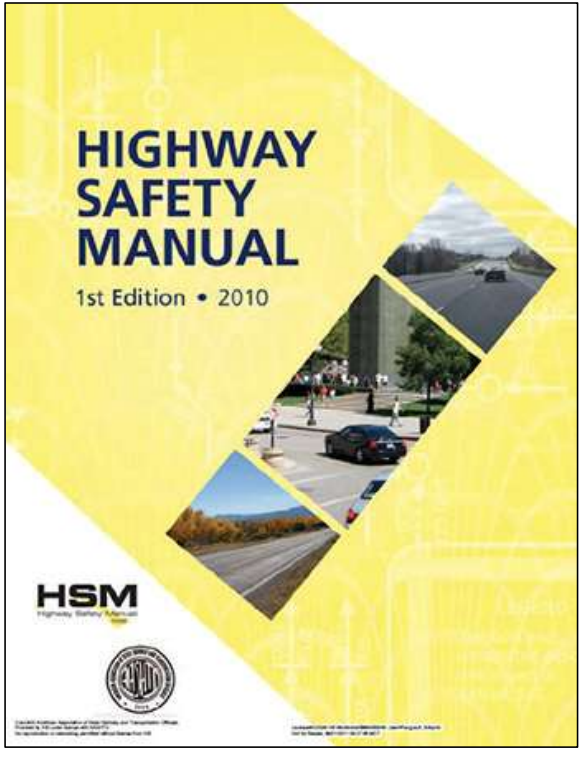


Safe System Approach vs Traditional Approach

Traditional Approach	Safe System Approach
Prevent Crashes	• Prevent Death and Serious Injury
Design for Perfect Behavior	• Design for Human Mistakes/Limitations
Accommodate High Speeds	• Reduce System Kinetic Energy
Individual Responsibility	• Shared Responsibility
Reactive to Crash History	• Proactively Identify and Address Risks

Traditional Road Safety Approach -Crash Reduction

- Crash Modification Factor
  - A multiplicative factor that indicates the proportion of crashes that would be expected after implementing a countermeasure.
  - CMF < 1 = reduction
  - CMF = 1 = no change
  - CMF > 1 = increase
- Crash Reduction Factor
  - Another way of representing the expected effect of a countermeasure in terms of the percentage decrease in crashes
  - CRF > 0% = reduction
  - CRF = 0% = no change
  - CRF < 0% = increase

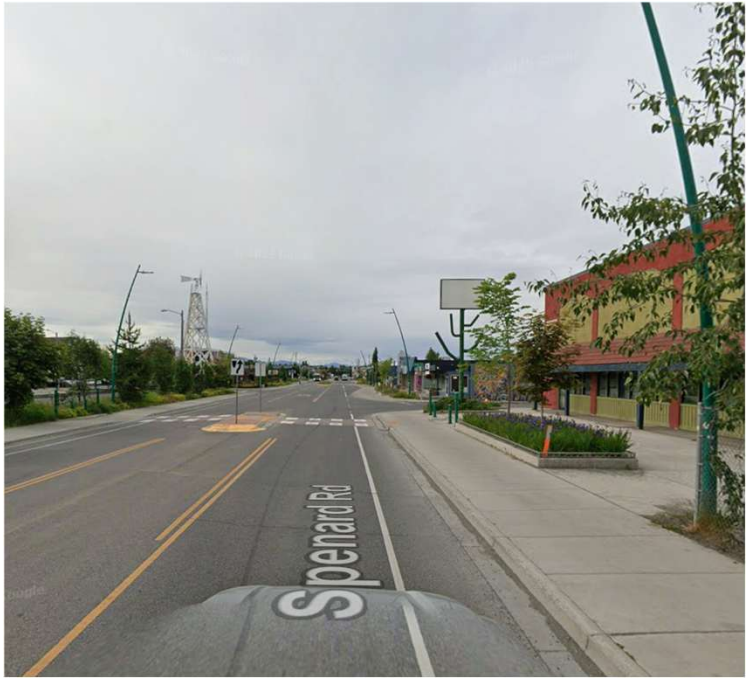


Traditional Road Safety Approach -Spenard Project Example

Traditional Approach

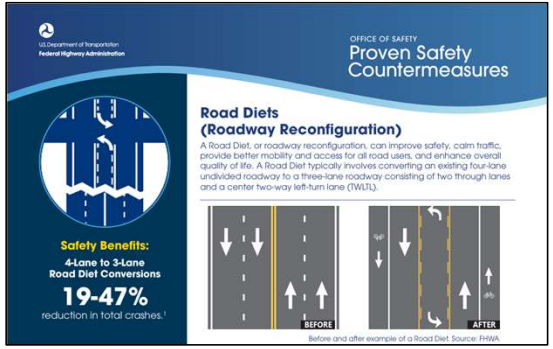
Spenard Rd 2011

Spenard Rd 2025

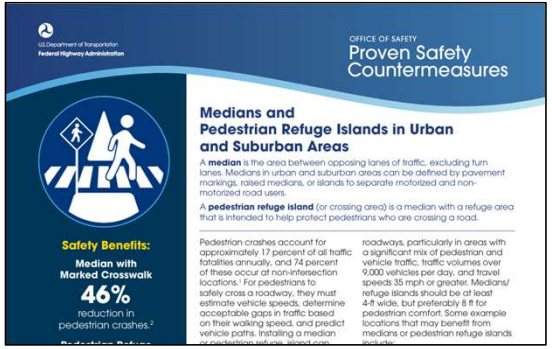


Traditional Road Safety Approach -Spenard Project Example

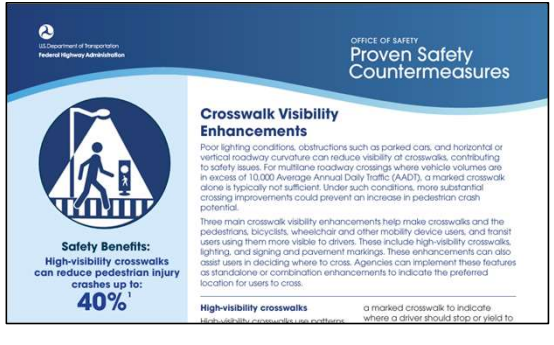
Road Diet
19-47% Reduction in Total Crashes



Pedestrian Refuge Island
46% Reduction in Pedestrian Crashes

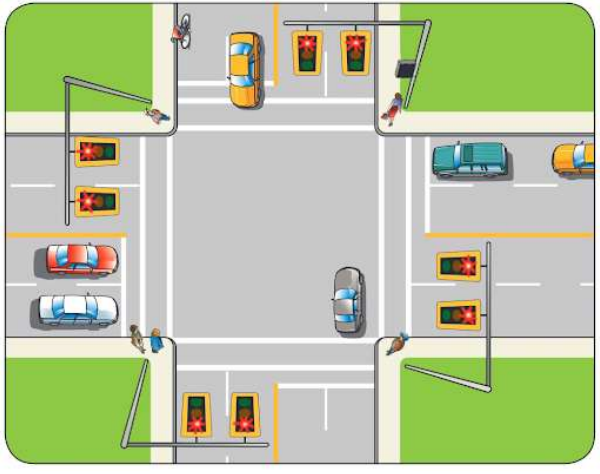


Crosswalk Visibility Enhancement
40% Reduction in Pedestrian Crashes



Traditional Road Safety Approach -Crash Reduction vs Crash Severity

Conversion of Intersection to Roundabout
CMF = 1.58 CRF = -58%



Source: Evaluating the Performance and Safety Effectiveness of Roundabouts – An Update, Savolainen, et al, June 2023

Traditional Road Safety Approach -Crash Reduction vs Crash Severity

Table 23 Crash Severity Distribution Before and After Roundabout Construction

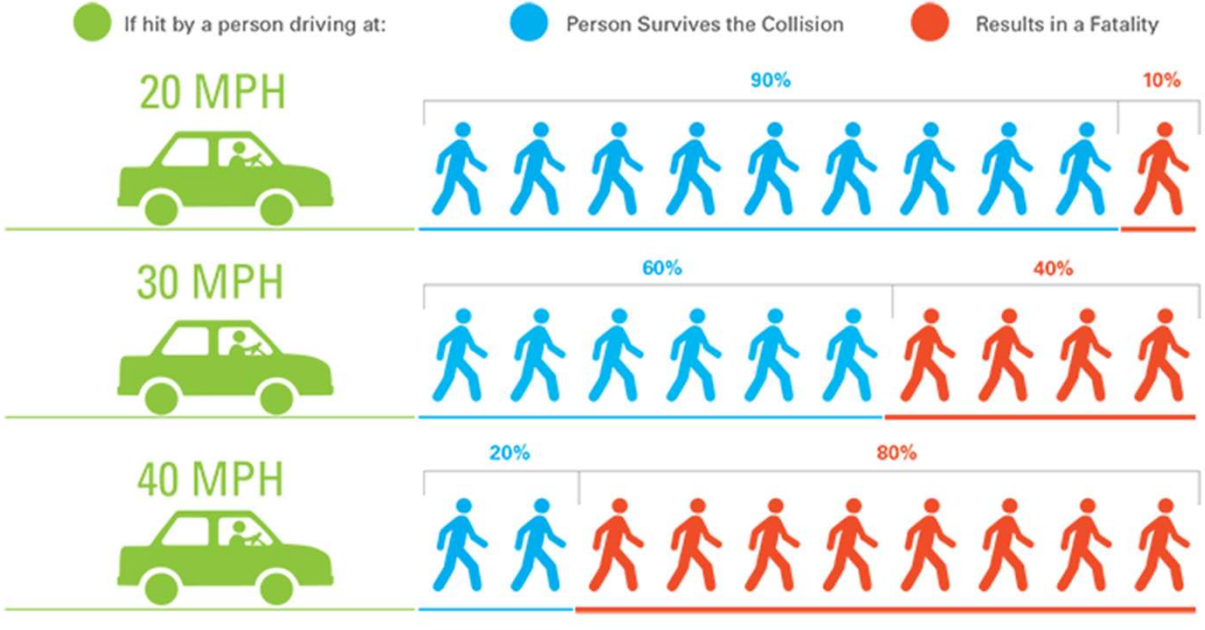
Severity Type	Before Period		After Period	
	Frequency	Percentage of Total	Frequency	Percentage of Total
Single and Double Lane Roundabouts				
Fatal	21	0.26%	5	0.06%
A-Level	129	1.62%	58	0.65%
B-Level	374	4.71%	192	2.14%
C-Level	1154	14.53%	577	6.42%
PDO	6265	78.87%	8160	90.75%
Total	7943	100.00%	8992	100.00%

A – Serious Injury **B** – Minor Injury **C** – Possible Injury **PDO** – Property Damage Only

Source: Evaluating the Performance and Safety Effectiveness of Roundabouts – An Update, Savolainen, et al, June 2023

Objectives of a Safe System Approach, Safer Speeds

- Why focus on Lower Speeds?
  - Safe System Approach focuses on the forces involved in a crash, reducing those forces to improve survivability.



Objectives of a Safe System Approach, Safer Speeds

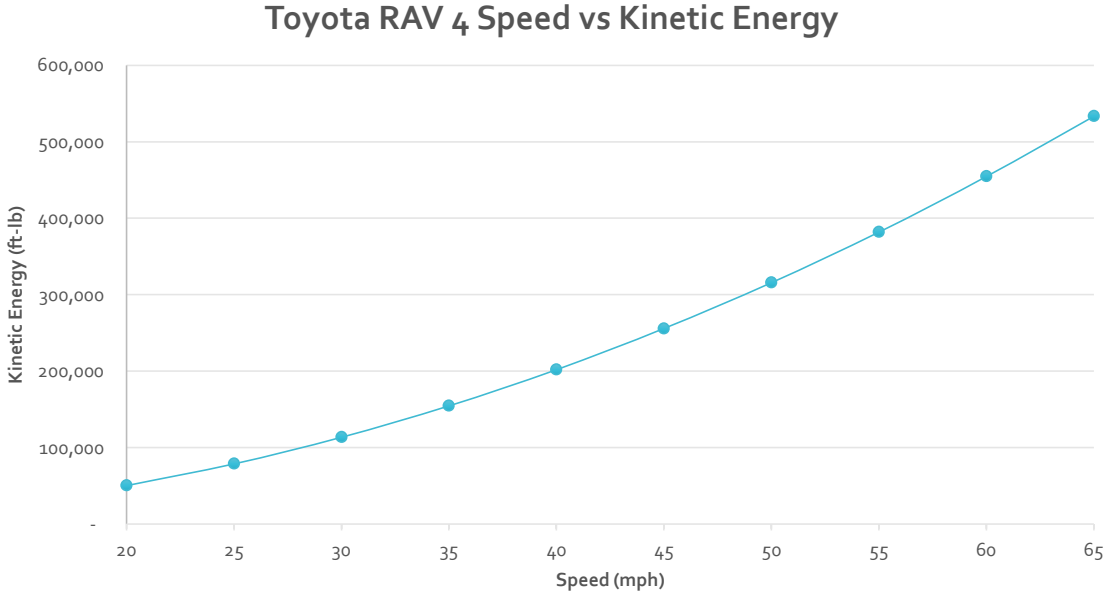
- Kinetic energy reduction through reduced speed (v) is not linear.

$$KE = \frac{1}{2}mv^2$$

m=mass (slugs)

v=velocity (ft/s)

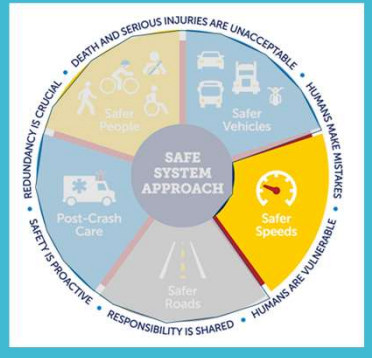
KE=Kinetic energy (lb-ft)



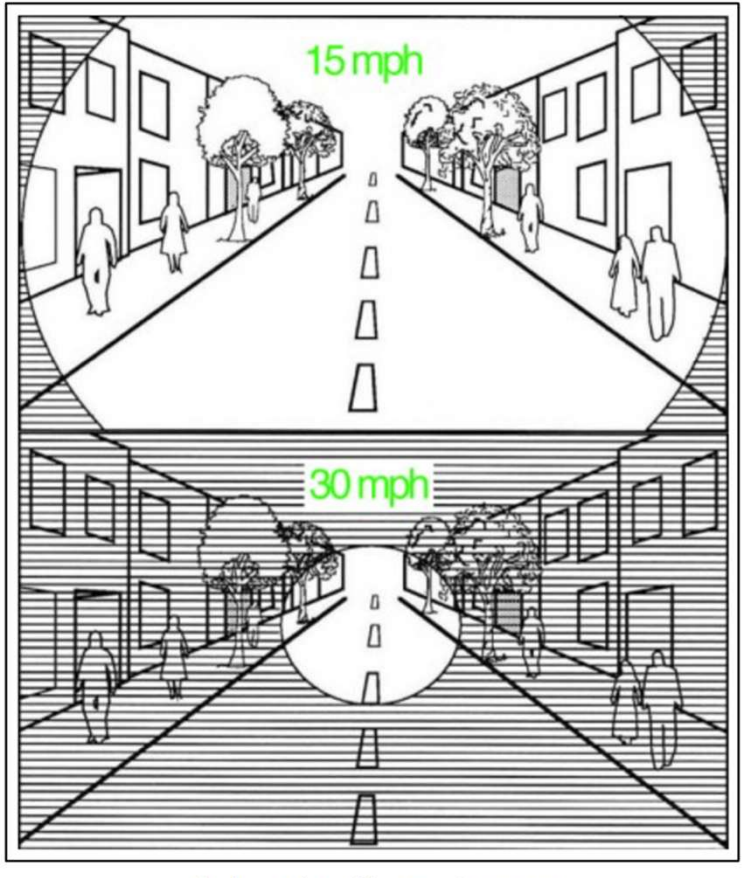
- New Zealand Road Safety: Mistakes

Trigger Warning

https://www.youtube.com/watch?v=B2rFTbvwteo



Objectives of a Safe System Approach, Safer Speeds



Visual perception at different speeds, streets.mn

Objectives of a Safe System Approach, Safer Roads

Source: Toole Design Group

Objectives of a Safe System Approach, Safer Roads

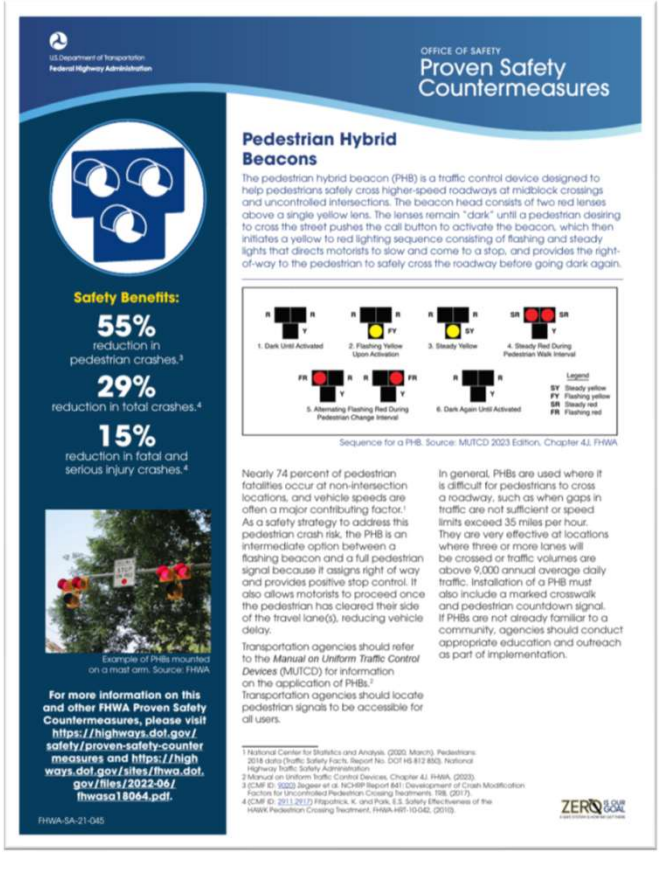
Anticipate Human Error

Separate Users in Space

Objectives of a Safe System Approach, Safer Roads

Anticipate Human Error

Separate Users in Time



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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.

Safety Benefits:

55% reduction in pedestrian crashes.[3]

29% reduction in total crashes.[4]

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

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

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

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

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: 9003) Jegeer et al. NCHRP Report 841: Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments. TRB. (2017).
4 (CMF ID: 2911,2913) Fitzpatrick, K. and Park, E.S. Safety Effectiveness of the HAWK Pedestrian Crossing Treatment. FHWA-HRT-10-042. (2010).

ZERO FATALITIES A SAFE & EQUITABLE GOAL

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Proven Safety Countermeasures

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.

Safety Benefits:

13% reduction in pedestrian-vehicle crashes at intersections.[2]

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.

FHWA-SA-21-032

1 Manual on Uniform Traffic Control Devices (MUTCD), Section 4L.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)

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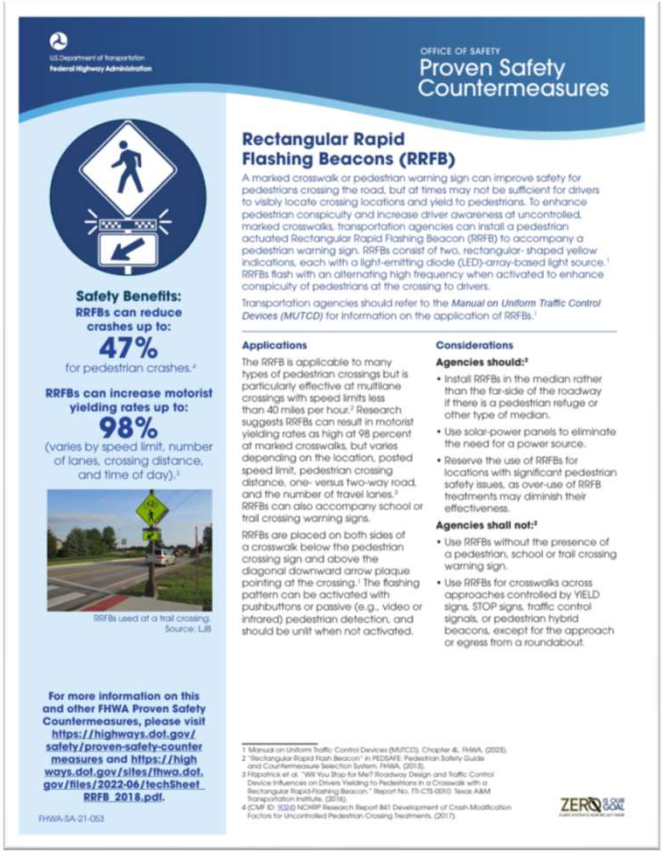
Objectives of a Safe System Approach, Safer Roads

Anticipate Human Error

Increase Attentiveness and Awareness



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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]

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).[2]

RRFBs used at a trail crossing.
Source: LJB

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]

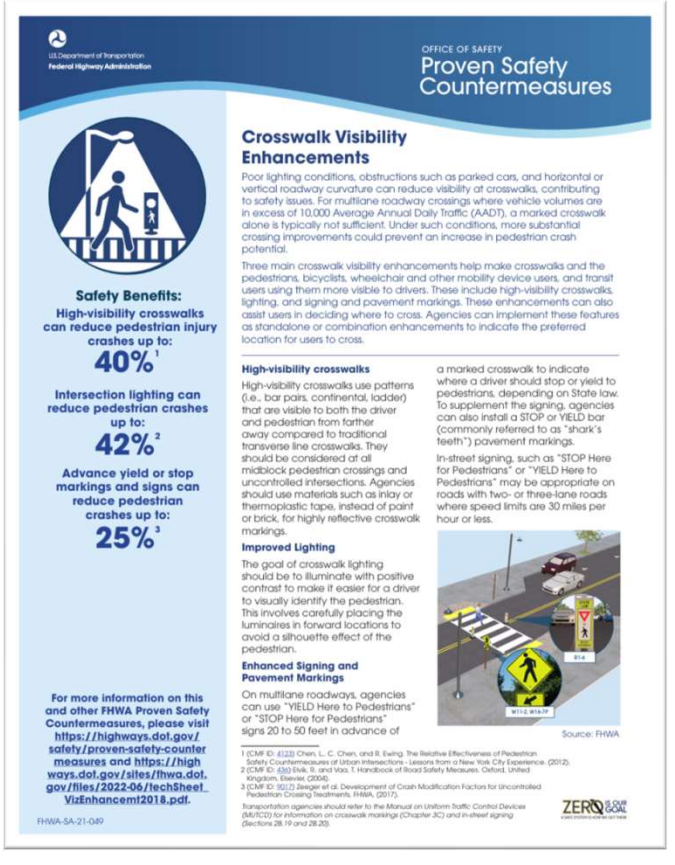
- Use RRFBs without the presence of a pedestrian, school or trail crossing warning sign.
- Use RRFBs for crosswalks across approaches controlled by YIELD signs, STOP signs, traffic control signals, or pedestrian hybrid beacons, except for the approach or egress from a roundabout.

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

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: 9224) NCHRP Research Report 841 Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments, (2017).

ZERO



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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/techSheet_VizEnhancem12018.pdf.

FHWA-SA-21-049

1 (CMF ID: 4122) 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: 486) 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).

ZERO

Objectives of a Safe System Approach, Safer Roads

Accommodate Human Injury Tolerances,

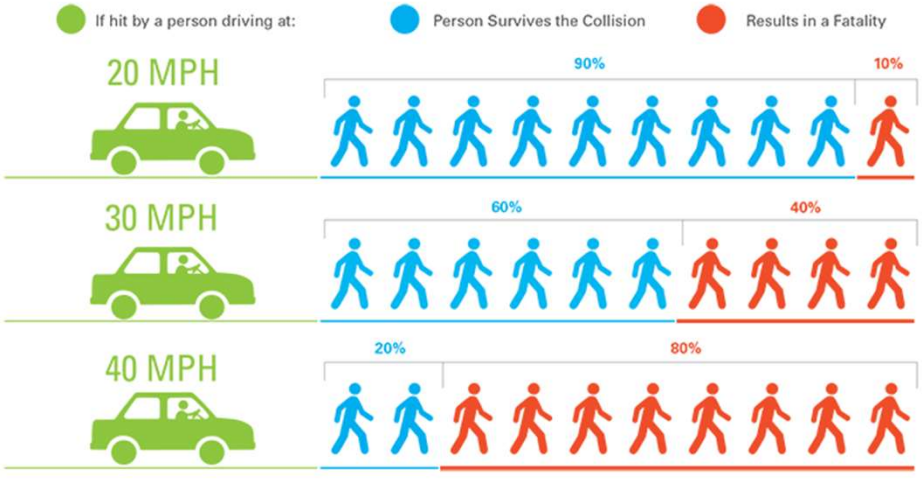
Reduce Speeds

Image Source: ChatGPT

Objectives of a Safe System Approach, Safer Roads

Accommodate Human Injury Tolerances,

Reduce Speeds



- The Challenge
  - Anchorage High Crash Network roads operate at speeds that represent a significant risk to pedestrians
  - Significant speed reductions are required to achieve speeds that accommodate human injury tolerances.

Average Operating Speeds for MOA Owned High Crash Network Roads		
Posted Speed	**Avg 85% Speed**	**Avg 50% Speed**
30	39	33
35	41	35
40	45	39
45	50	44

Source: *Inrix IQ*

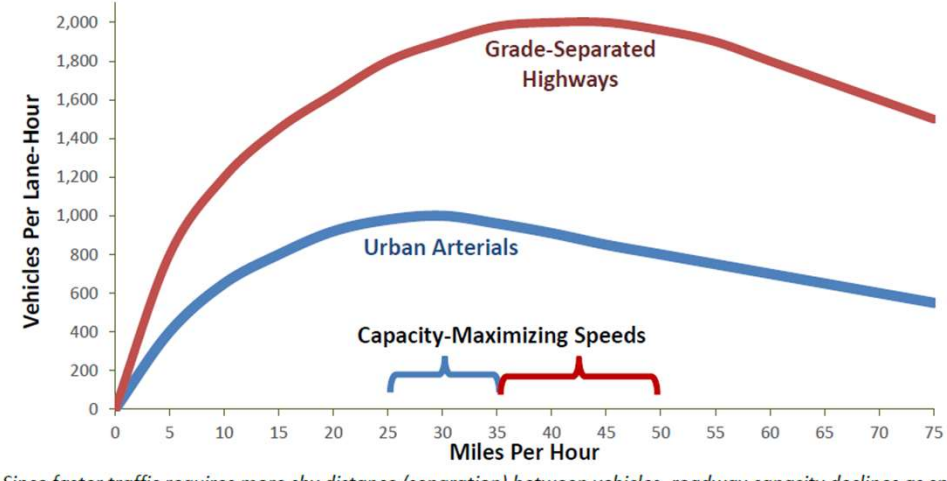
Objectives of a Safe System Approach, Safer Roads

Accommodate Human Injury Tolerances,

Reduce Speeds

- The Good News
  - Reducing speed is possible even on urban arterials.
  - Reducing speed may even benefit traffic capacity on urban arterials.

Figure 14 **Traffic Volumes Versus Speed for Urban Arterials and Highways**



Since faster traffic requires more shy distance (separation) between vehicles, roadway capacity declines as speeds increase. Under optimal (dry, clear and level) conditions capacity typically peaks at 25-35 mph (40-60 kph) on urban arterials and 35-50 mph (60-80 kph) on grade-separated highways, reflecting LOS C-D. Capacity-optimizing speeds tend to decline with more interchanges and denser traffic.

Source: *Traffic Speed Versus Roadway Capacity; Evaluating how tariff speeds affect vehicle flows and congestion costs,* Victoria Transport Policy Institute, 2025

Objectives of a Safe System Approach, Safer Roads

Accommodate Human Injury Tolerances,

Reduce Speeds

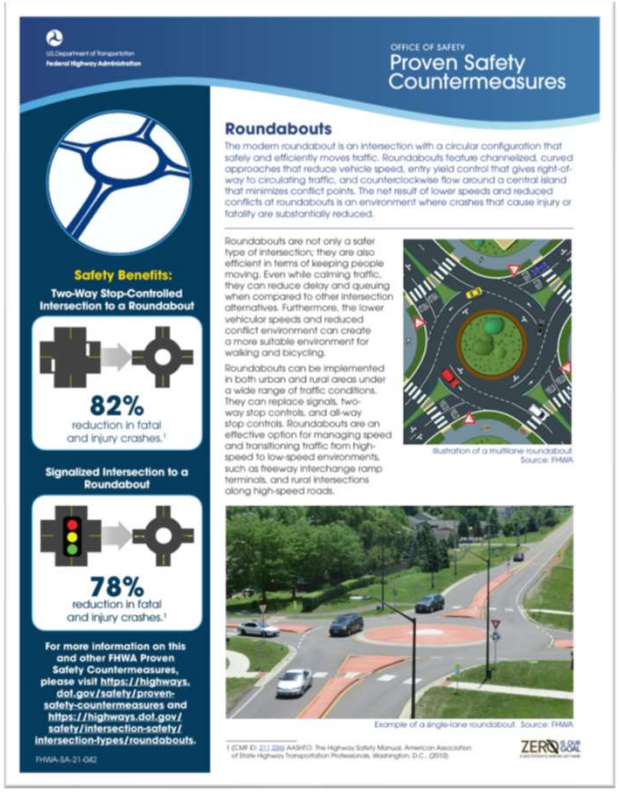
- The Other News
  - Research shows that significant speed reductions are not achieved when only one speed management tool is deployed.
  - Significant speed reductions require multiple tools deployed together, in a context appropriate way.

Lane Width Reduction	Reduced Posted Speed	Pedestrian and Bicycle Countermeasures	Street Network Design
Roadway Cross-Section Reallocation	Enforcement	Messaging & Education	Street Trees
On-Street Parking	Coordinated Signals	Traffic Calming Devices	

Objectives of a Safe System Approach, Safer Roads

Accommodate Human Injury Tolerances,

Reduce Impact Forces



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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

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

1 (CMF ID: 211,220) AASHTO. The Highway Safety Manual. American Association of State Highway Transportation Professionals, Washington, D.C., (2010).

ZERO FATALITIES VISION GOAL

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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. These 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.

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:

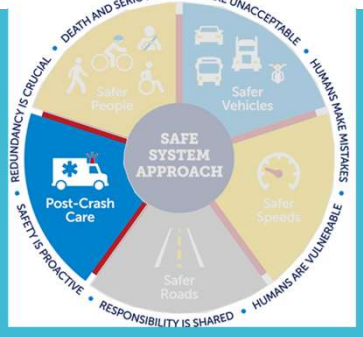
44%
reduction for all crashes.[3]

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.

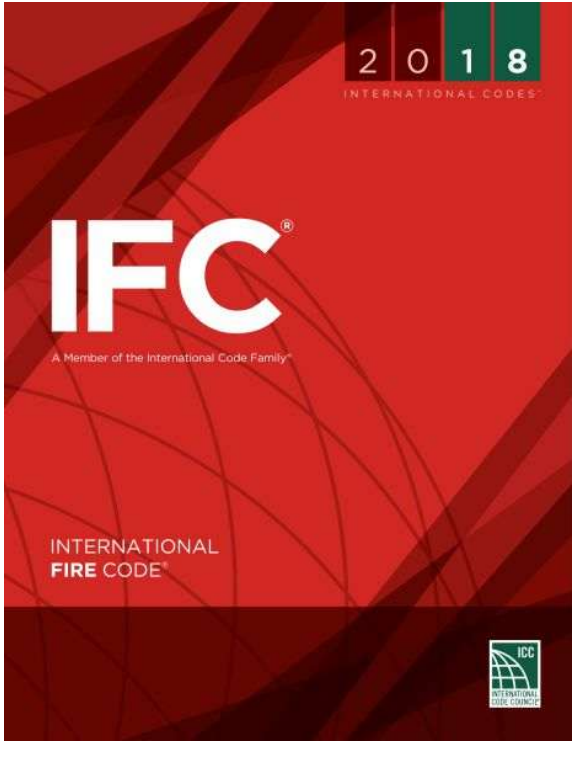
FHWA-SA-21-029

1 Fatality Analysis Reporting System.
2 (CMF ID: 4627, 4622) NCHRP Report 617: Accident Modification Factors for Traffic Engineering and ITS Improvements, (2008).
3 (CMF ID: 30,361) Elvik, R., and Vaa, T. Handbook of Road Safety Measures, (2004).

ZERO FATALITIES VISION GOAL

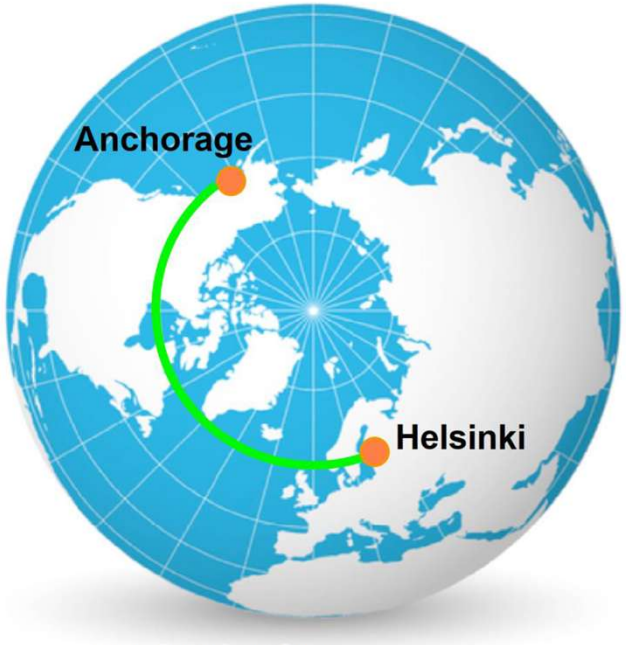


Objectives of a Safe System Approach, Post-Crash Care



VISION ZERO
ANCHORAGE

Zero Traffic Deaths in Anchorage



Picture: Finnish Cycling Embassy

Vision Zero Lesson from Finland