Orlando, FL

November 7-8, 2024

2024 TRANSPORTATION SYMPOSIUM

Strategies for Enhancing Pedestrian Safety at Intersections

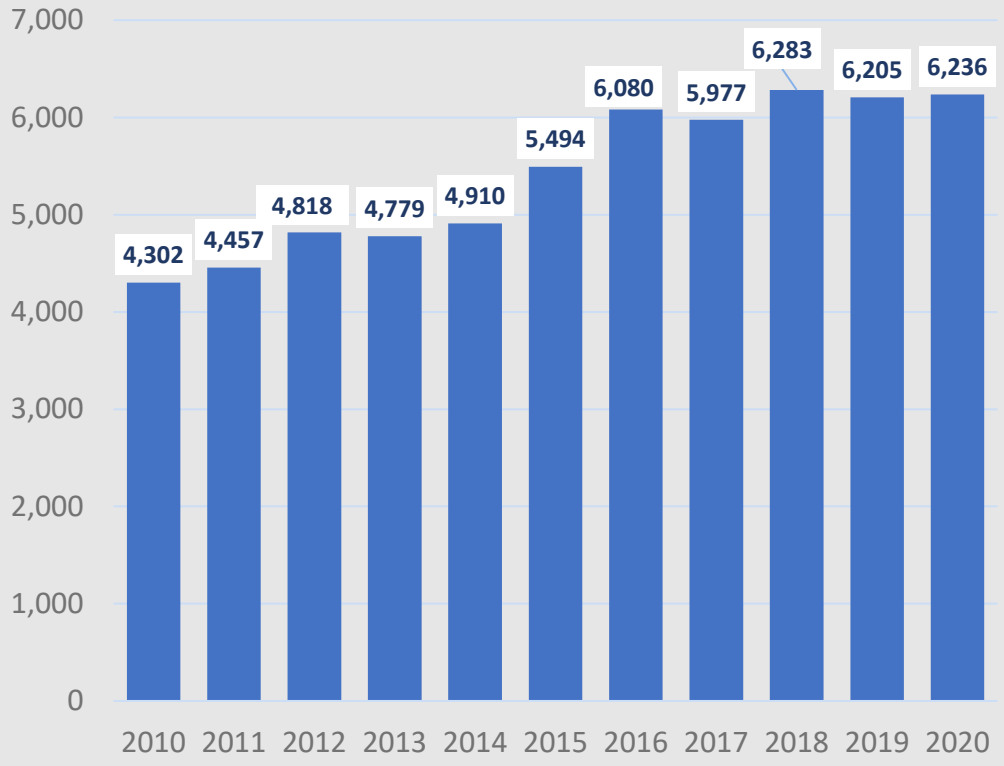
Mark Doctor

FHWA Resource Center

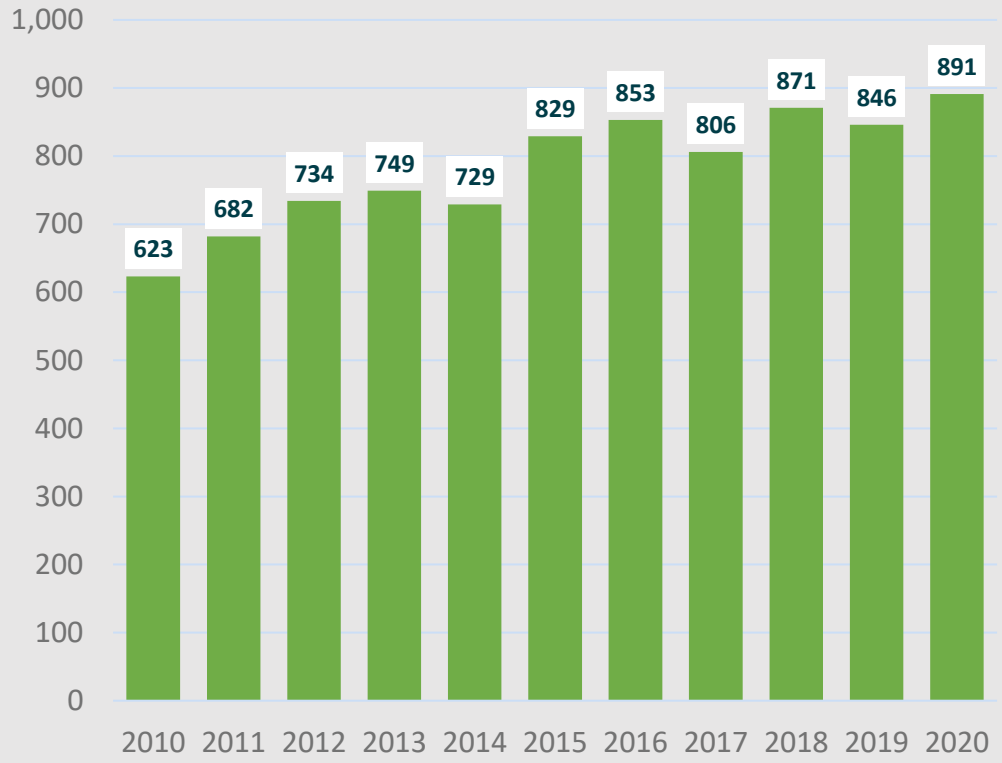
FDOT

National Trends

Total US Pedestrian Fatalities
2010-2020

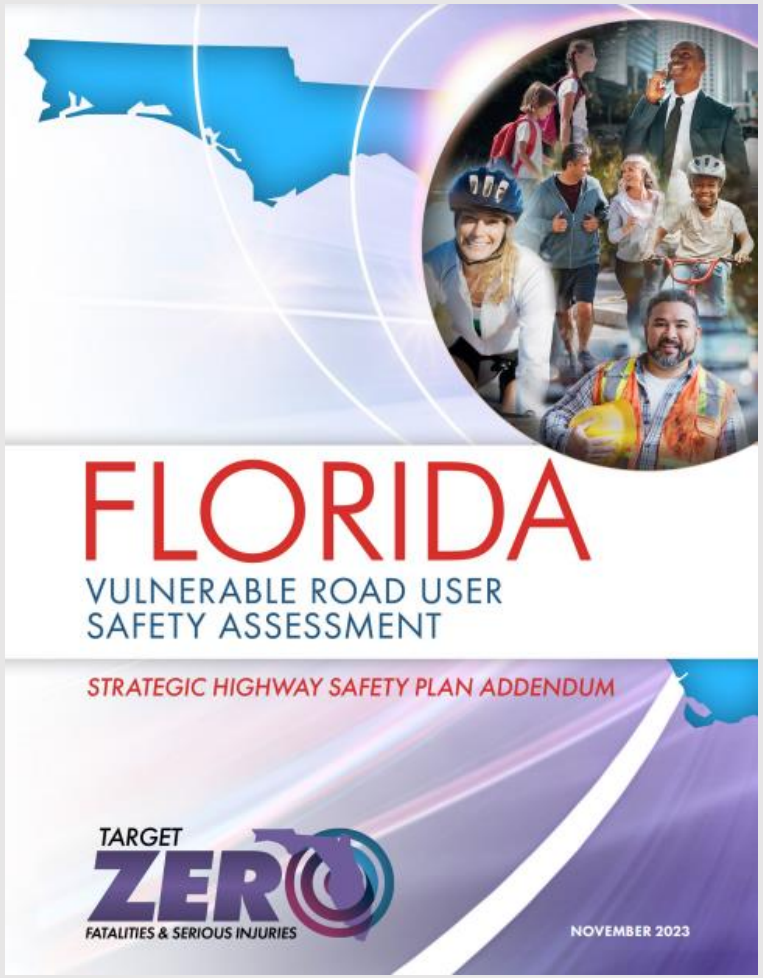


Total US Bicyclist Fatalities
2010-2020



Source: NHTSA

Florida Trends



PEDESTRIAN & BICYCLISTS

ACCOUNT FOR

27%

OF **ALL FATALITIES** IN FLORIDA DURING **2017-2021**

Source: Florida Department of Highway Safety and Motor Vehicles (FLHSMV).

LOCATION OF CRASHES FOR 2017-2021 BY ROAD MAINTAINING AGENCY:

STATE: 40%

CITY: 35%

COUNTY: 17%

OTHER: 8%

Source: FDOT Pedestrian & Bicycle Crash Facts.

https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/safety/shsp-2021/fdot_vru_safetyassessment_nov-2023.pdf?sfvrsn=83097770_1

OVER

3,600 **PEDESTRIANS DIED** AND OVER

6,800 WERE **SERIOUSLY INJURED**

IN FLORIDA DURING **2017-2021**

Source: FLHSMV

OVER

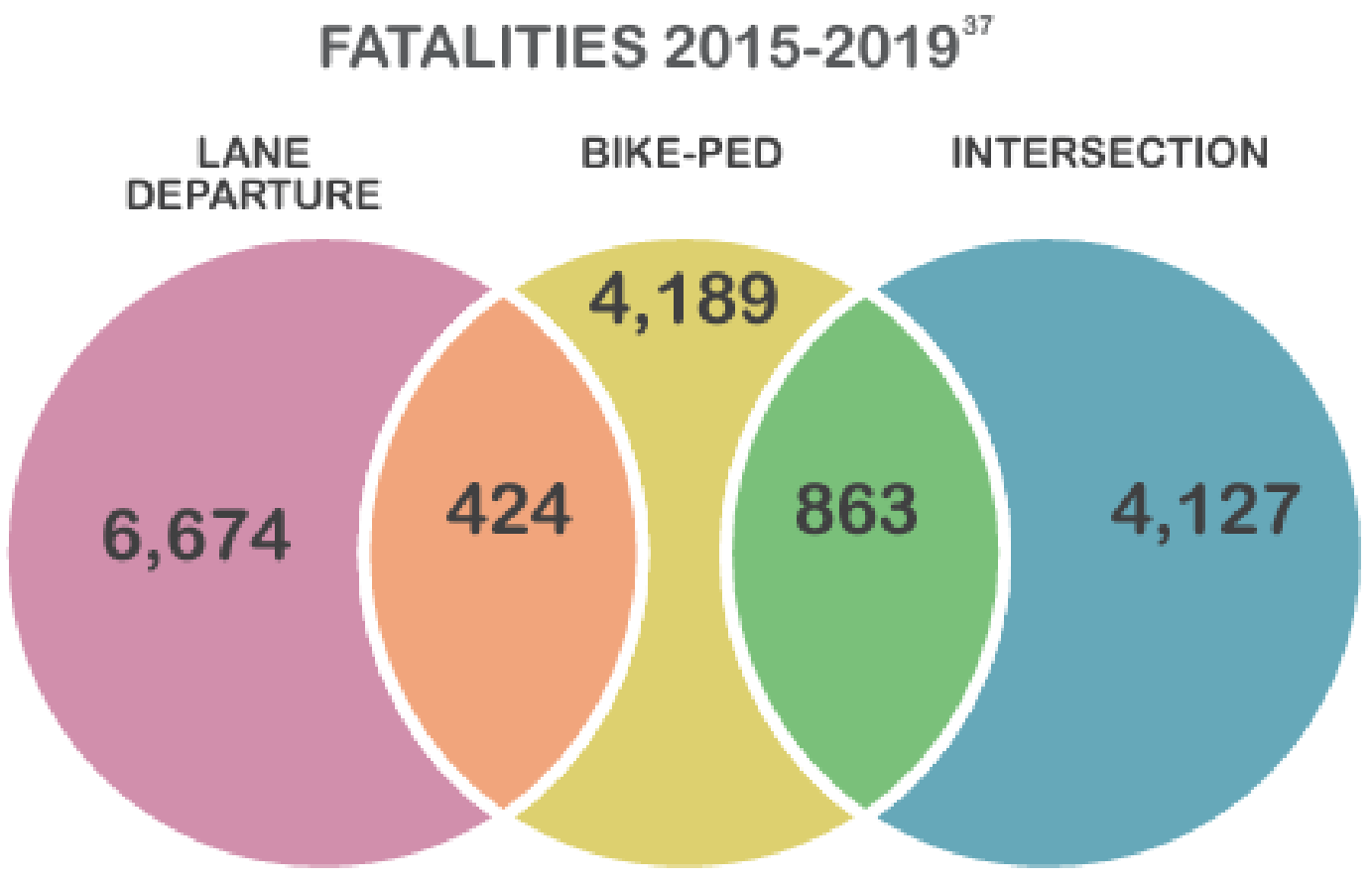
800 **BICYCLISTS DIED** AND OVER

3,800 WERE **SERIOUSLY INJURED**

IN FLORIDA DURING **2017-2021**

Source: FLHSMV.

Florida's Reality



Data Source: Florida Strategic Highway Safety Plan
https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/safety/shsp-2021/shsp_mar21.pdf?sfvrsn=5452dad_0

In **Florida**, there is **one pedestrian death** at an intersection every **50 hours**

At least 3 pedestrians will **die** every week

…at or near an intersection.

Intersection Challenges

- Safety for all users
- Capacity choke points
- Access to adjacent parcels
- Right-of-way constraints
- $$$

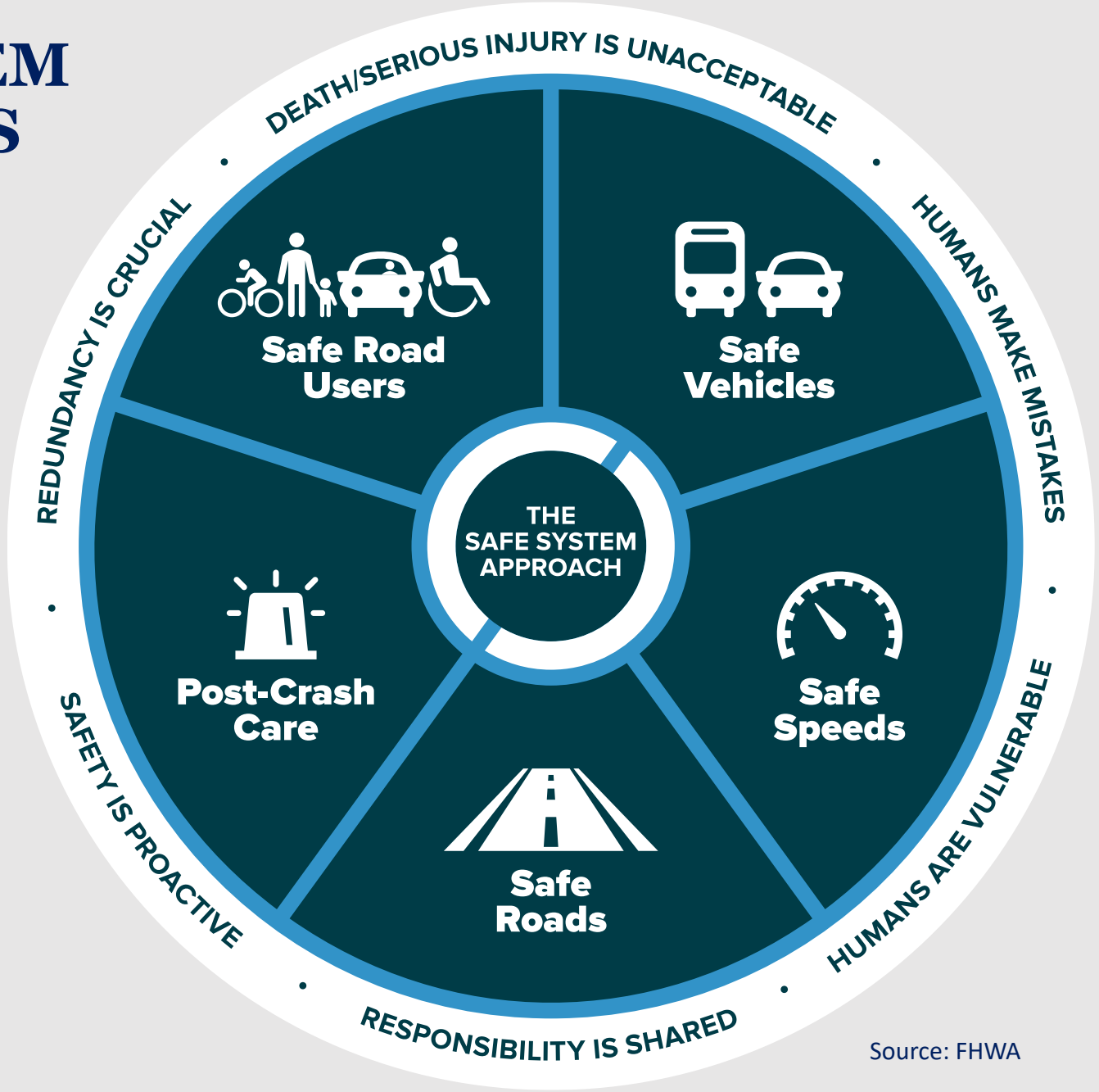
Source: Mark Doctor, FHWA

SAFE SYSTEM PRINCIPLES

Death/serious injury is unacceptable

Humans make mistakes

Humans are vulnerable



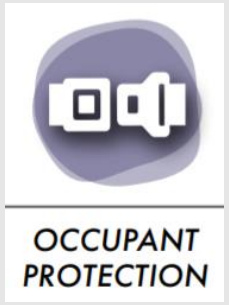
Responsibility is shared

Safety is proactive

Redundancy is crucial

Source: FHWA

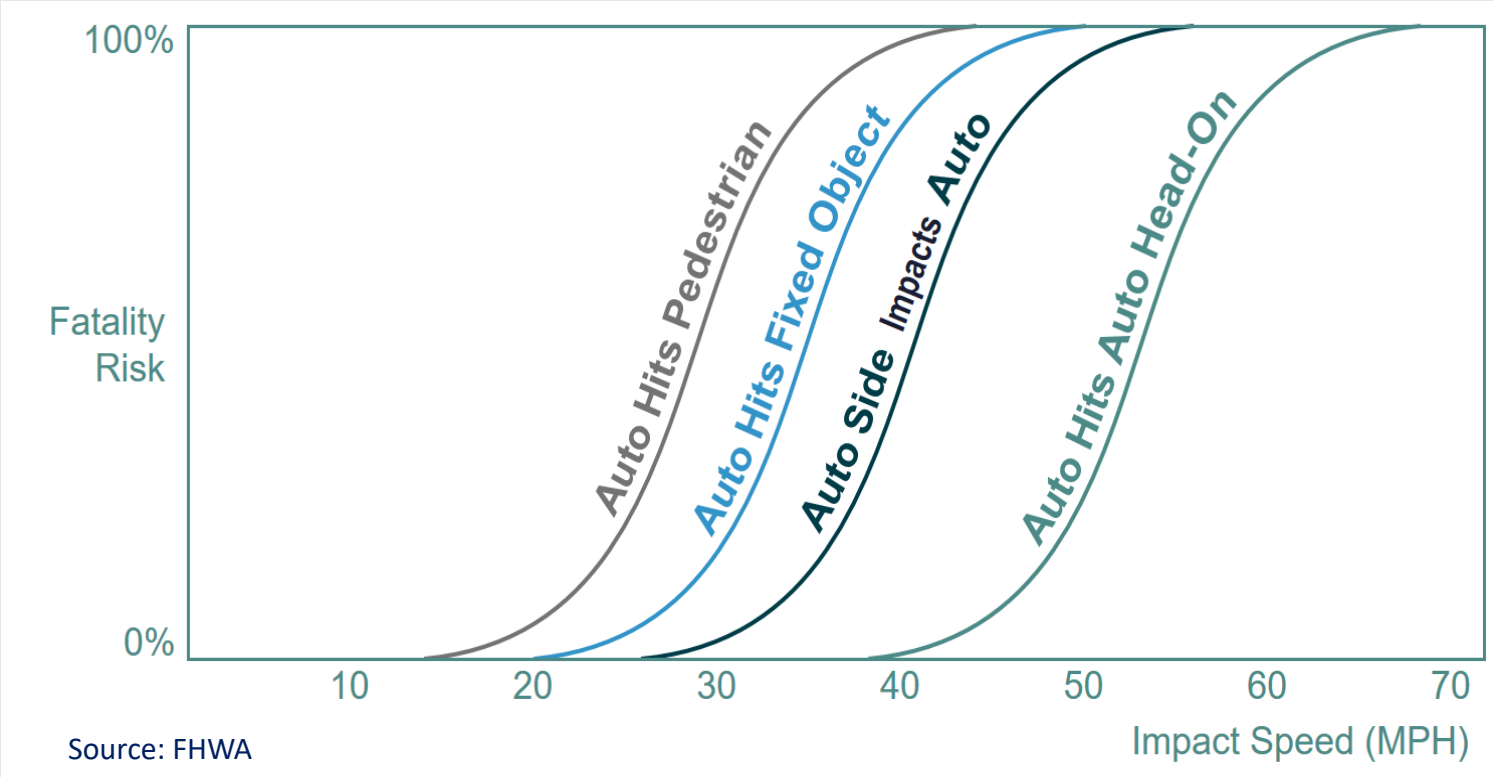
Why are people killed and seriously injured on our roads?...



People are killed and seriously injured on the roads when the collision forces transferred onto the human body exceed tolerable thresholds.

Safer Roads by Managing Kinetic Energy

Humans are vulnerable

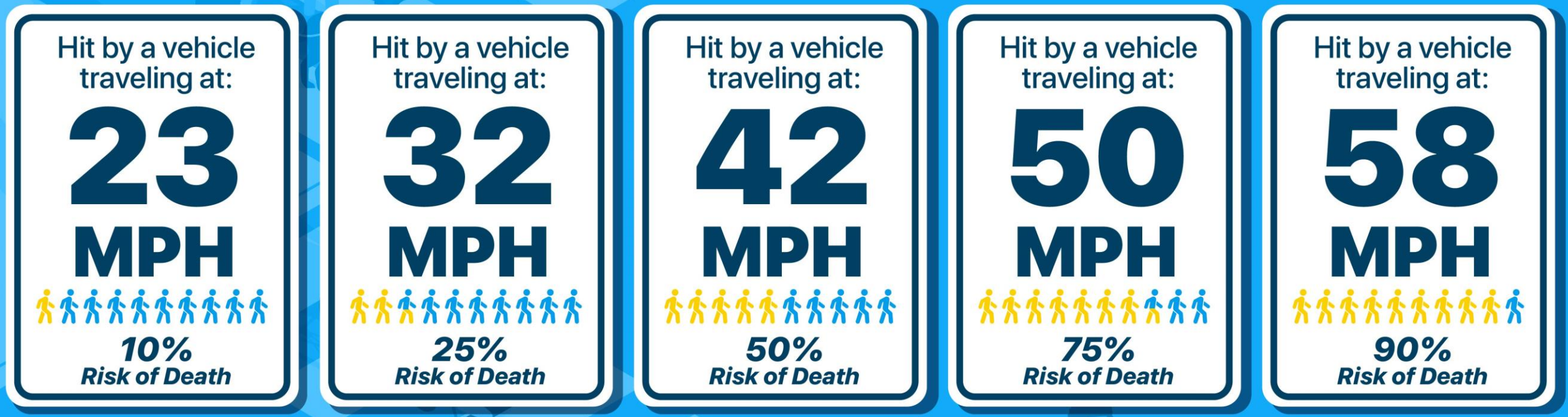


Source: FHWA

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

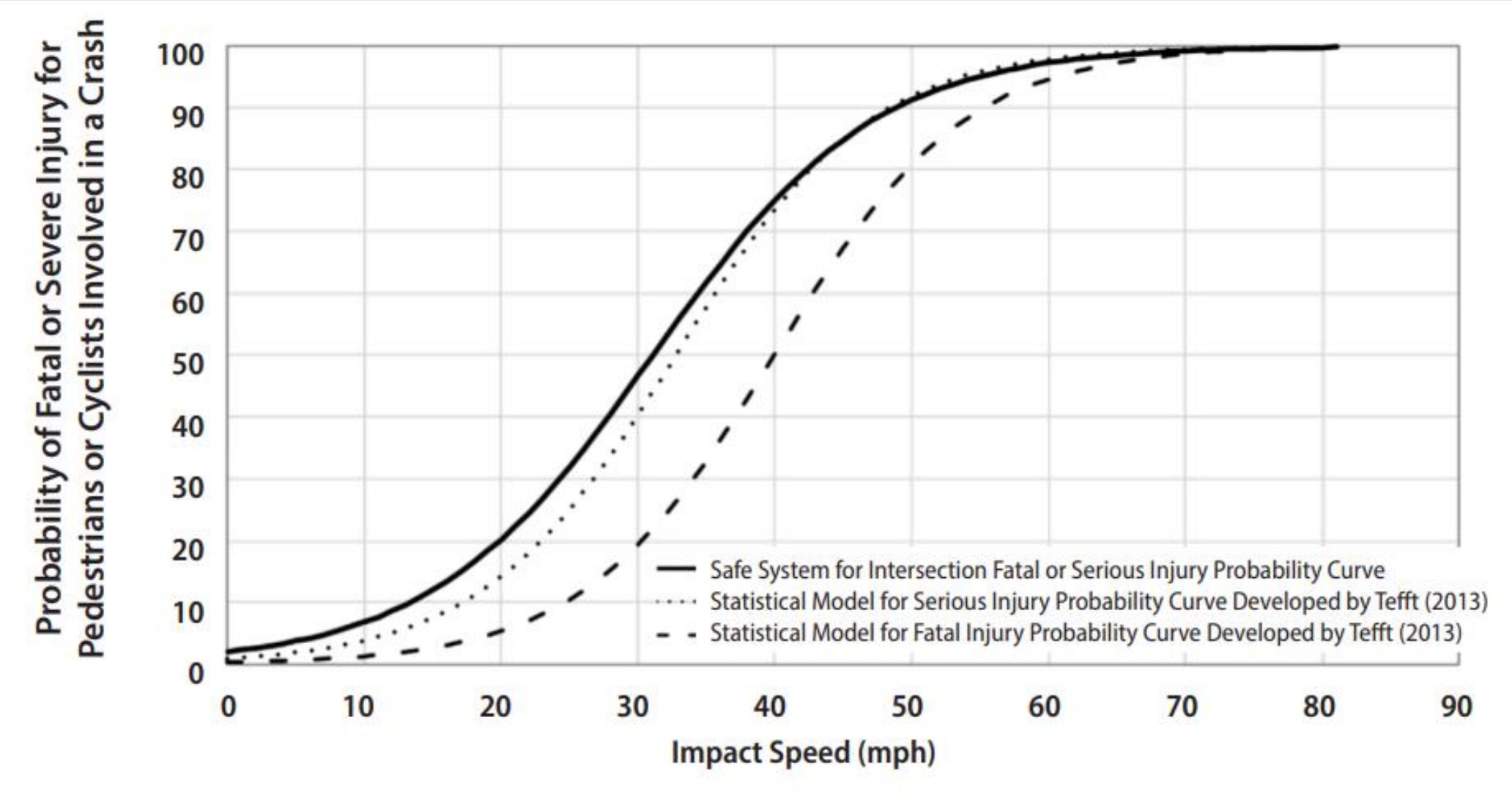
Velocity is a Vector

- Speed
- Direction (angle of impact)


Hit by a vehicle traveling at:
23
MPH
10%
Risk of Death
Hit by a vehicle traveling at:
32
MPH
25%
Risk of Death
Hit by a vehicle traveling at:
42
MPH
50%
Risk of Death
Hit by a vehicle traveling at:
50
MPH
75%
Risk of Death
Hit by a vehicle traveling at:
58
MPH
90%
Risk of Death

NHTSA

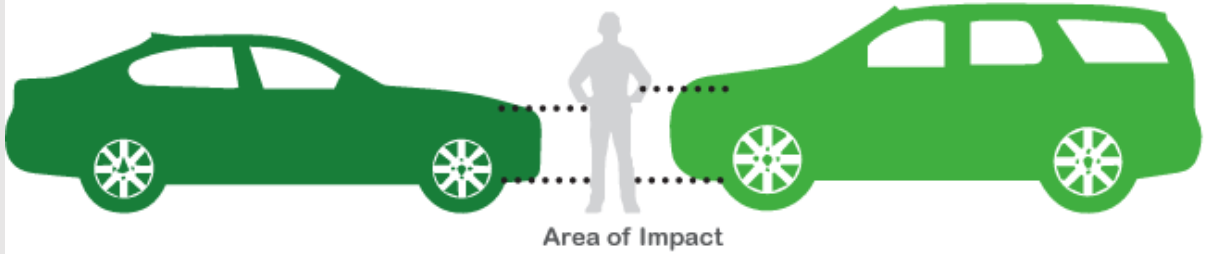
Human tolerance to impact speed



Vehicle Trends

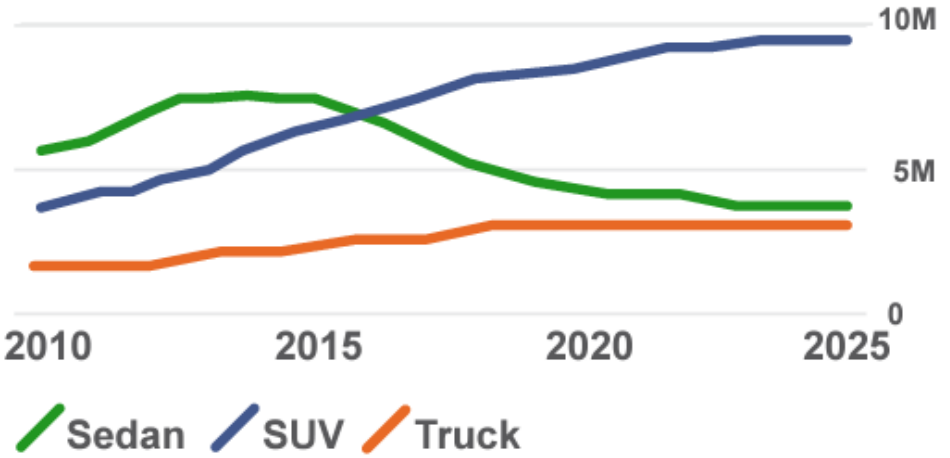
HIGHER IMPACTS

Taller than cars, SUVs strike pedestrians higher on the body, increasing the likelihood of severe injury or even death.[20]



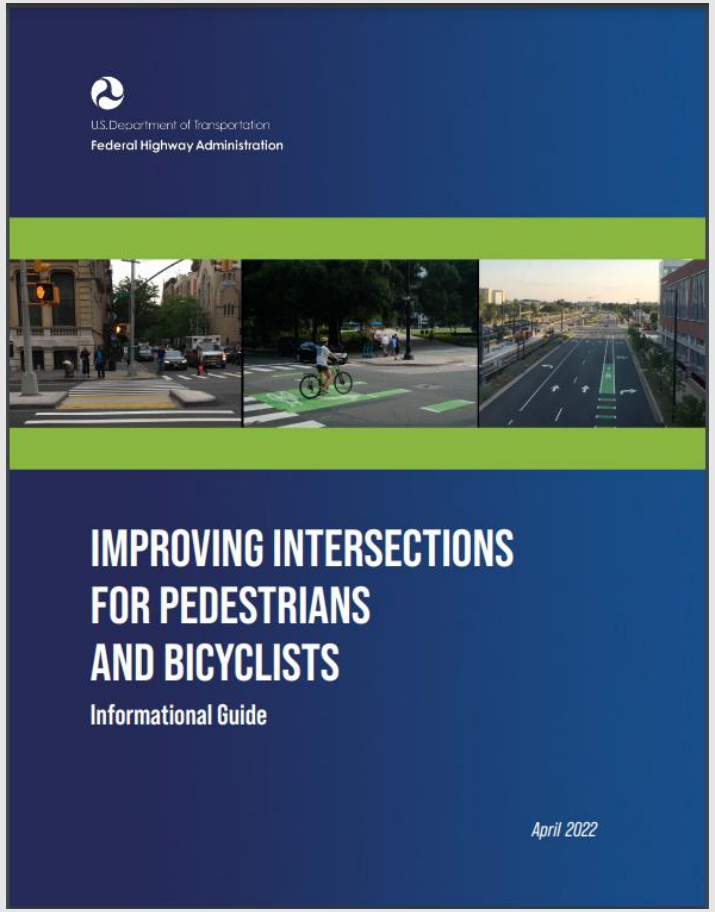
THE RISE OF SUVS

Sales of larger vehicles surpassed sedans over the last decade.[21]



20) U.S. Department of Transportation, Federal Highway Administration. (2019). Bikeway Selection Guide
21) Florida Department of Transportation. (2021). FDOT Design Manual, Section 223 Bicycle Facilities

New(*ish*) Resource!

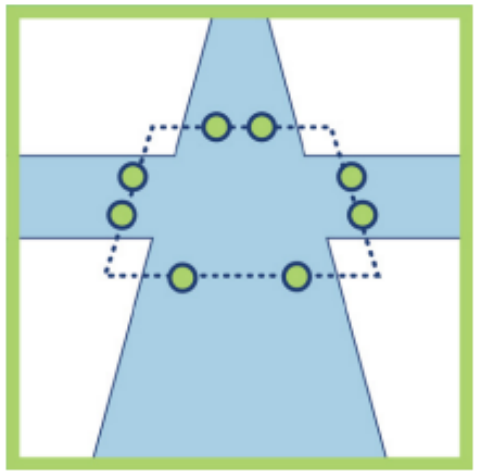


"The purpose of this guide is to inform the state of the practice concerning intersection planning and design to implement solutions that help achieve the goal for zero fatalities and serious injuries while also making roads better places for walking and bicycling."

https://safety.fhwa.dot.gov/intersection/about/fhwasa22017.pdf

Improving Intersections for Peds & Bikes

Expect Pedestrians and Bicyclists at All Intersections



Use a Safe System Approach

Provide Access for All Ages and Abilities

Fact Sheets


Roundabouts
Median U-Turn Intersections
Restricted Crossing U-Turn Intersections
Quadrant Roadway (QR) Intersections
Displaced Left Turn (DLT) Intersections
Diverging Diamond Interchange (DDI)

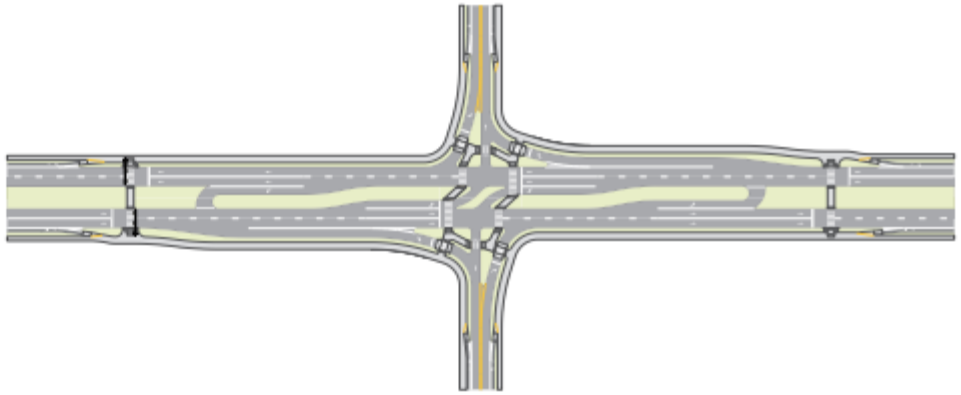
Restricted Crossing U-Turn Intersections

Restricted Crossing U-Turn (RCUT) intersections replace direct through and left-turn movements from the minor approaches with an indirect movement of a right-turn/U-turn combination.

All graphics source: FHWA

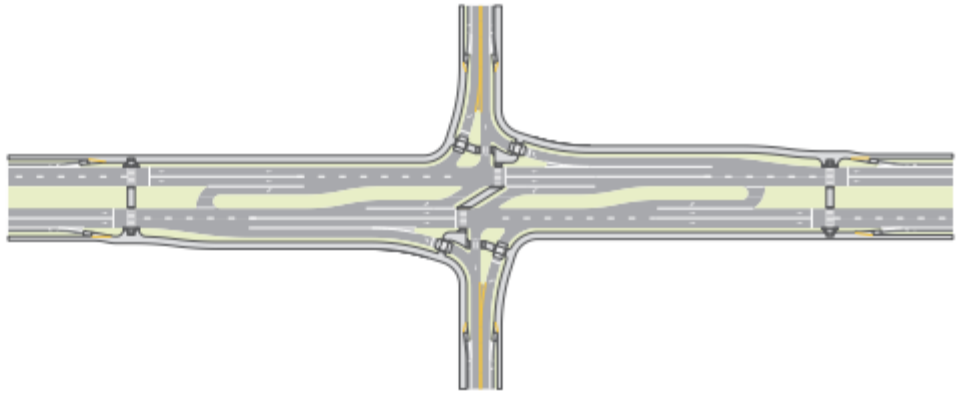
SIDEPATH

This design features sidepaths through the intersection, as well as crosswalk positioning that more closely resembles a traditional intersection.



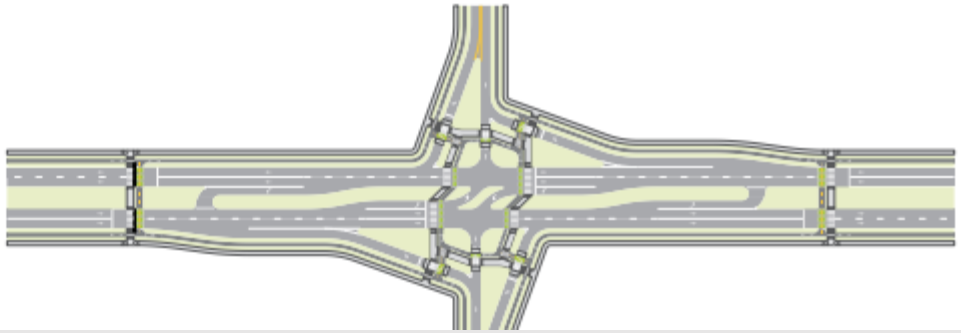
SIDEPATH Z-CROSSING

The RCUT layout optimized for motor vehicles calls for a "Z-pattern" pedestrian crossing at the main intersection. This reduces conflict points between motorists, bicyclists, and pedestrians, but causes crossing pedestrians and bicyclists to travel out of their direct, intended path.



SEPARATED BIKE LANE

This RCUT design features separated bike lanes and a more direct and intuitive pedestrian and bicyclist crossing configuration at the intersection.



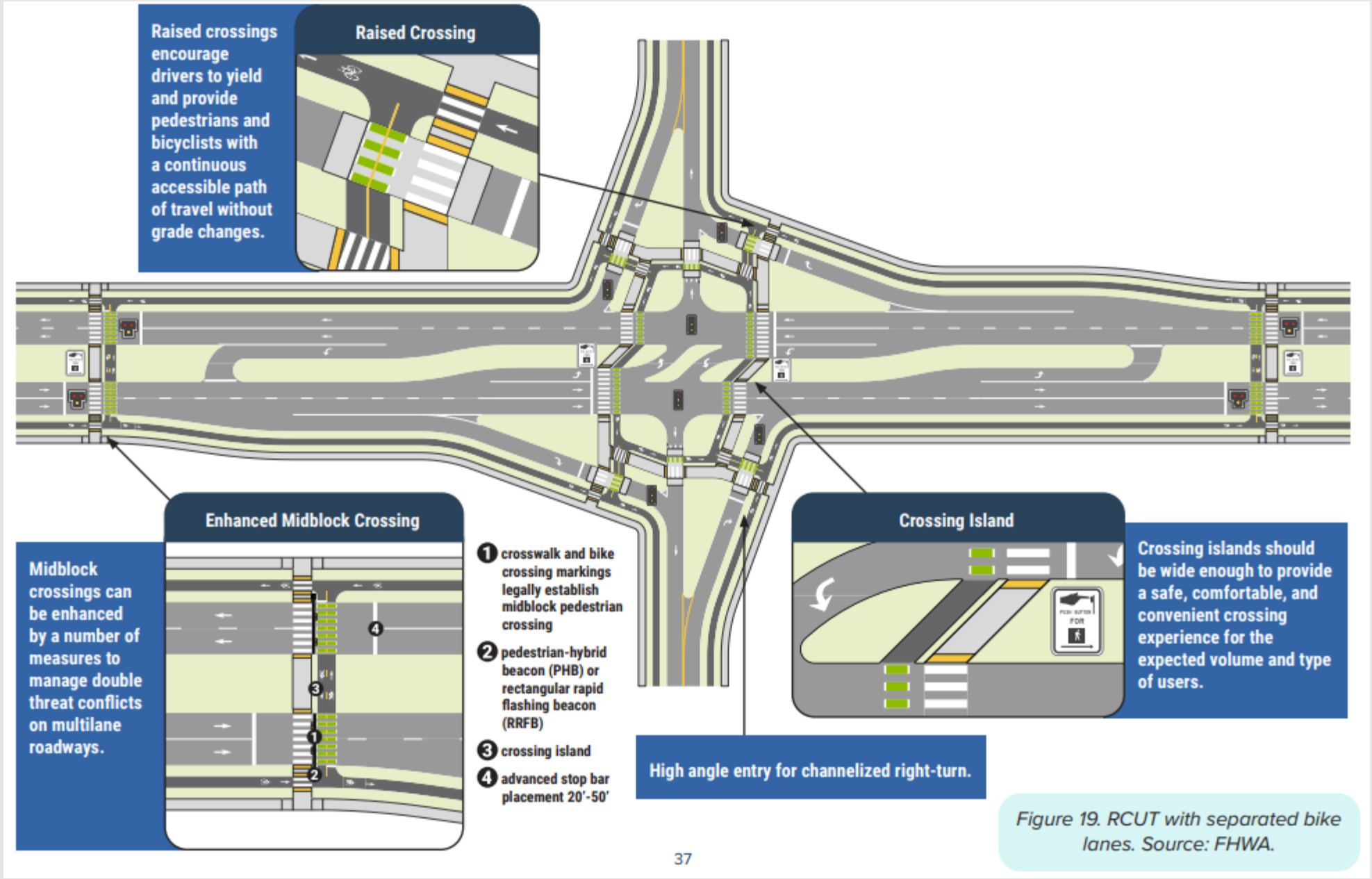


Figure 19. RCUT with separated bike lanes. Source: FHWA.

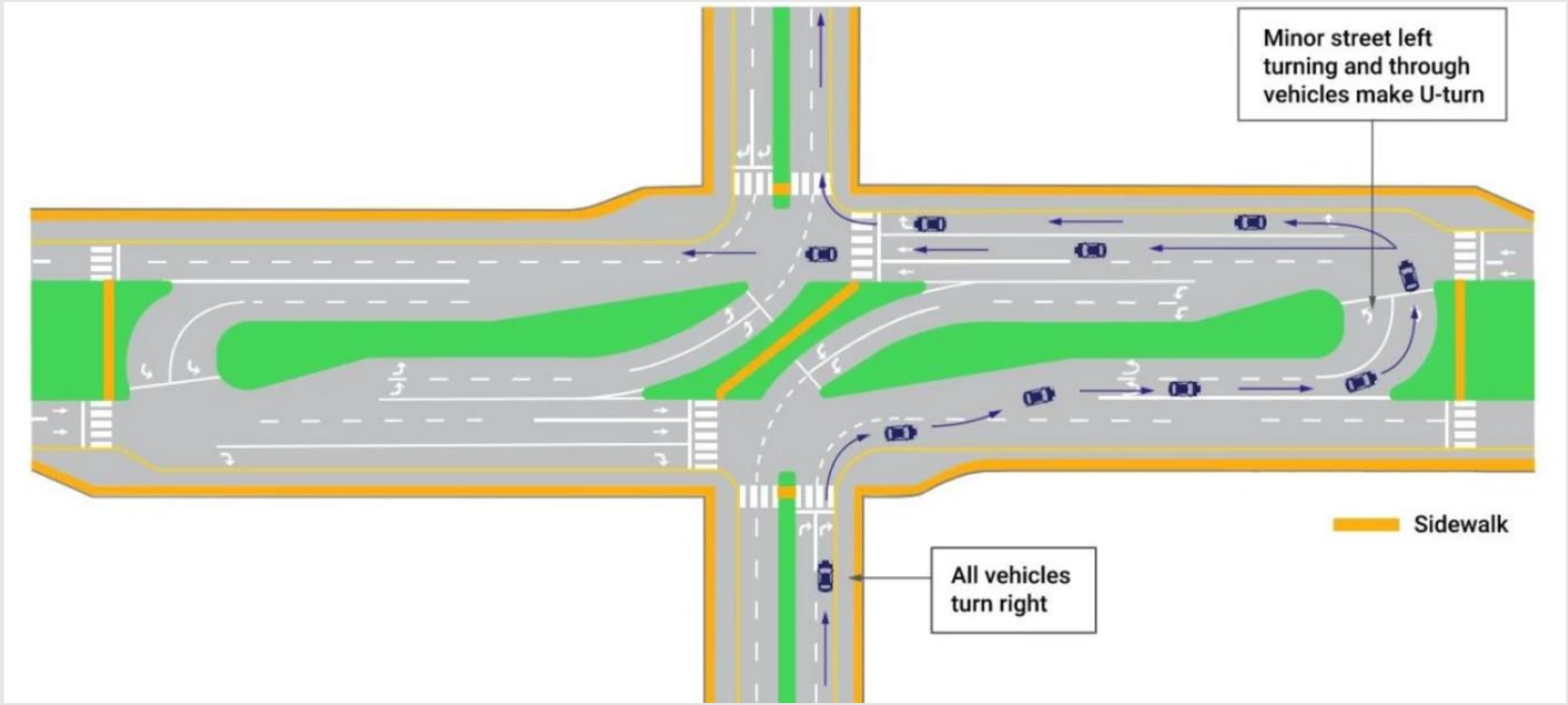
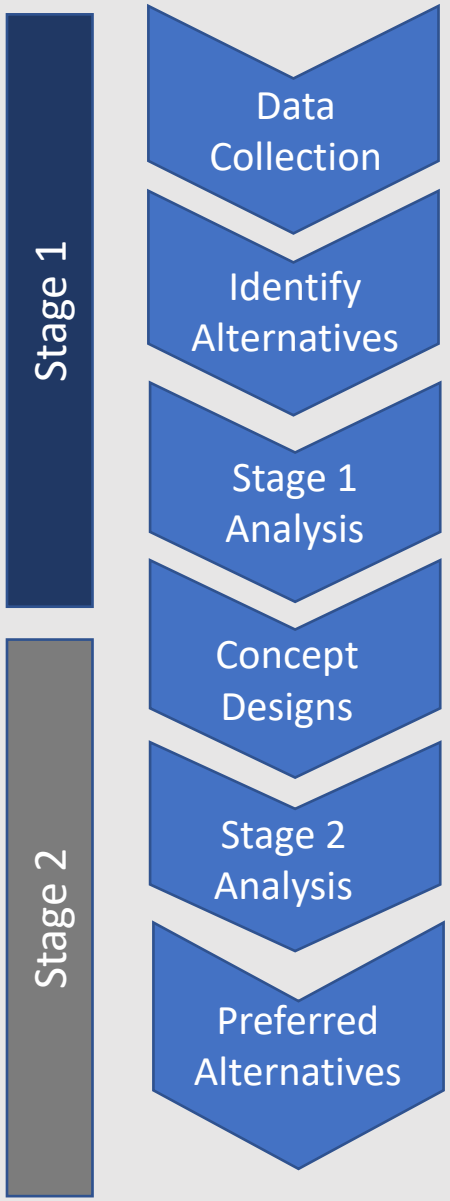


Figure Source: Florida DOT

RCUTs: An Innovative Approach to Solving Complexities in Safety and Operations in Florida – Florida Department of Transportation Research Showcase

Intersection control evaluation (ICE)



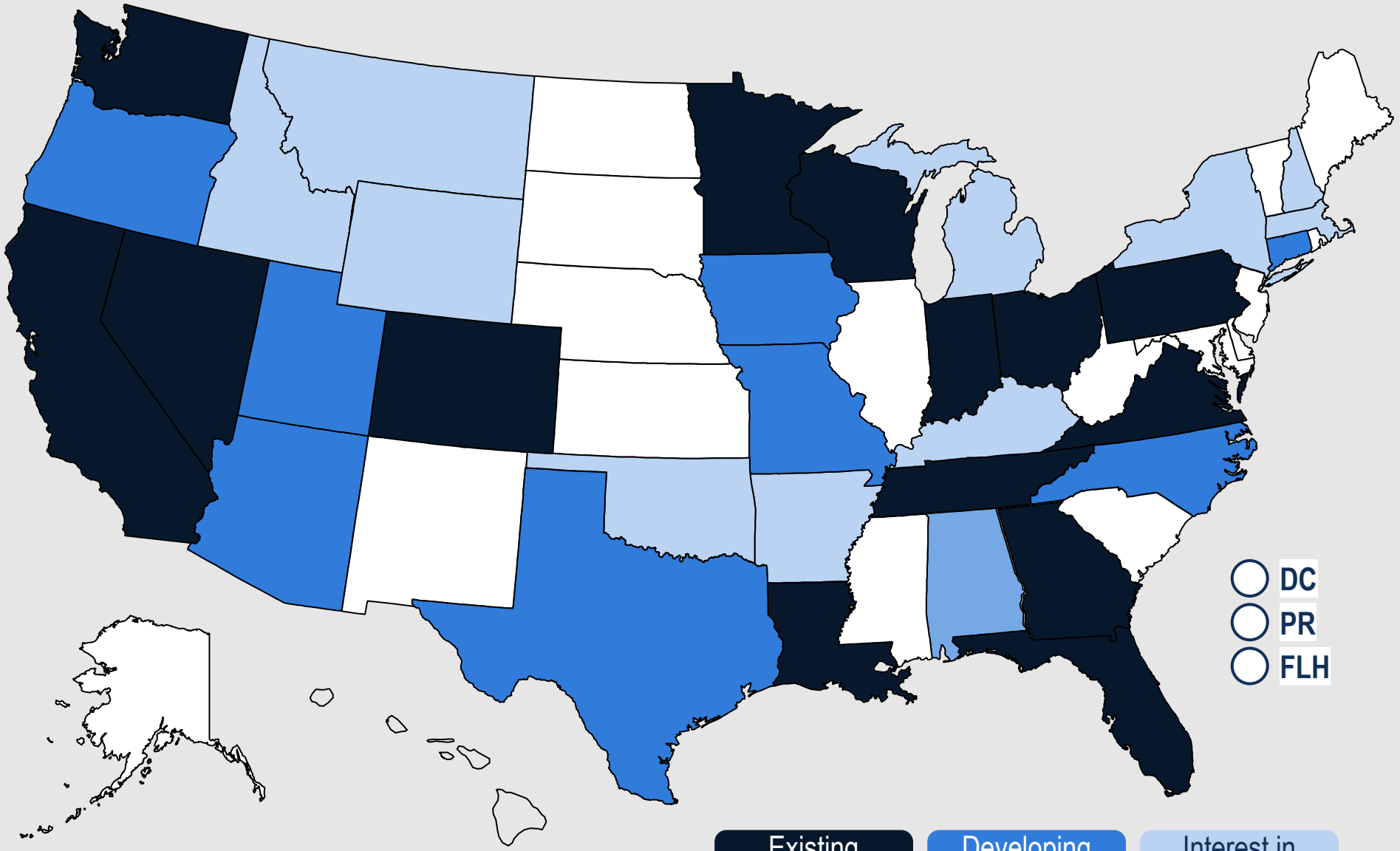
Stage I is a scoping stage

- Initially consider a full array of options
- Use screening tools that consider operational and safety goals, project needs, and practicality
- Develop a short list of alternatives that merit further consideration & analysis to be carried into Stage II

Stage II is an alternative development & selection stage

- Objectively differentiates among the alternatives brought forward from the Stage I scoping analysis
- Preferred alternative(s) determined based on more detailed evaluations
  - Multimodal provisions
  - Safety performance
  - Operational performance
  - Lifecycle benefits and costs
  - Environmental, utility, and right-of-way impacts

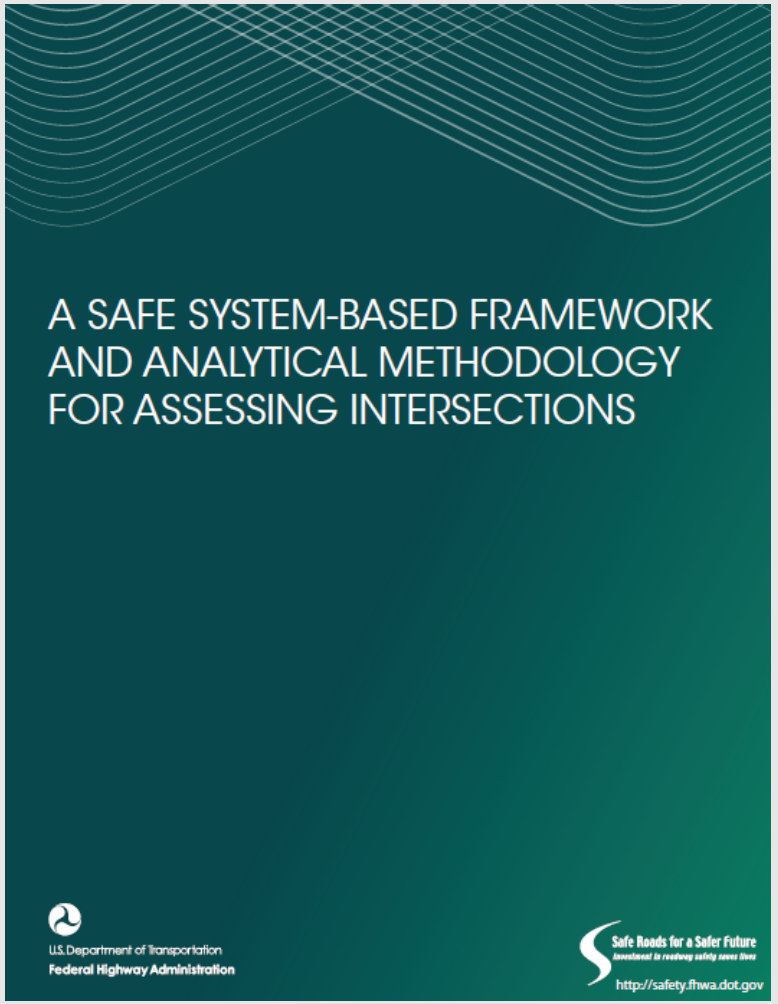
ICE Policies & Guidance - 2024



Safe System for Intersections (SSI) Framework

Objectives:

- Readily implementable
- Common project-level data inputs
- Stage I ICE (scoping phase)

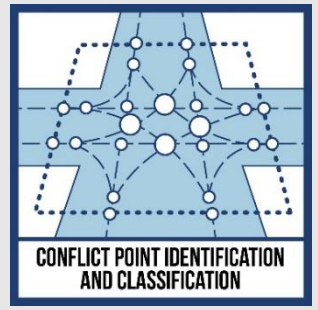


Full report and Tech Brief available at
https://safety.fhwa.dot.gov/intersection/ssi/index.cfm
Report Number FHWA-SA-21-008

SSI Method Overview

1. Conflict point identification and classification

Crossing, merging, diverging, nonmotorized



2. Conflict point exposure

Volumes (vehicular and nonmotorized)

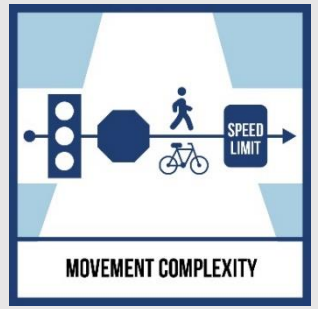
3. Conflict point severity (probability of FSI)

Vehicle-vehicle: speeds and conflict angles

Nonmotorized: speeds

4. Movement Complexity

- Conflicting traffic
- Traffic control devices
- Additional complexity for nonmotorized users



SPICE FDOT V5.1.1

Safe System for Intersection (SSI) Inputs

Specify the geomtric, exposure, severity, and conflicting traffic complexity inputs required for an SSI analysis.

1. Roadway Geometry	Lanes
Major number thru lanes (one direction)	
Minor number thru lanes (one direction)	

Major Street Designation	
Select major street direction	N-S
Median Presence on Major Road	
Median Presence on Minor Road	

	Required Inputs
	Default Available, Override Optional
	Planning-Level Default Input
	Computed Value, Override Optional
	Computed Value - No Override
	Disabled Cell (Often based on input selections)

2. Complete the "Exposure" inputs. These inputs will apply to all interesections selected for analysis.
3. Complete the "Severity" inputs
4. Complete the "Conflicting Traffic Complexity" inputs

2. Exposure - All Intersections

Average Daily Traffic (veh/day)	Open	Design
Major	--	--
Minor	--	--

ADT Directional Split	
Major	0.50
Minor	0.50

Nonmotorized Total ADBP (ped-bike/day)	Activity Level
Open Year Total Intersection NM	Low (20)
Design Year Total Intersection NM	Low (20)
(or overwrite ped movement ADBPs below)	

Nonmotorized Movement ADBP (ped-bike/day)	Open
Major NM 1 (NM mvmt crossing Maj1)	5
Major NM 2	5
Minor NM 1	5
Minor NM 2	5

Are turning movement ADT values are available?	If "Yes", input values in Table 2-A
Are peak hour turning movement counts available?	If "Yes", input values in Table 2-B

If no turning movment volumes or counts are available, a user can optionally override the planning-level default turning movment proportions in Table 2-C

Table 2-A: Turning Movement (vol/day)

	Open	Design

Table 2-B: Turning Movement Counts (Optional)

	Mvmt	AM Peak	AM %	PM Peak	PM %	Avg %

Table 2-C: Turning Proportions (optional)

Introduction | Project Information | Changelog | Definitions | Control Strategy Selection | At-Grade Inputs | SSI Inputs | Calibration | Historical

“Design Flags”

RED Flags: for design elements directly related to a SAFETY concern for pedestrians or bicyclists

Yellow Flags: for design elements negatively affecting USER COMFORT (i.e., increasing user stress) or the QUALITY of the walking or cycling experience.

Design Principles for Ped Facilities

- Pedestrian Routing and Delay

- Provide a highly visible and coherent route;
- Consider pedestrian desire lines and reducing out-of-direction travel
- Minimize the use of multistage crossings unless a multistage crossing can reduce delay or eliminate crossings of high-volume, free-flow ramps;
- Minimize pedestrian exposure to high-speed and/or high-volume traffic movements.

Design Principles for Ped Facilities

Minimizing Conflicts w/ Motor Vehicles

- Maximize visibility between pedestrians and motorists;
- Reduce motor vehicle speeds at conflict areas with uncontrolled or concurrent motor vehicle movements
- Separating movements in time using traffic controls.
- Separating movements in space using geometry.
- Minimizing exposure to conflicts with motorists by providing short crossing distances.
- Minimizing the speed of vehicles at conflict points.

20 Flags

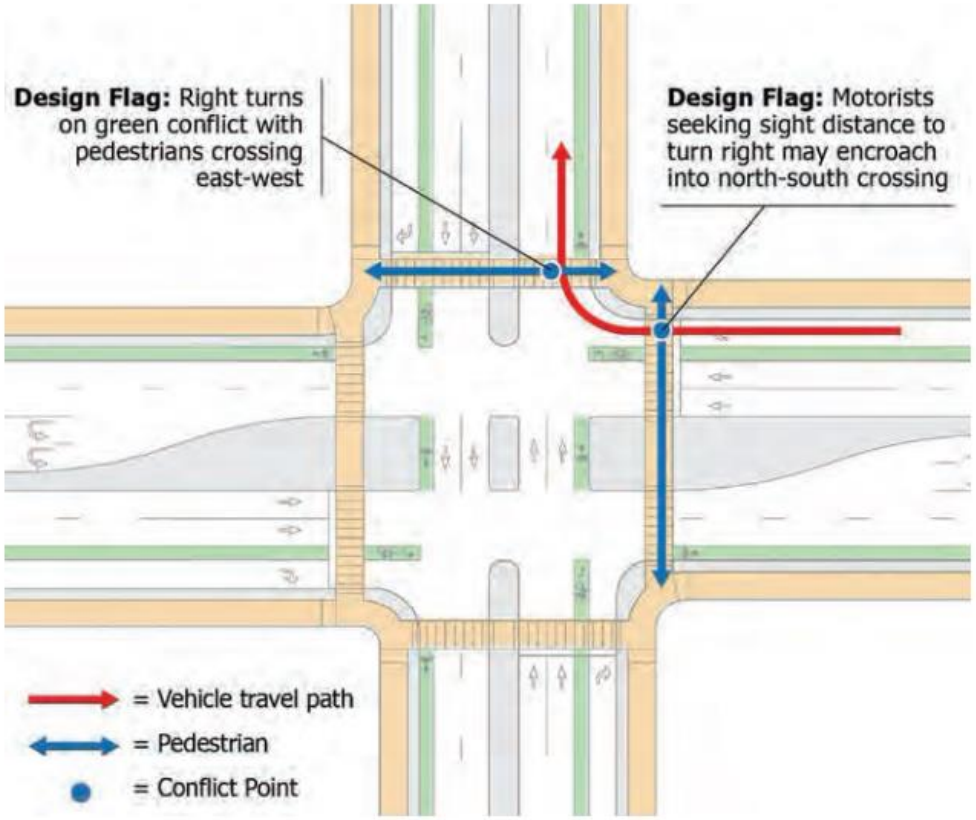


Exhibit 4-9. Design Flag 1 – Motor vehicle right-turns.

Vehicle speed directly relates to pedestrian safety… Similarly, an increase in the number of vehicles turning across a pedestrian's path increases the likelihood of the pedestrian to encounter a vehicle while crossing. Turning speeds less than or equal to 20 mph and vehicle volumes less than or equal to 50 veh/h are therefore given a yellow flag, while a turning speed or volume beyond these thresholds increases the safety risk for the pedestrian and results in a red flag.

Exhibit 4-10. Design Flag 1 – Yellow- and red-flag thresholds.

Flag	Applicable Mode	Measure of Effectiveness	Yellow-Flag Threshold*	Red-Flag Threshold*
Motor Vehicle Right-Turns	Pedestrian	Vehicle Turning Speed & Vehicle Volume	<=20 mph AND <= 50 veh/h	>20 mph OR >50 veh/h

Note: mph = miles per hour; veh/h = vehicles per hour
** If the vehicle movement is stop-controlled or signalized (with no right-turns-on-red), or speeds are below 10 mph (e.g., through a raised crosswalk) this flag is eliminated.*

20 Flags

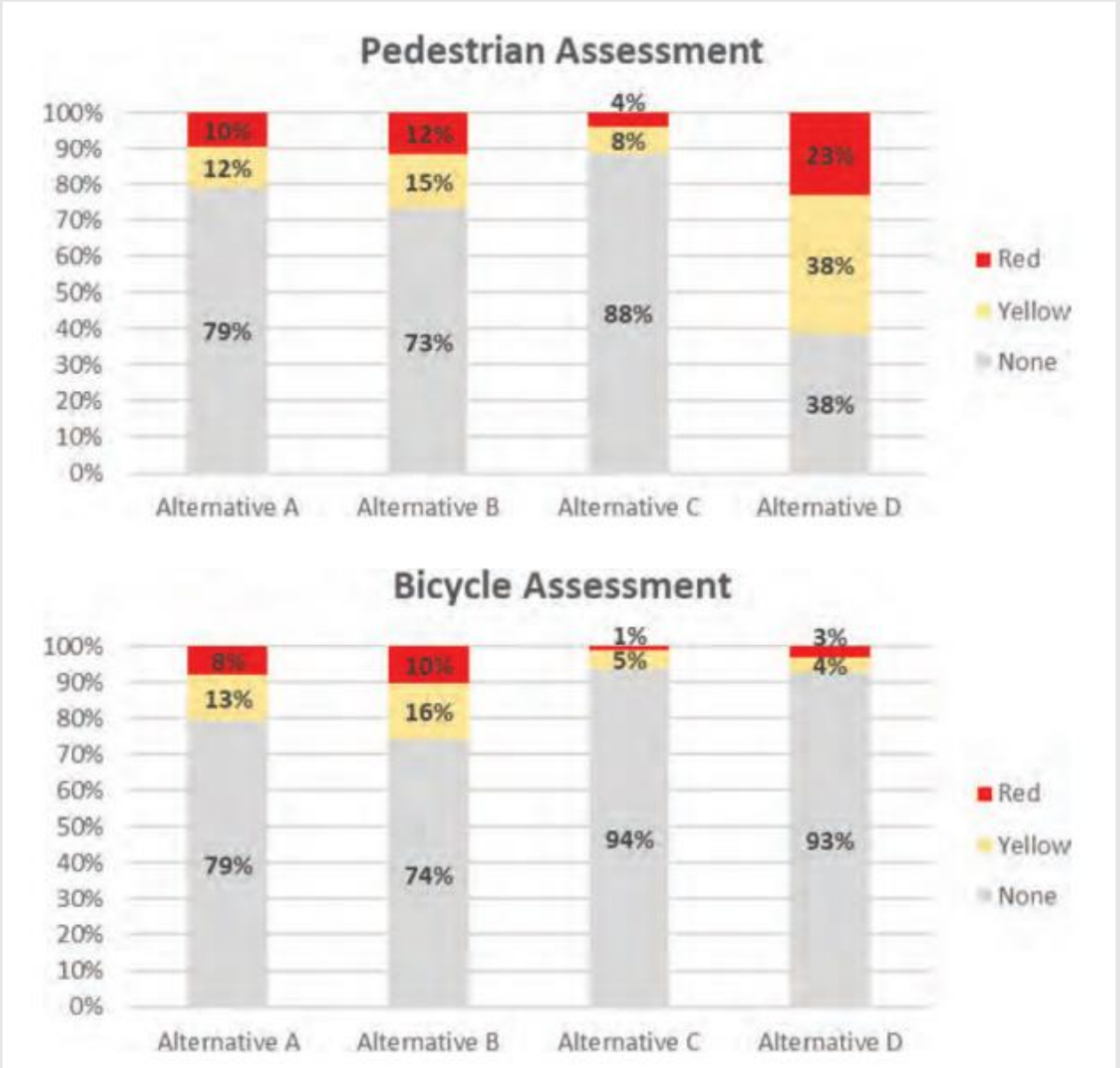
Exhibit 4-5. Summary of design flags pedestrian and bicycle assessment.

Sec.	Design Flag	Bikes	Peds.	Flag Type	Flag Description
4.4.1	Motor Vehicle Right-Turns		X	Y/R	Permissive motor vehicles right-turns across pedestrian paths
4.4.2	Uncomfortable/Tight Walking Environment		X	Y	Pedestrian facilities of narrow width
4.4.3	Nonintuitive Motor Vehicle Movements		X	Y/R	Motor vehicle movements arriving from an unexpected direction
4.4.4	Crossing Yield- or Uncontrolled Vehicle Paths	X	X	Y/R	Yield or uncontrolled pedestrian crossings
4.4.5	Indirect Paths	X	X	Y/R	Paths resulting in out-of-direction travel
4.4.6	Executing Unusual Movements	X	X	Y	Movements that are unexpected given local context
4.4.7	Multilane Crossings	X	X	Y/R	Crossing distances of significant length across multiple lanes
4.4.8	Long Red Times	X	X	Y/R	Excessive stopped delay at signalized crossings
4.4.9	Undefined Crossings at Intersections	X	X	Y	Unmarked paths through intersections
4.4.10	Motor Vehicle Left-Turns	X	X	Y/R	Permissive and protected left-turns across pedestrian and bicycle paths
4.4.11	Intersection Driveways and Side Streets	X	X	Y/R	Driveways or streets within intersection area of influence
4.4.12	Sight Distance for Gap Acceptance Movements	X	X	R	Providing adequate sight distance to conflict points
4.4.13	Grade Change	X	X	Y/R	Vertical curves adjacent to intersections
4.4.14	Riding in Mixed Traffic	X		Y/R	On-street bicycle facilities on high-speed/volume roads
4.4.15	Bicycle Clearance Times	X		Y/R	Bicycles require longer clearance times than vehicles at signals
4.4.16	Lane Change Across Motor Vehicle Travel Lane(s)	X		Y/R	Lane changes by bicycles across motor vehicle lanes
4.4.17	Channelized Lanes	X		Y/R	Bicyclist Traveling in Channelized Lane Adjacent to Motor Vehicles
4.4.18	Turning Motorists Crossing Bicycle Path	X		Y/R	Lane changes by motor vehicles across bicycle facility
4.4.19	Riding between Travel Lanes, Lane Additions, or Lane Merges	X		Y/R	Bicycle lanes with motor vehicle lanes on both sides
4.4.20	Off-Tracking Trucks in Multilane Curves	X		Y/R	The tendency of trucks to swing into bicycle lanes while turning

Note: Sec. = Section in this Guide; Peds. = Pedestrians; X = Applicable to this mode; Y = Yellow; R = Red

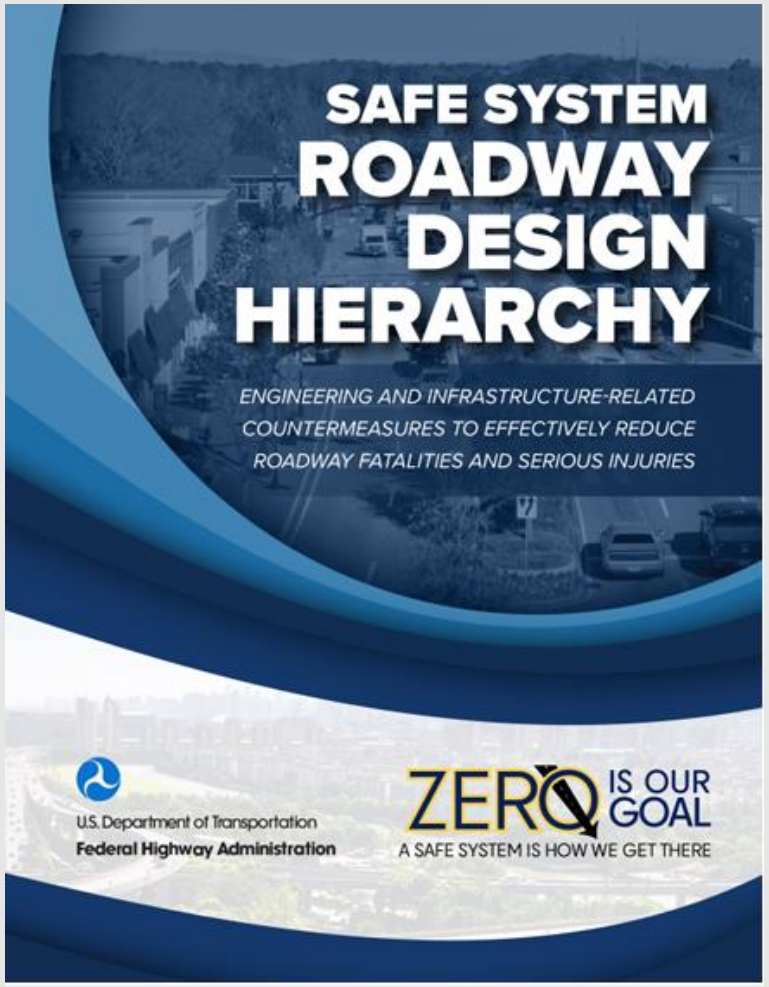
Source: NCHRP 948

20 Flags

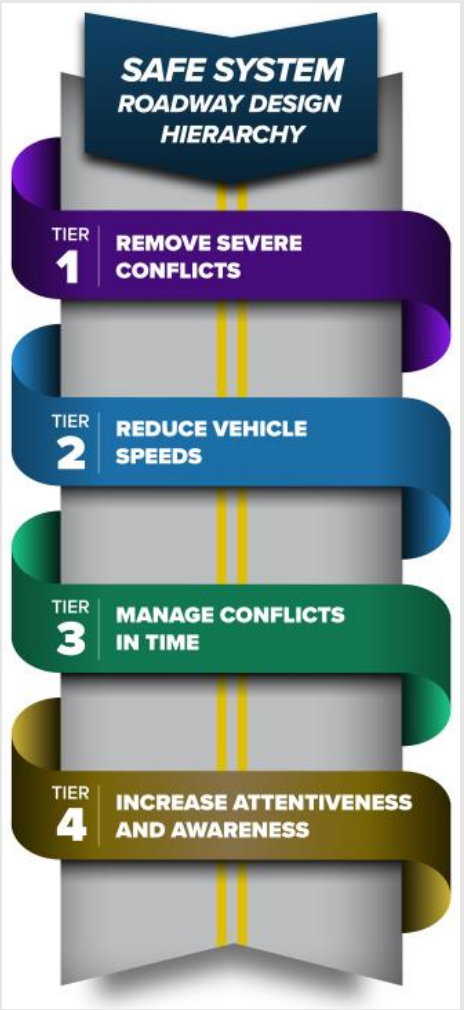


Source: NCHRP 948

Safe System Roadway Design Hierarchy



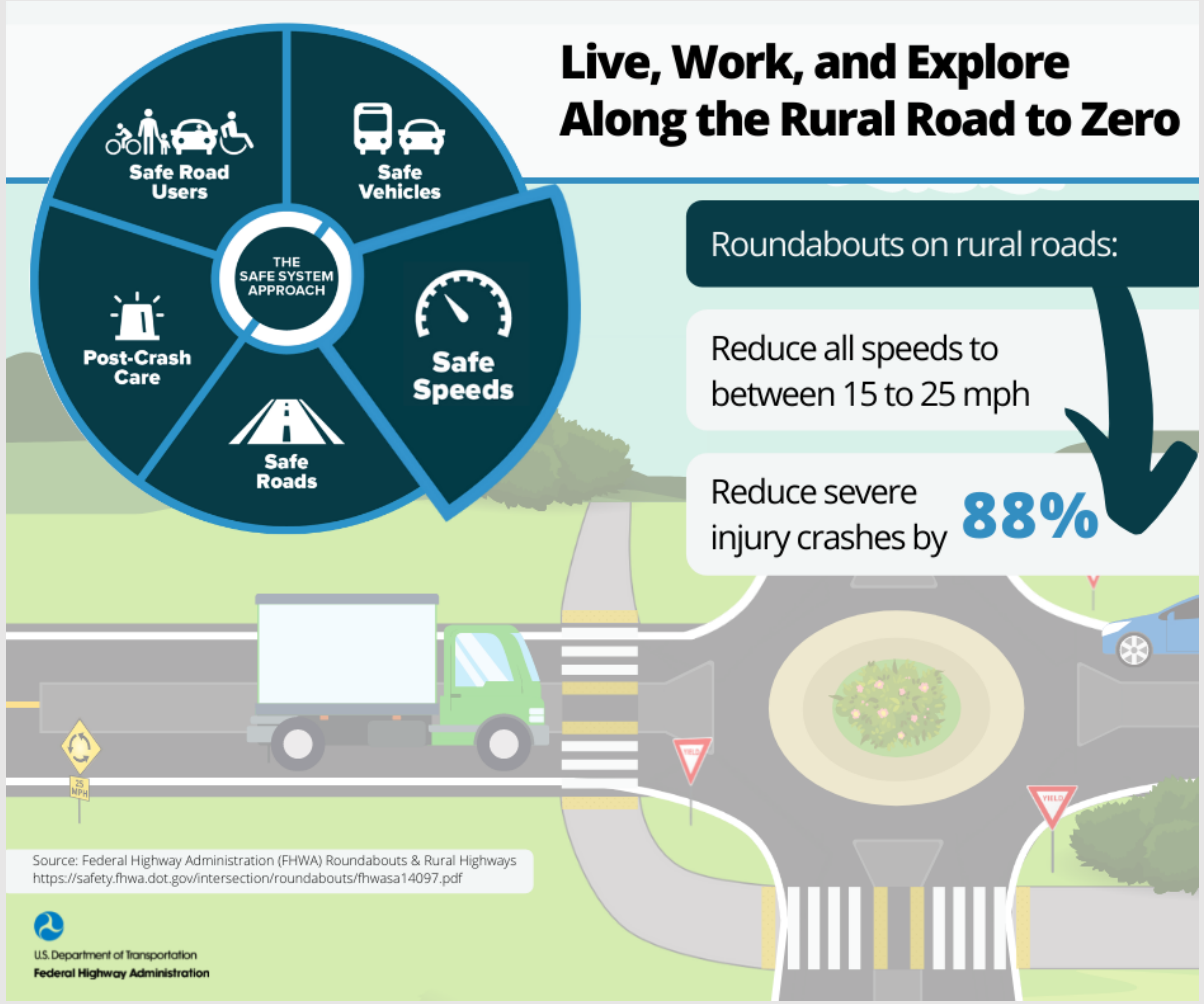
"The purpose of the hierarchy is to help transportation agencies and practitioners identify and prioritize countermeasures and strategies when developing transportation projects."

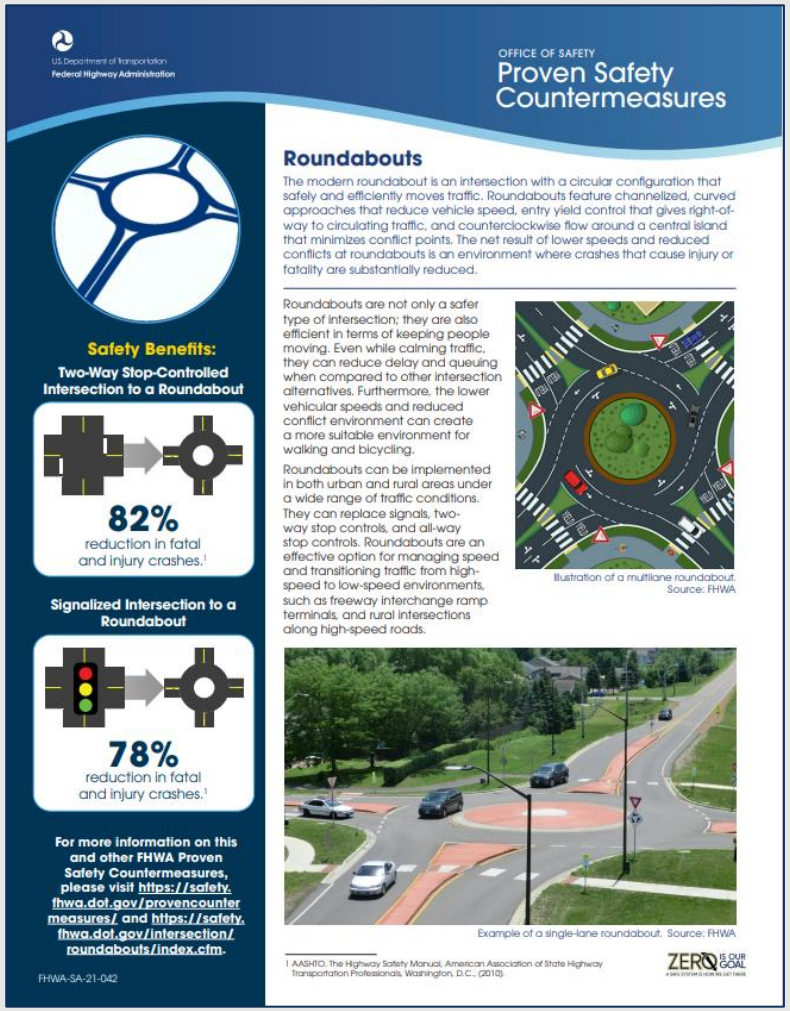


Roundabouts Save Lives!

TIER 1 REMOVE SEVERE CONFLICTS

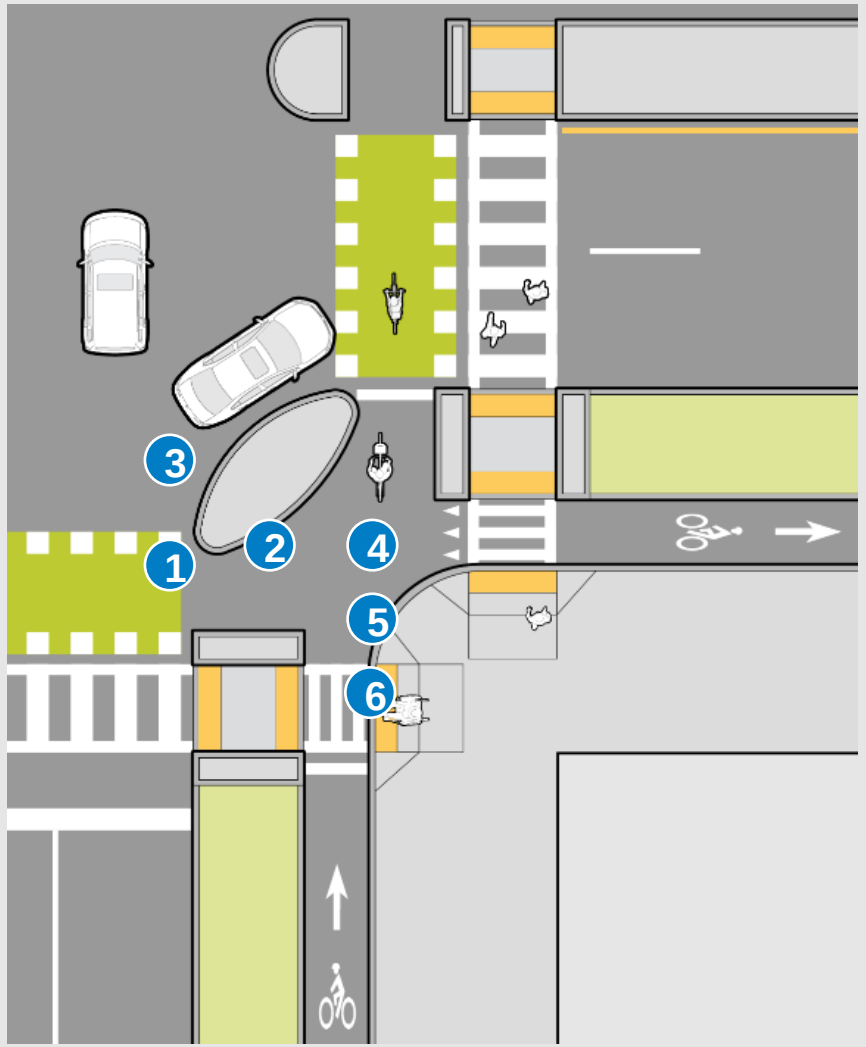
TIER 2 REDUCE VEHICLE SPEEDS





Protected Intersections

1. Corner refuge island
2. Forward bicycle queuing area
3. Motorist yield zone
4. Pedestrian crossing island
5. Pedestrian crossing separated bike lane
6. Pedestrian curb ramp



massDOT

Protected Intersections

Salt Lake City, UT

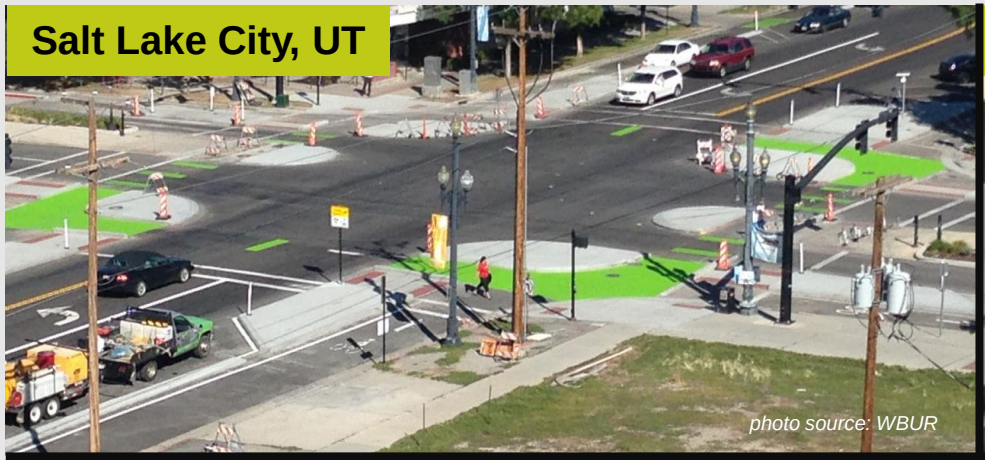


photo source: WBUR

Chicago, IL

photo source: Streetsblog

Austin, TX

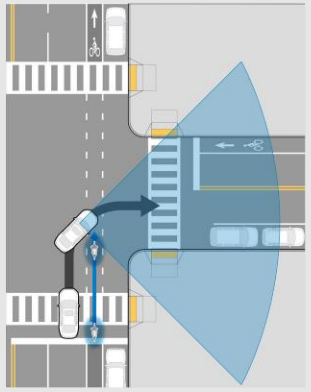
photo source: Google

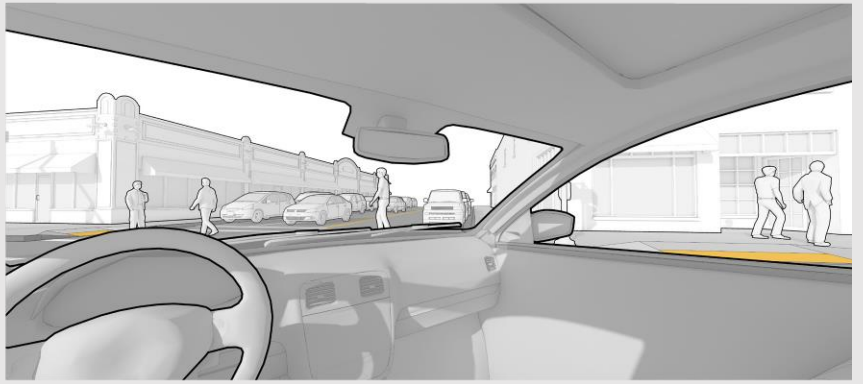
Davis, CA

photo source: People for Bikes

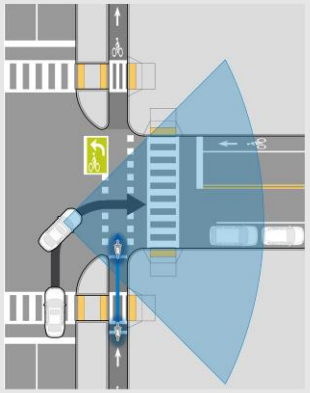
Visibility at Conflict Points

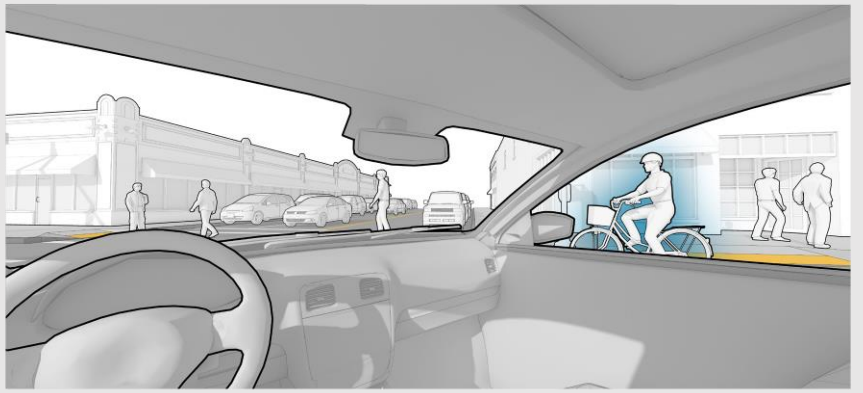
motorist's view at conventional bike lane



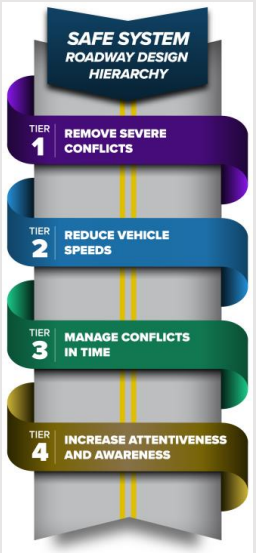


motorist's view at **separated bike lane**





massDOT



Visibility at Conflict Points

protected intersection

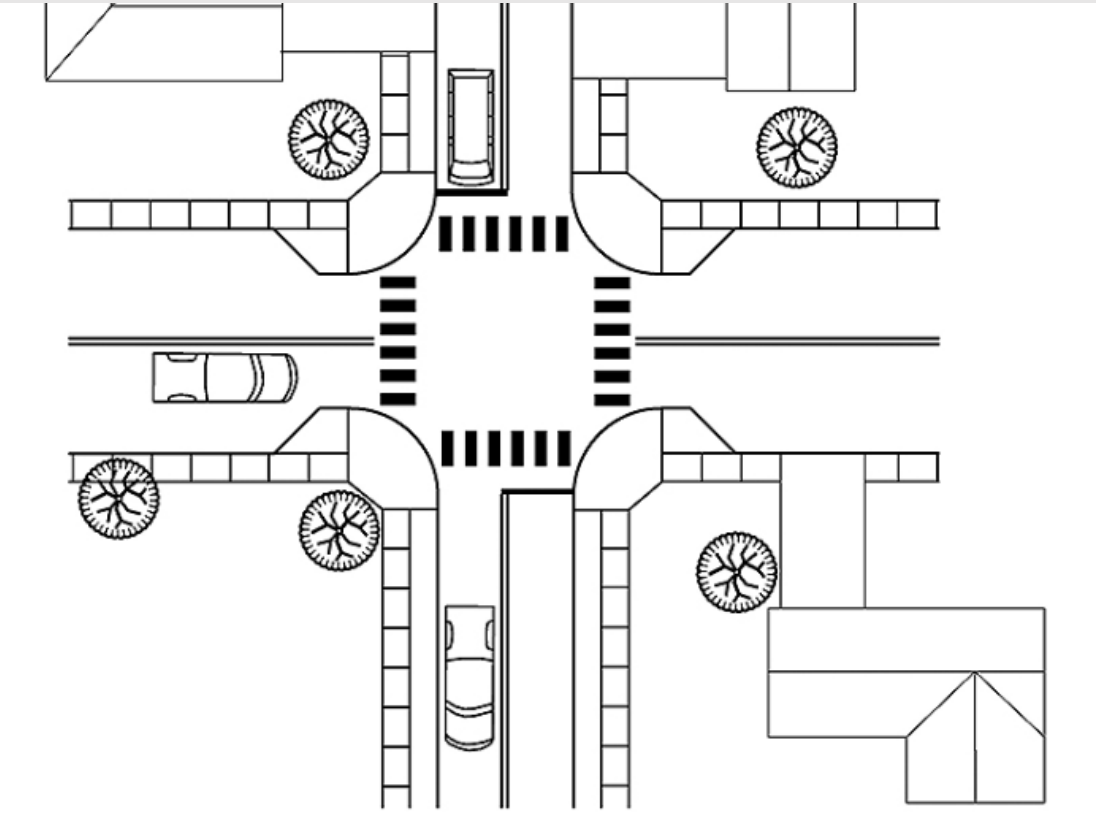
photo source: Jonathan Maus

conventional bike lane

- Yielding increased from 34% to 38%
- Right-turn speeds reduced 2.6 mph

https://rosap.ntl.bts.gov/view/dot/66612/dot_66612_DS1.pdf

Corner Extensions



Source: Delaware DOT

Source: Hillary Orr

Left turn centerline hardening

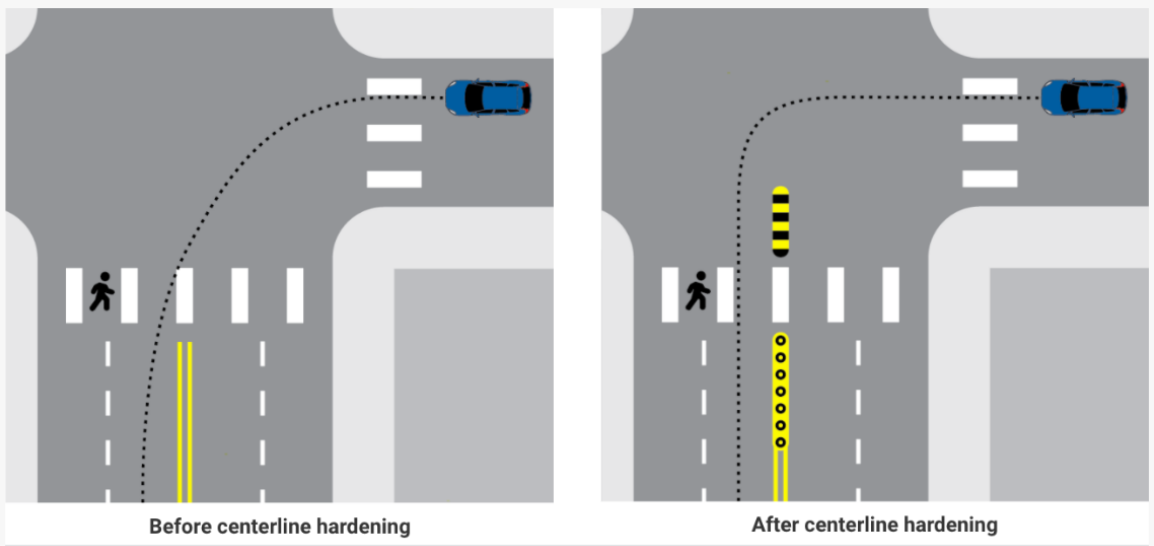


Image source: Insurance Institute for Highway Safety

https://ssti.us/2020/07/30/centerline-hardening-protects-pedestrian-from-left-turning-vehicles

TIER 3 MANAGE CONFLICTS IN TIME

Leading Pedestrian Interval (LPI)

Source: FHWA

- 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.

TIER 3 MANAGE CONFLICTS IN TIME

Pedestrians vs Permissive Lefts

Source: FHWA.

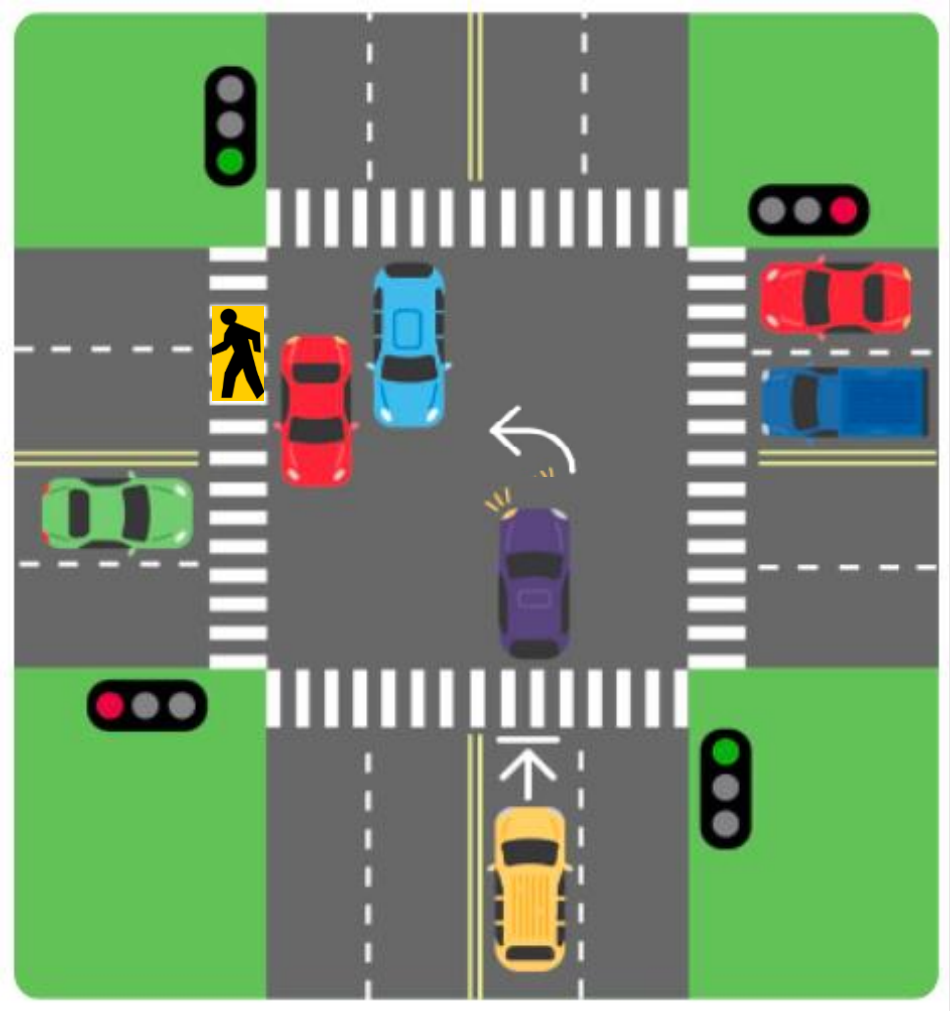
- Left turning driver attention is focused on judging gaps in oncoming through traffic rather than looking out for pedestrians crossing the street.
- Drivers may attempt to accelerate quickly to take a short gap in oncoming traffic.
- During the left turn, the vehicle driver's line of sight is not clear, with the vehicle's A pillar concealing part of the outside view.

TIER 3 | MANAGE CONFLICTS IN TIME

Protected Only Left Turn Signals

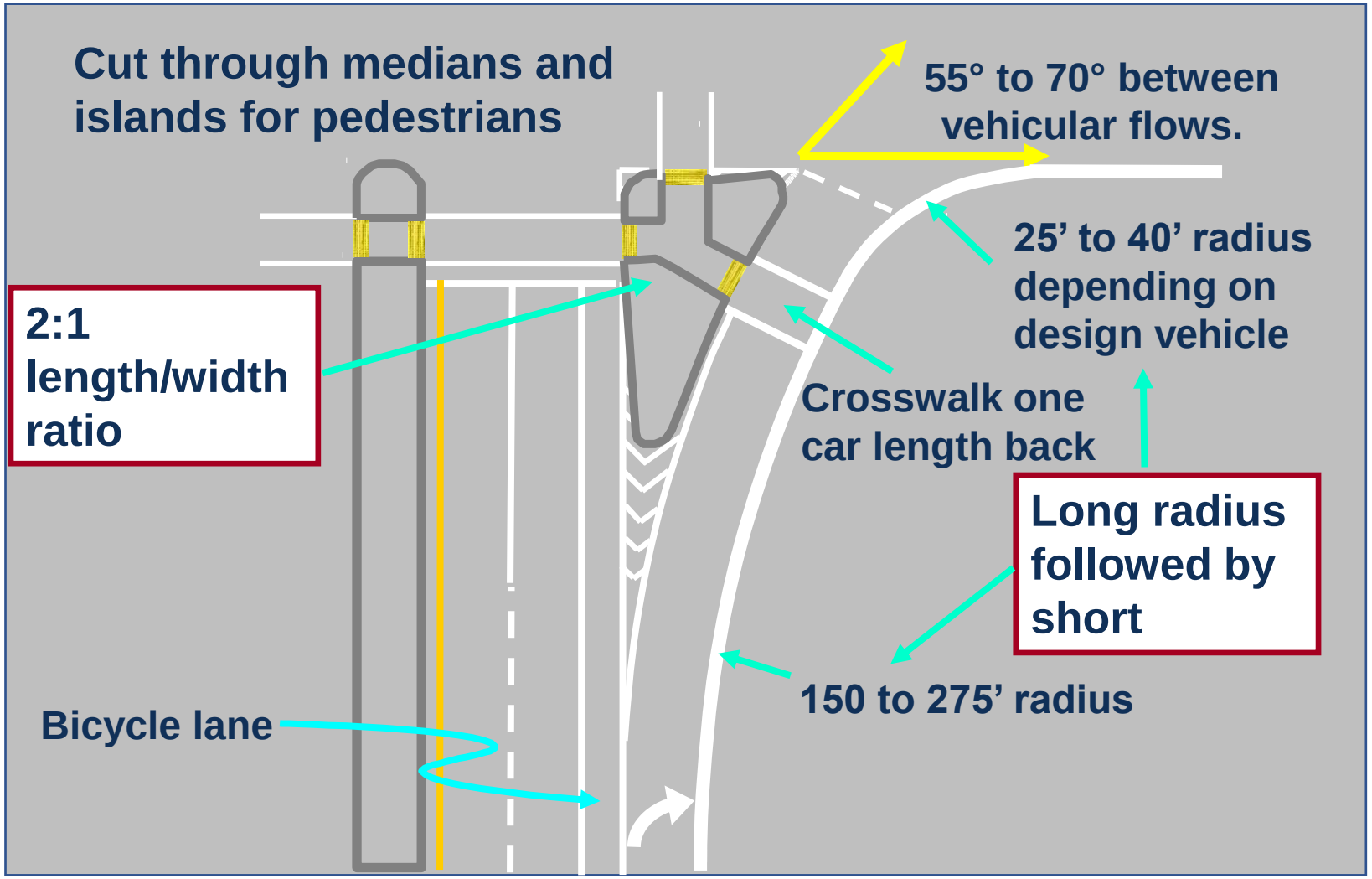
Consider:

- Protected only left turn signal phasing; or
- Flashing Yellow Arrow to omit permissive movement when there is a pedestrian call



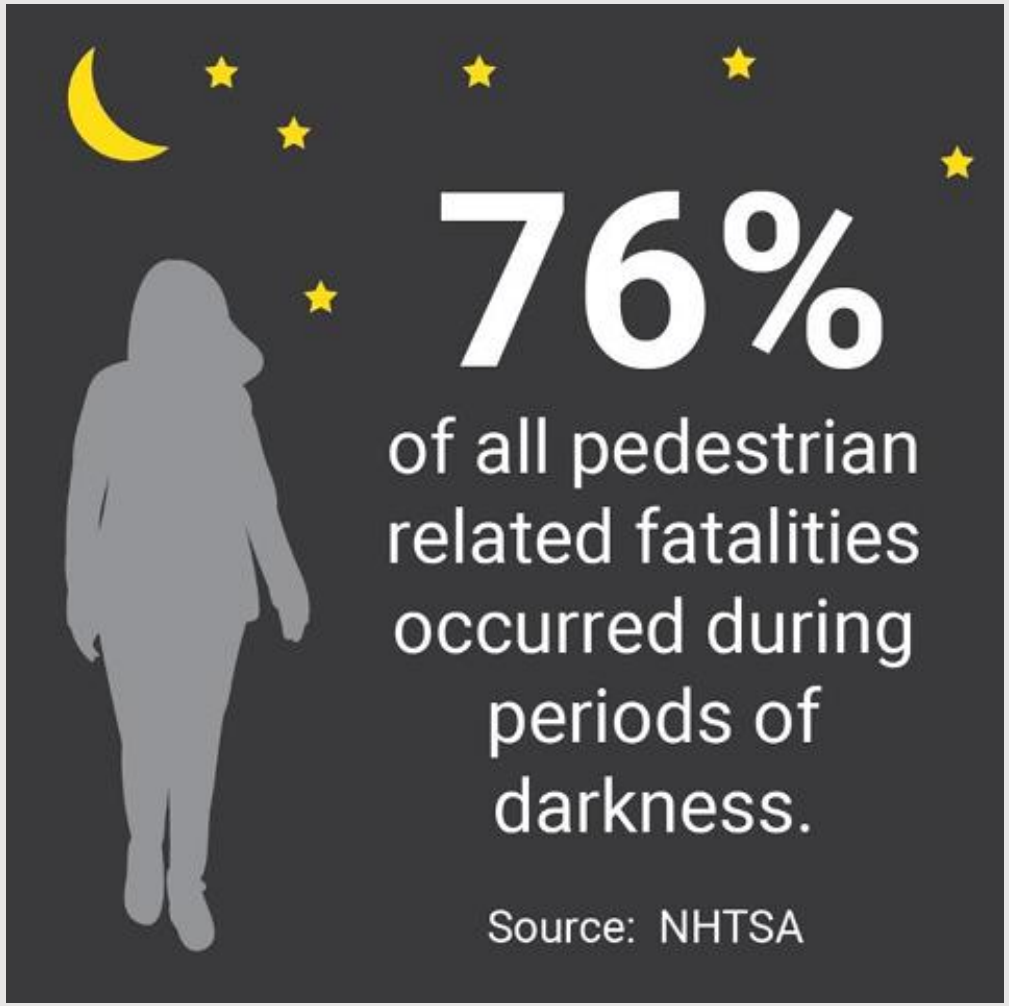
TIER 4 INCREASE ATTENTIVENESS AND AWARENESS

Right-Turn Slip Lanes: Design for Pedestrians



TIER 4 INCREASE ATTENTIVENESS AND AWARENESS

Nighttime Visibility



U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration
RESOURCE CENTER

FHWA Resource Center

Office of Technical Services

Mark Doctor, PE
mark.doctor@dot.gov