Hollywood, FL

June 13-14, 2024

2024 TRANSPORTATION SYMPOSIUM

Strategies for Enhancing Pedestrian Safety at Intersections

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FHWA – Resource Center – Safety and Design Team

FDOT

← NEWS

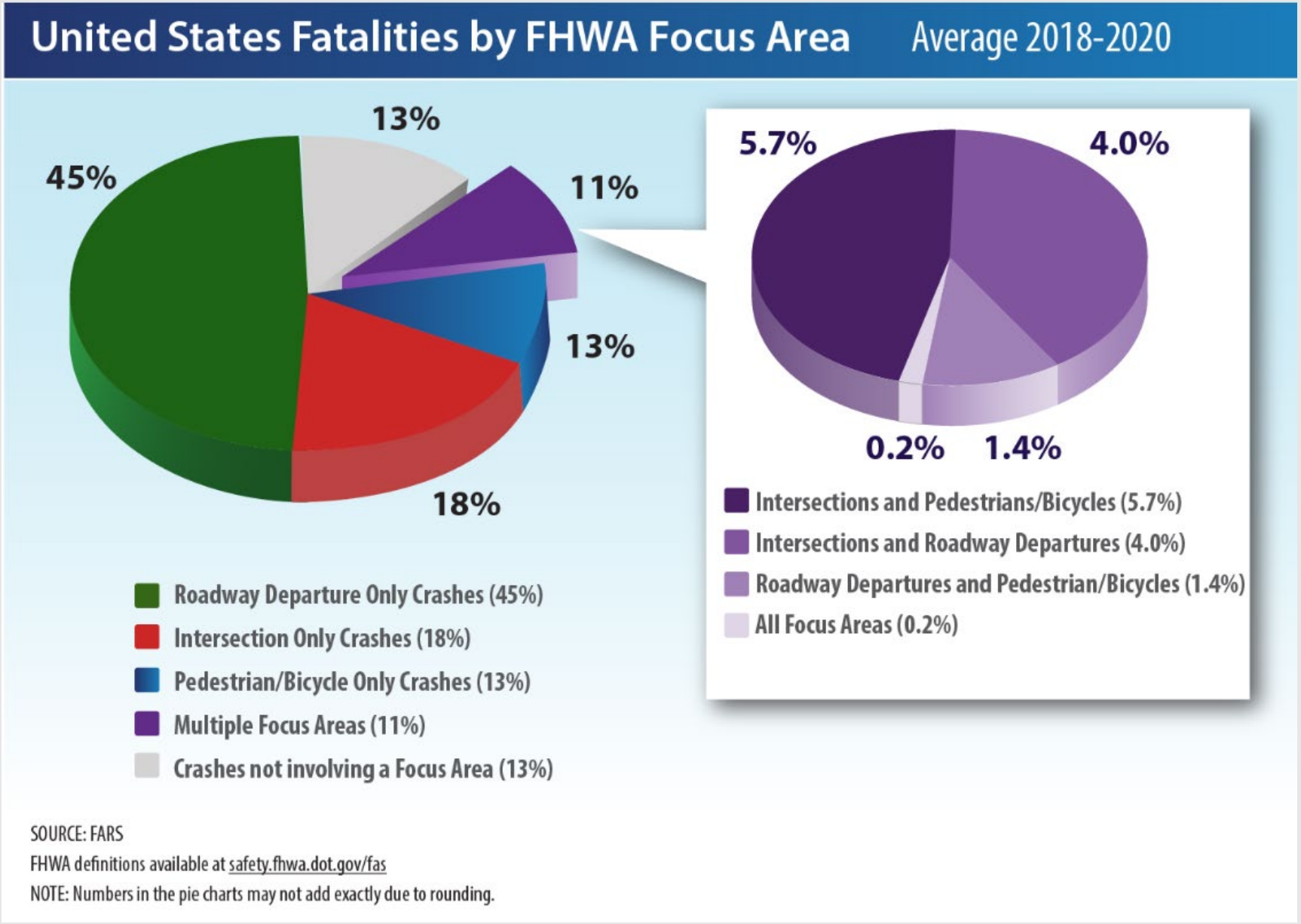
NHTSA Launches Put the Phone Away or Pay Campaign; Releases 2023 Fatality Early Estimates

Projections show a seventh consecutive quarter of decline in fatalities

April 1, 2024

Data Source: NHTSA

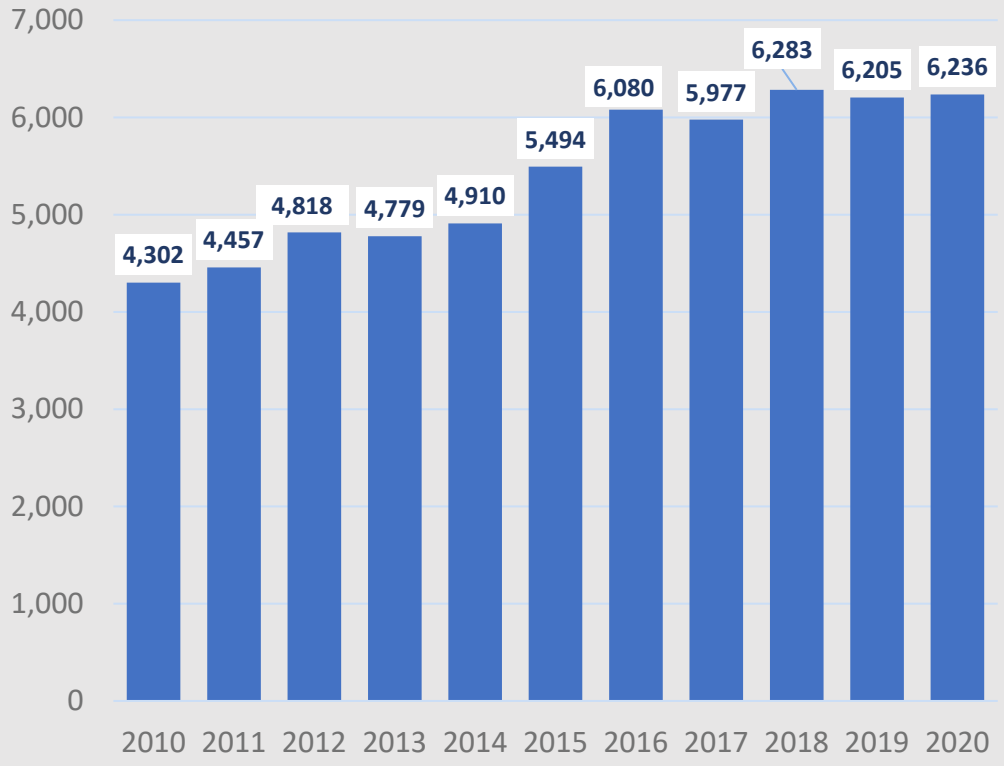
40,990



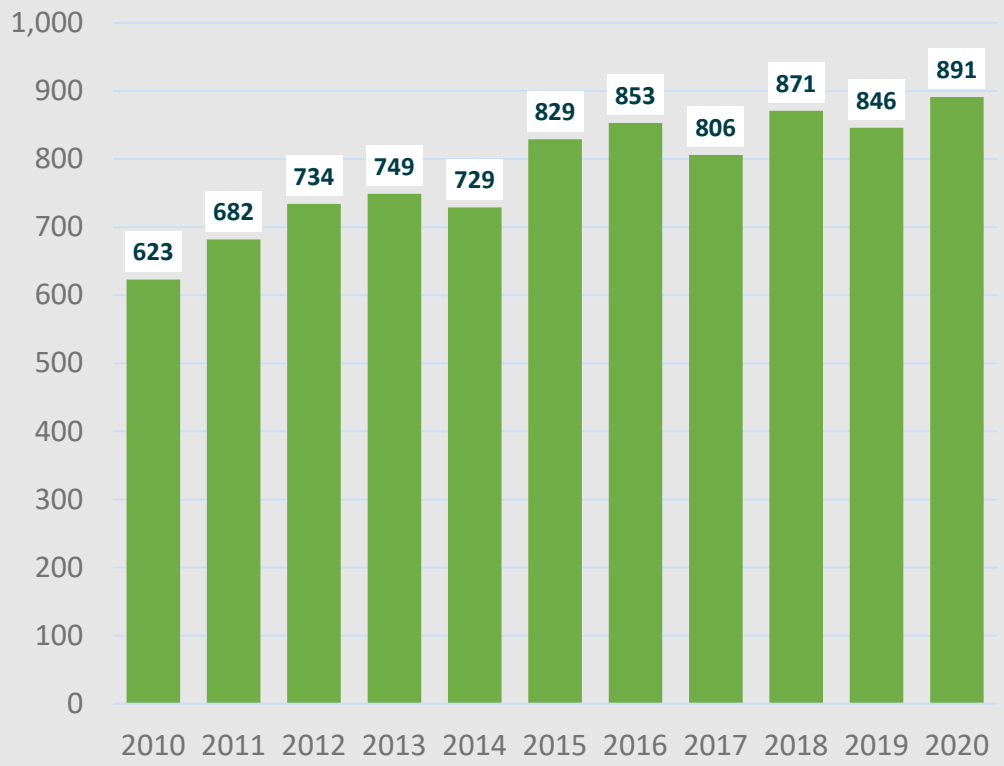
Over **1 in 4** of all traffic-related fatalities in the US are at intersections

Trends

Total US Pedestrian Fatalities
2010-2020



Total US Bicyclist Fatalities
2010-2020

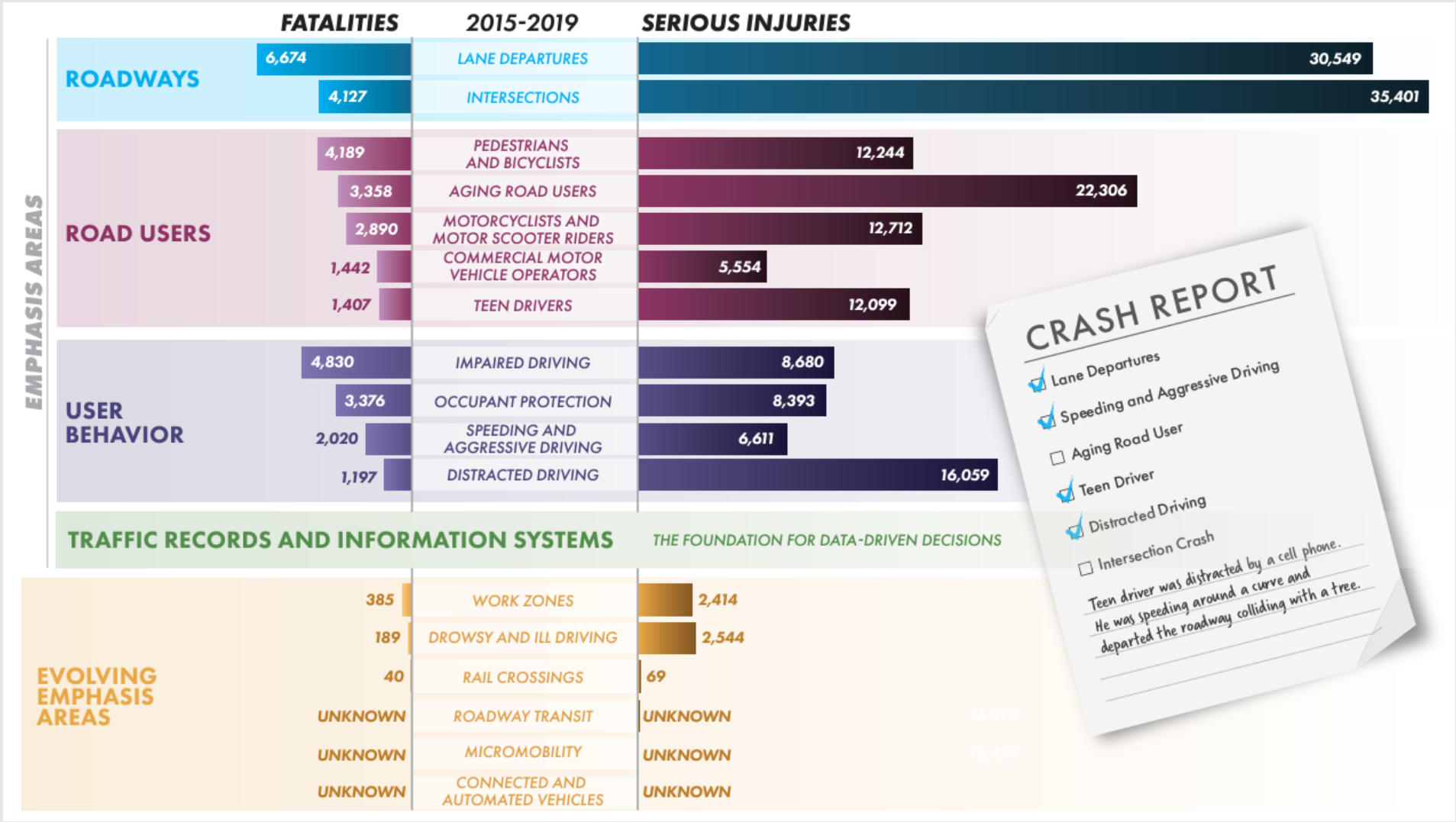


Source: NHTSA

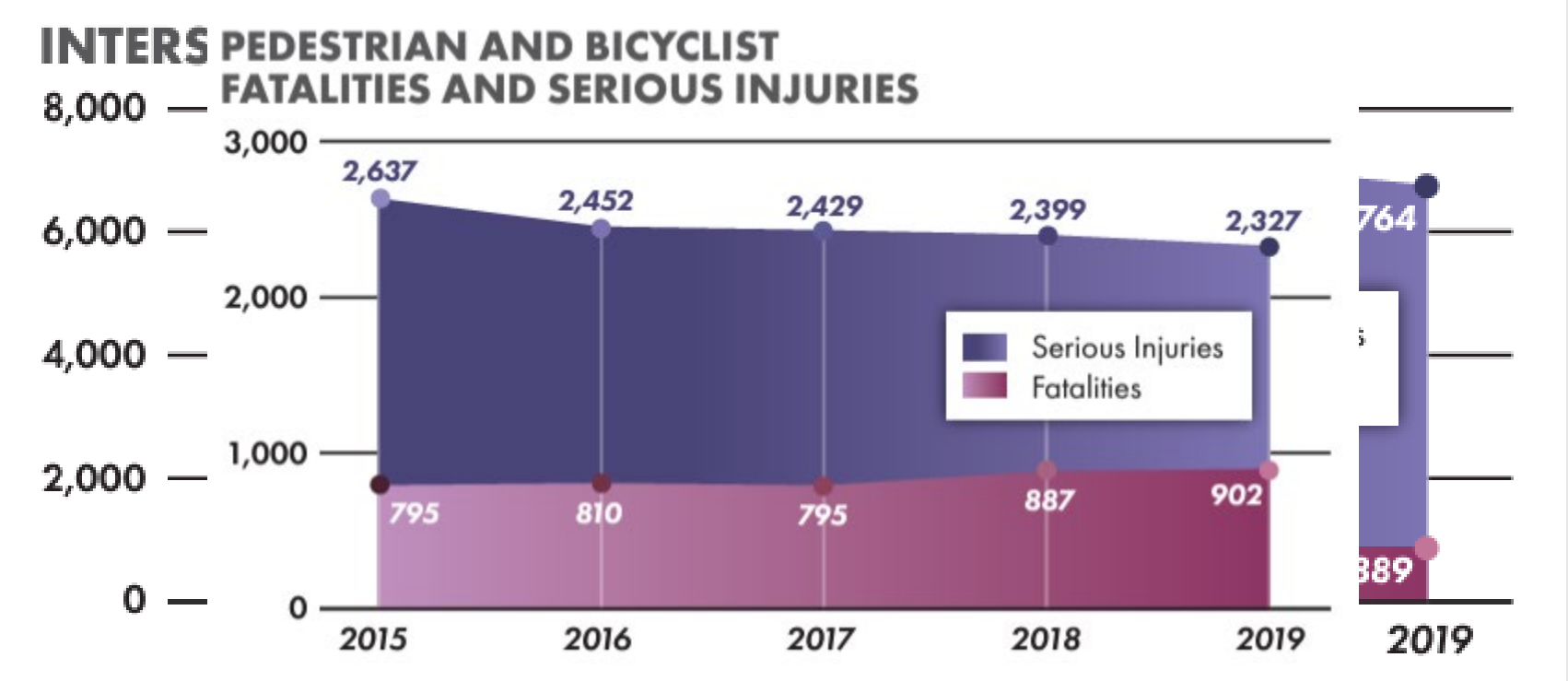
https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/safety/shsp-2021/shsp_mar21.pdf?sfvrsn=5452dad_0

https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/safety/2a-programs/bike-ped/2021_pbssp.pdf?sfvrsn=5737a595_2

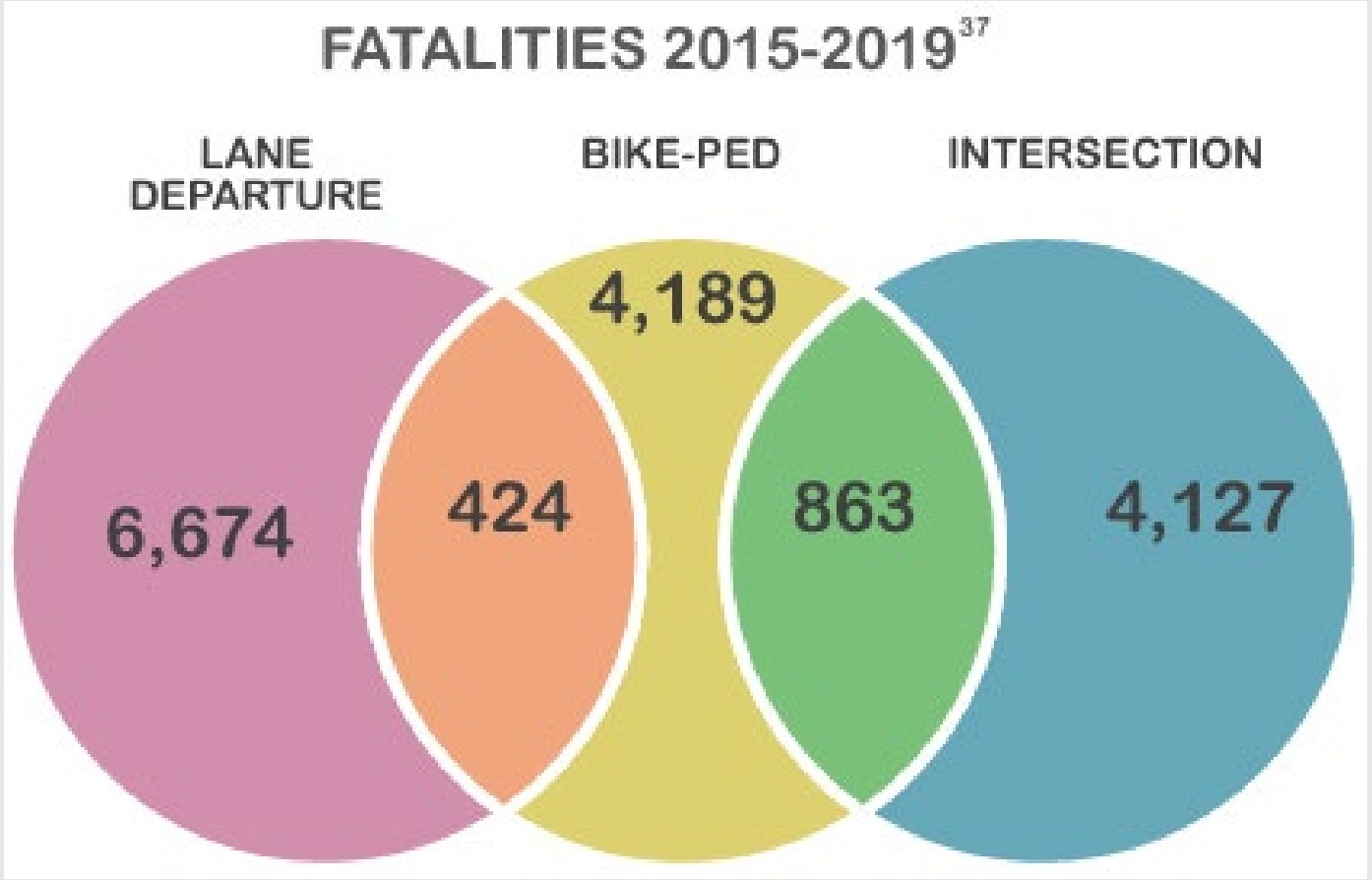
Florida's Emphasis Areas



Florida's Reality



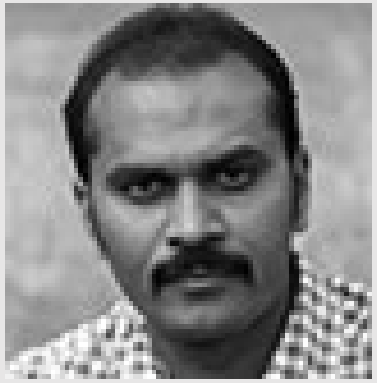
Florida's Reality



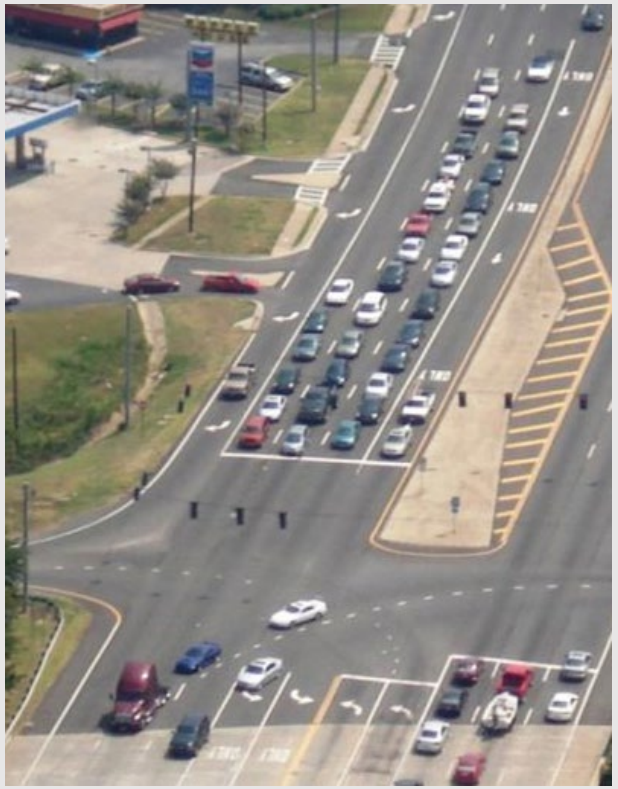
In **Florida**, there is **one pedestrian death** at an intersection every **50 hours**

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

…at or near an intersection.



Intersection Challenges



- Safety for all users
- Capacity choke points
- Access & mobility
- Right-of-way constraints
- $$$

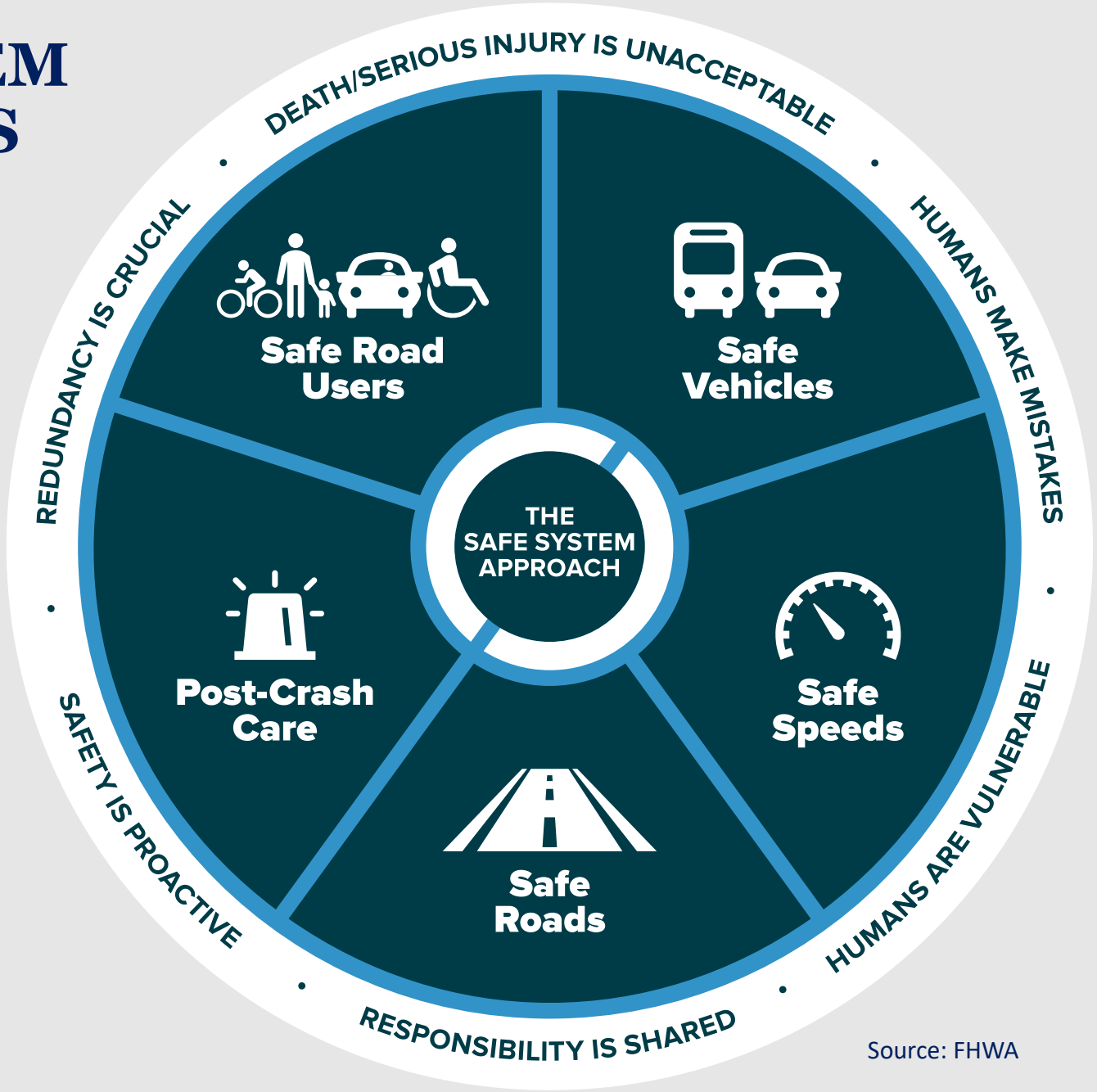
Source: Mark Doctor, FHWA

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

Florida Gets It!

HOW THE SAFE SYSTEM APPROACH IMPROVES SAFETY FOR PEOPLE WALKING AND BIKING

SAFE ROAD USERS

The Safe System approach recognizes safety for all road users and specifically considers those most vulnerable to fatal and serious injury crashes, such as people walking and biking.

SAFE VEHICLES

Motor vehicle innovation and technology have made collisions more survivable for those traveling inside of a motor vehicle. However, the same technological progress has not yet advanced safety for those involved in crashes with the outside of a vehicle.

SAFE SPEEDS

Reducing speeds decreases severe injuries and deaths for people walking and biking.

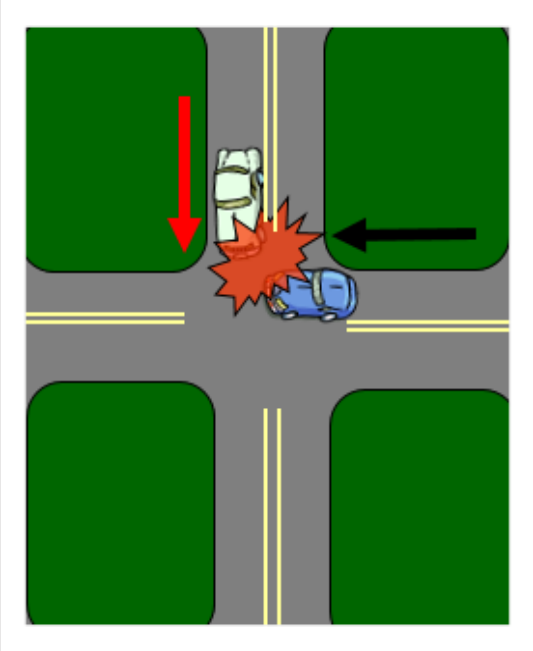
SAFE ROADS

Since people walking and biking are more vulnerable to serious injuries and fatalities, it is imperative to separate them from motor vehicles, which travel at higher speeds and have a heavier mass.

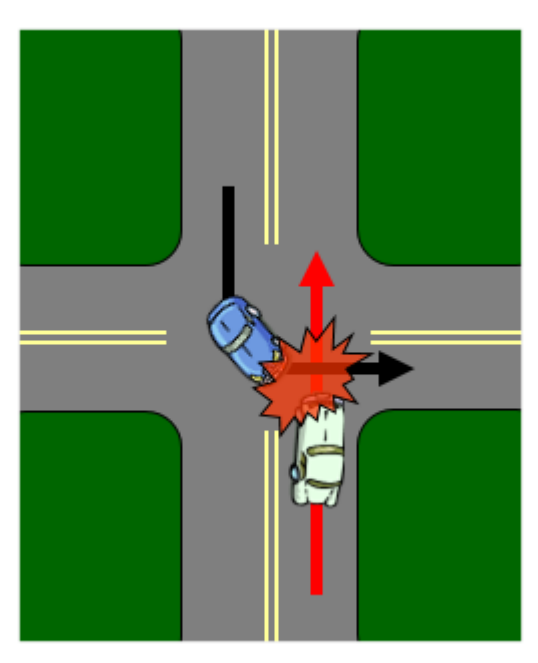
POST-CRASH CARE

Post-crash care is vital to the survival of a person walking or biking since they are more likely to be injured or killed in a crash relative to the motorist.

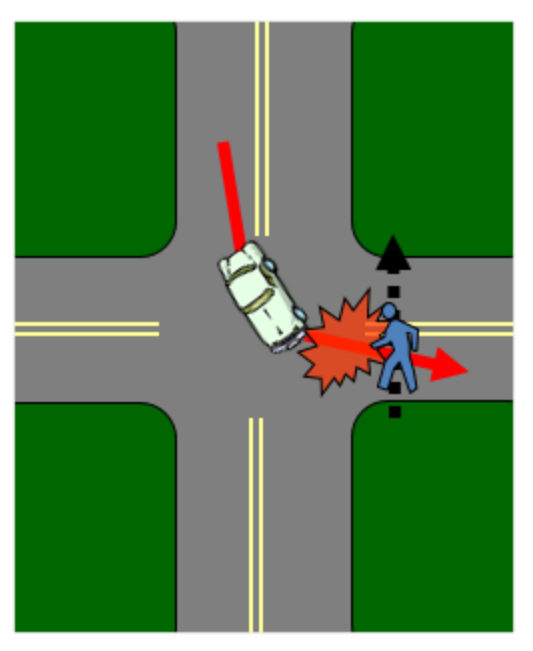
Intersection Challenges – Safety



Side Impact (right-angle)
40% of fatal
intersection crashes

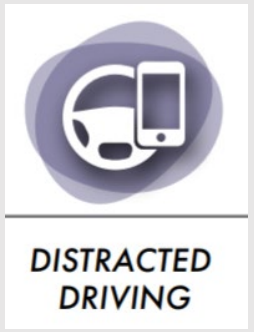


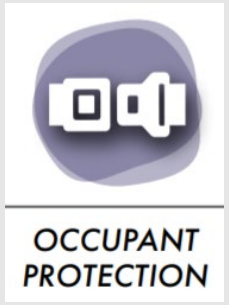
Left Turn (side-impact)
20% of fatal
intersection crashes



Pedestrians
15% of fatal
intersection crashes

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

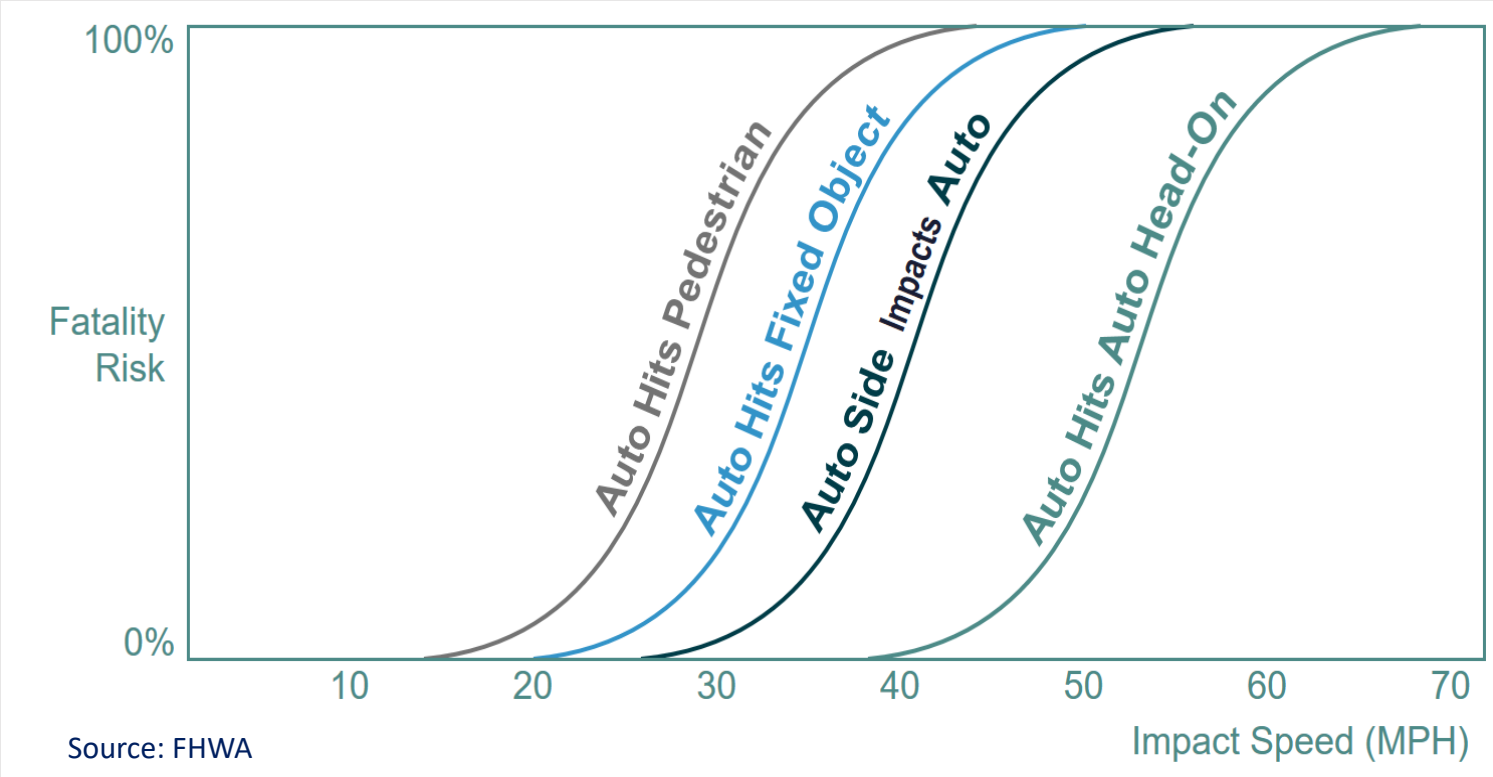




People are killed and seriously injured on the roads when the collision forces transferred onto the human body exceed tolerable thresholds.

Safer Roads by Managing Kinetic Energy

Humans are vulnerable



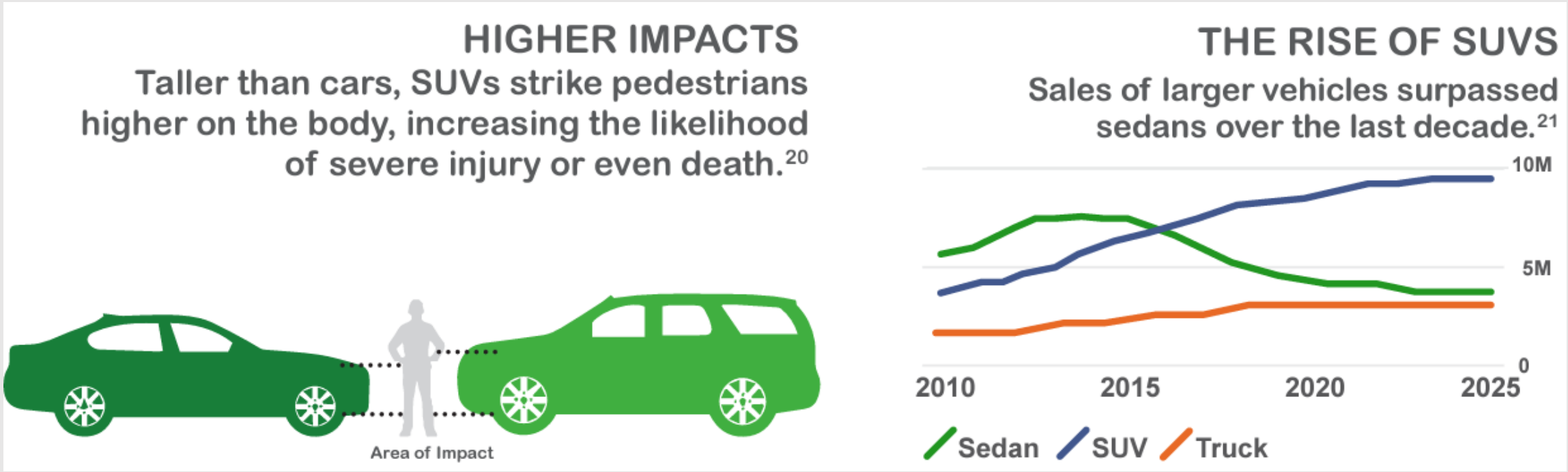
Source: FHWA

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

Velocity is a Vector

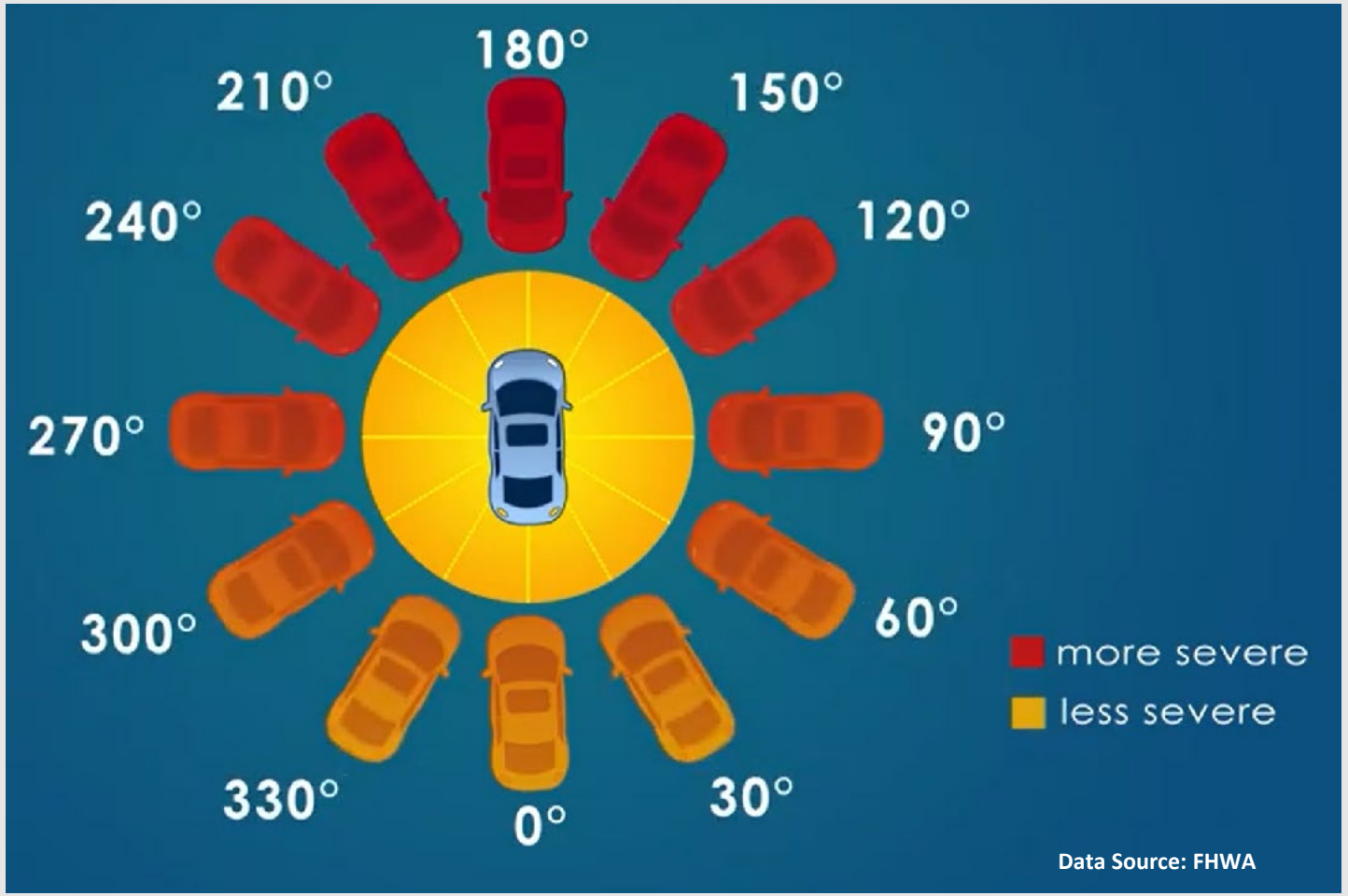
- Speed
- Direction (angle of impact)

Vehicle Trends

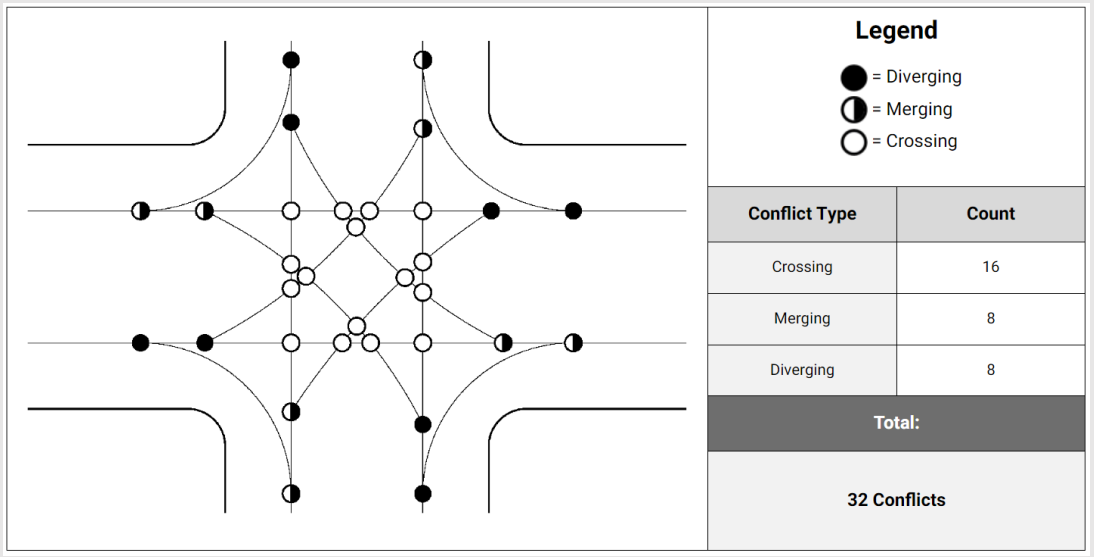


20) U.S. Department of Transportation, Federal Highway Administration. (2019). Bikeway Selection Guide
21) Florida Department of Transportation. (2021). FDOT Design Manual, Section 223 Bicycle Facilities

Conflict Points: Speed and Collision Angles



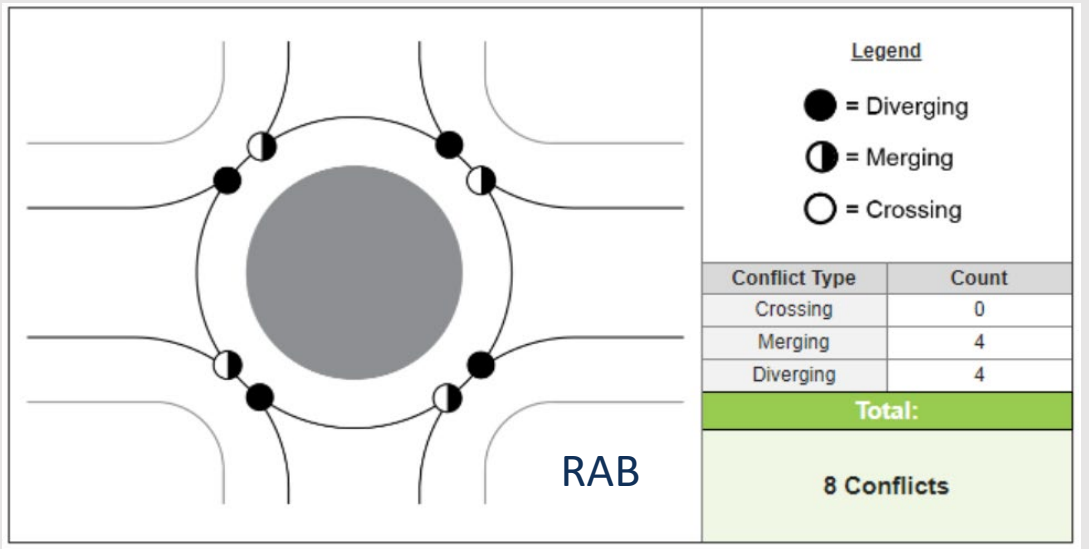
Conflict Points as a Safety Surrogate



Legend

● = Diverging
◑ = Merging
○ = Crossing

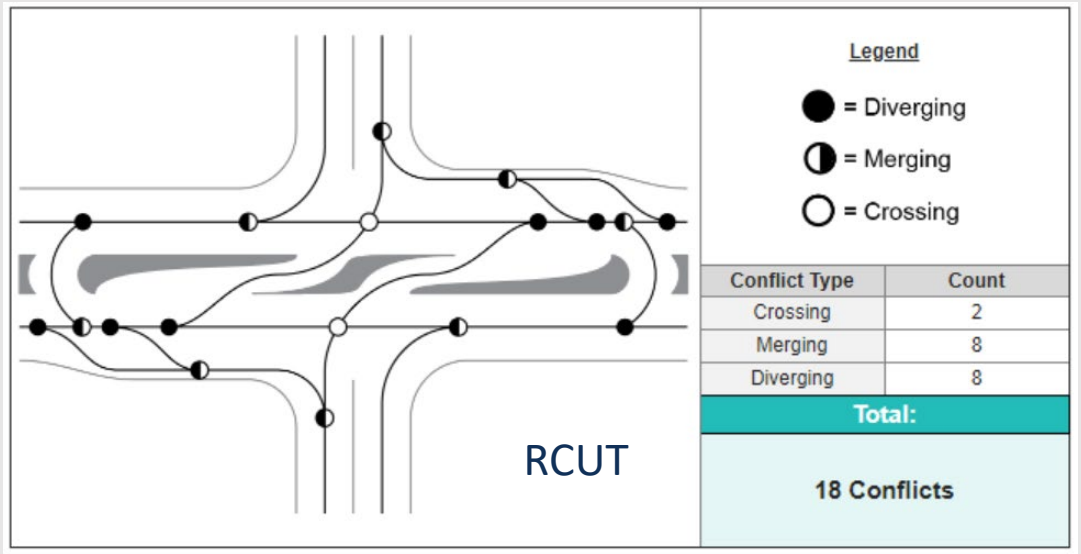
Conflict Type	Count
Crossing	16
Merging	8
Diverging	8
Total:	
32 Conflicts	



Legend

● = Diverging
◑ = Merging
○ = Crossing

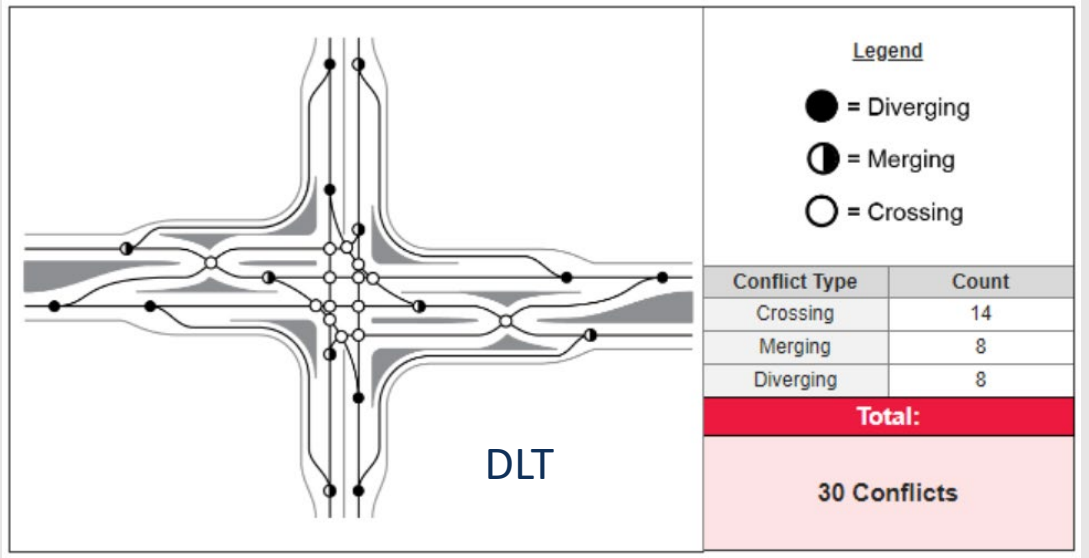
Conflict Type	Count
Crossing	0
Merging	4
Diverging	4
Total:	
8 Conflicts	



Legend

● = Diverging
◑ = Merging
○ = Crossing

Conflict Type	Count
Crossing	2
Merging	8
Diverging	8
Total:	
18 Conflicts	



Legend

● = Diverging
◑ = Merging
○ = Crossing

Conflict Type	Count
Crossing	14
Merging	8
Diverging	8
Total:	
30 Conflicts	

Source: VDOT

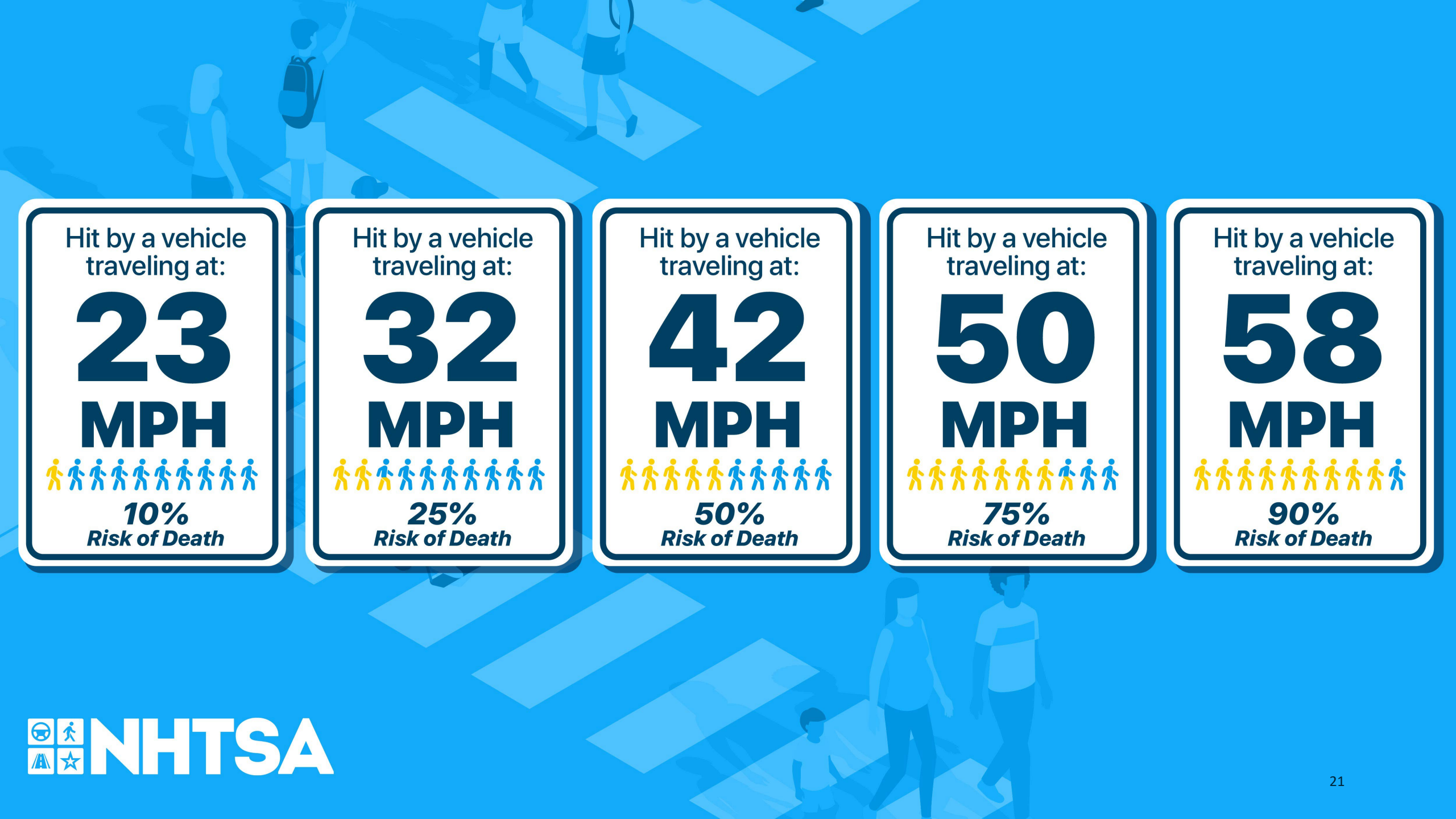
Higher speeds also affect a driver's ability to perceive, focus on, and react to things in their line of vision.

15 mph

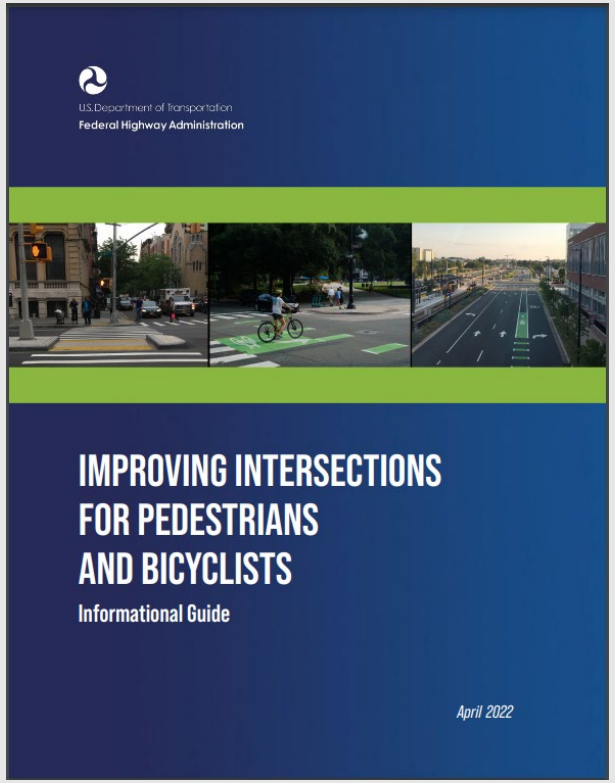
20 mph

30 mph

40 mph


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

New(*ish*) Resource!

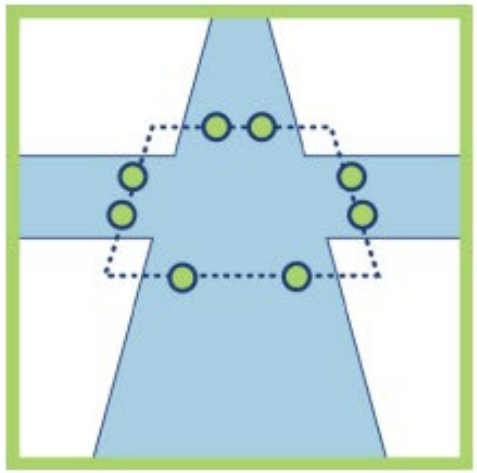


"The purpose of this guide is to inform the state of the practice concerning intersection planning and design to implement solutions that help achieve the goal for zero fatalities and serious injuries while also making roads better places for walking and bicycling."

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

Improving Intersections for Peds & Bikes

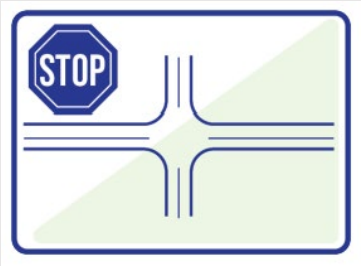
Expect Pedestrians and Bicyclists at All Intersections



Use a Safe System Approach

Provide Access for All Ages and Abilities

Improving Intersections for Peds & Bikes



Condition	Description	Assessment Technique
Uncontrolled crossings; Multilane crossings	For pedestrians and bicyclists, risk of crash harm is higher and convenience and comfort are lower, at uncontrolled or multilane crossings, especially along higher speed or rural roads.	» The Design Flag Assessment includes a flag for "yield- or uncontrolled vehicle paths" and a flag for "multilane crossings" emphasizing consideration at multi-threat or high-speed crossings.
Crossing distance	Stop-controlled intersections with multiple through or turn lanes can lead to longer pedestrian and bicyclist crossing distances and greater exposure to traffic. Certain road users may need extended time to cross longer distances, further increasing exposure and stress for the user.	» The SSI method considers the number of through lanes crossed as a concern for pedestrian and bicyclist exposure. » Travel time data collection can be used to identify locations with long crossing distances.
Visibility of pathway and bikeway crossings	The mutual visibility among pedestrians, bicyclists and motor vehicle drivers is essential for effective yielding and stopping behaviors. Further, the need to identify and act upon gaps in traffic for uncontrolled crossings or alternating stop-and-go for controlled crossings makes sight distance and view angles critical.	» The Design Flag Assessment includes a flag for "Sight Distance for Gap Acceptance Movements"

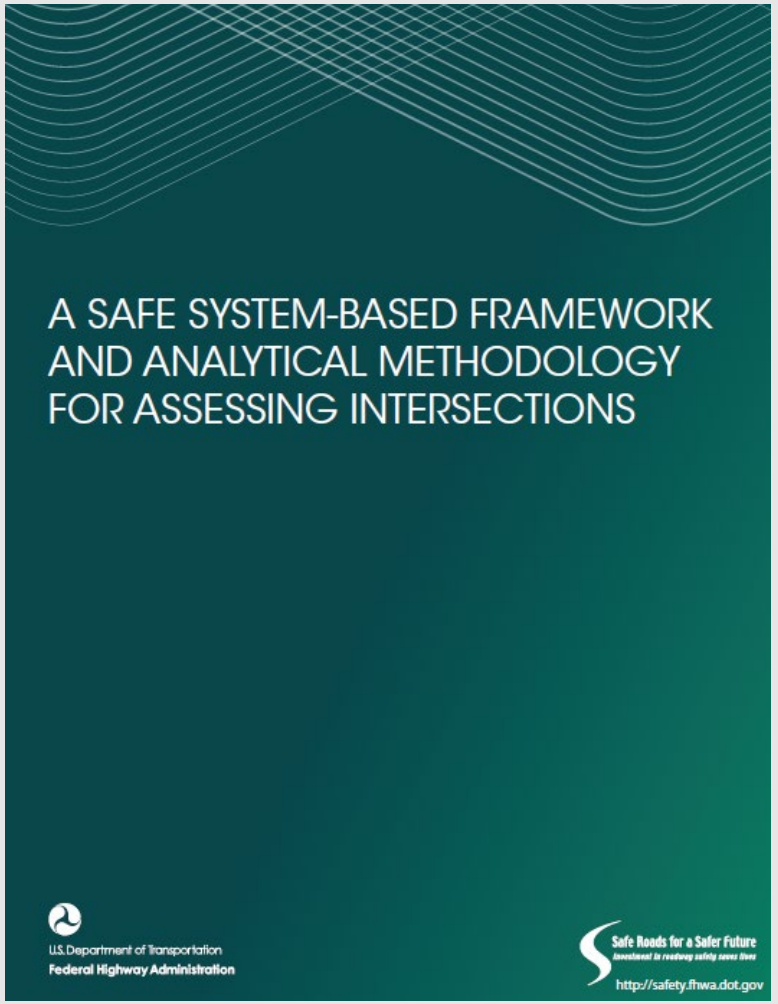
Fact Sheets


Roundabouts
Roundabouts are circular intersections characterized by channelized approaches and counterclockwise traffic flow around a center island.
Design Features
Benefits
Intersection Types
SHARED LANE
SEPARATED BIKE LANE
SIDEPATH
References
Median U-Turn Intersections
Median U-Turn (MUT) intersections refer to any intersection replacing direct left turns at an intersection with indirect left turns that rely on a U-turn/right-turn combination.
Design Features
Benefits
Intersection Types
SEPARATED BIKE LANE
SIDEPATH
SIDEPATH WITH BULB
References
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.
Design Features
Benefits
Intersection Types
SIDEPATH
SIDEPATH Z-CROSSING
SEPARATED BIKE LANE
References
Quadrant Roadway (QR) Intersections
Quadrant Roadway (QR) intersections feature one main intersection and two secondary, or auxiliary, intersections where left turns are displaced to a connector road in one quadrant of the main intersection.
Design Features
Benefits
Intersection Types
SEPARATED BIKE LANE
SIDEPATH
References
Displaced Left Turn (DLT) Intersections
Displaced Left Turn (DLT) intersections are crossover-type intersections that can be applied to high-volume signalized arterial intersections—especially those characterized by heavy left-turn volumes that conflict with heavy opposing through volumes.
Design Features
Benefits
Intersection Types
SEPARATED BIKE LANE
SIDEPATH
References
Diverging Diamond Interchange (DDI)
Diverging Diamond Interchanges (DDIs) are characterized by crossover intersections at the ramp termini where cross-street traffic crosses over to the left-hand side of the roadway between the ramps to allow unopposed left turns to and from the ramps. DDIs are used in situations with grade-separated interchanges.
Design Features
Benefits
Intersection Types
SEPARATED BIKE LANE (OUTER)
SEPARATED BIKE LANE (INNER)
SIDEPATH
References

Safe System for Intersections (SSI) Framework

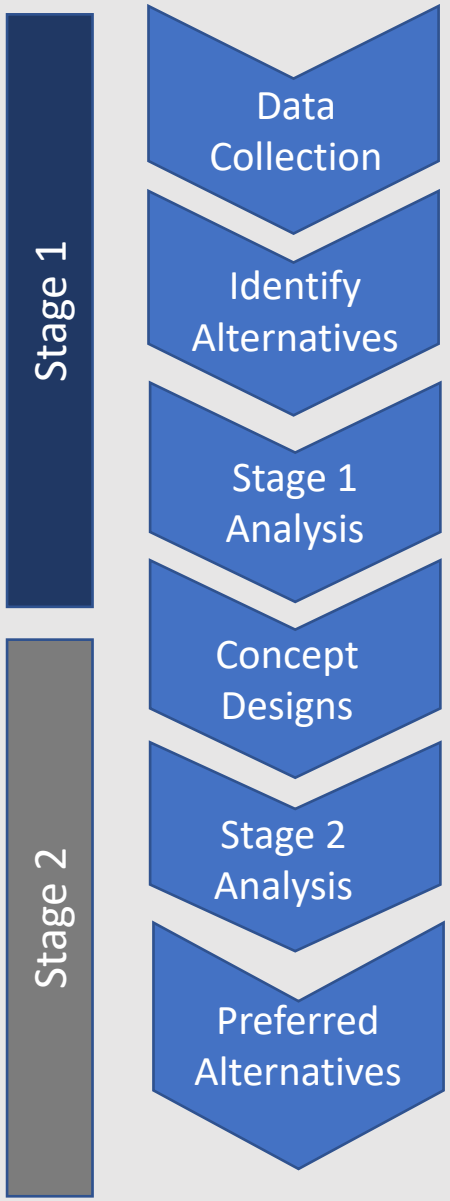
Objectives:

- 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

Intersection control evaluation (ICE)



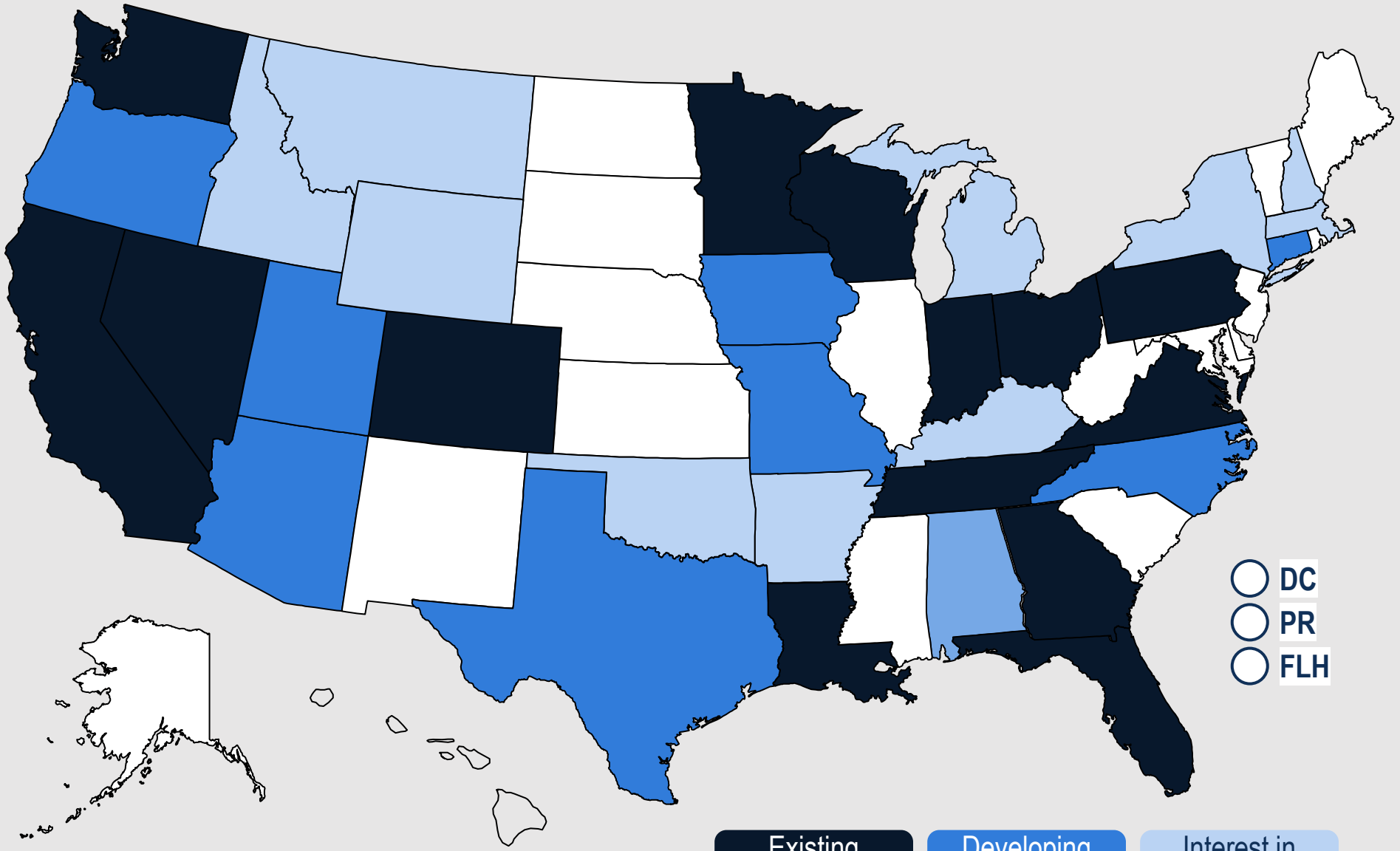
Stage I is a scoping stage

- 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

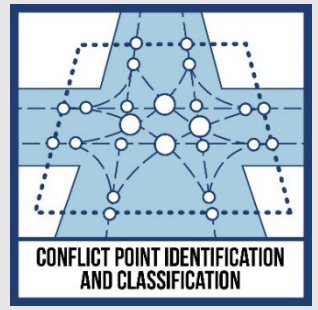
ICE Policies & Guidance - 2024



SSI Method Overview

1. Conflict point identification and classification

Crossing, merging, diverging, nonmotorized



2. Conflict point exposure

Volumes (vehicular and nonmotorized)

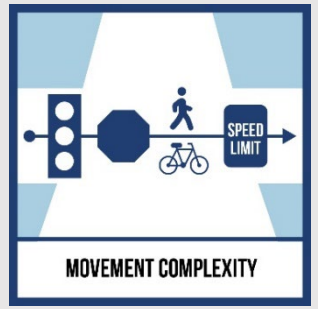
3. Conflict point severity (probability of FSI)

Vehicle-vehicle: speeds and conflict angles

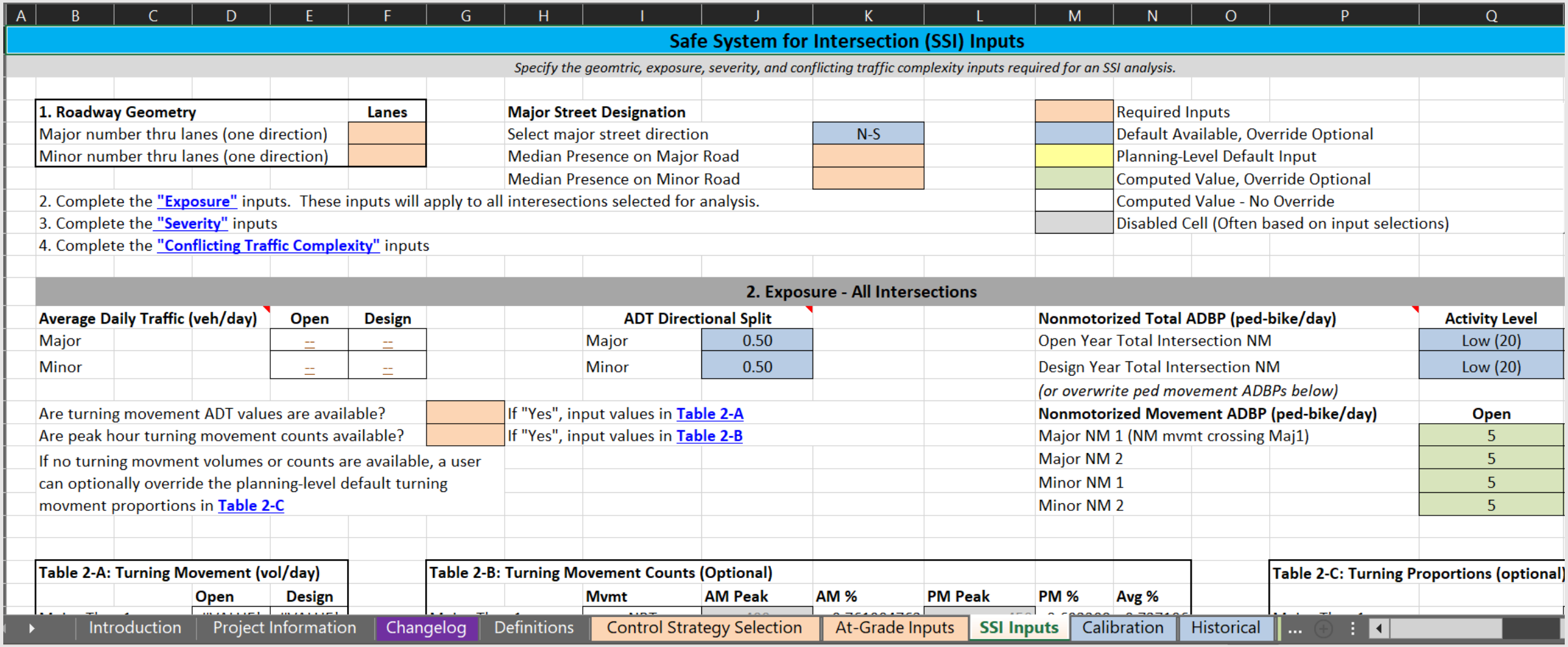
Nonmotorized: speeds

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)	

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

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

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

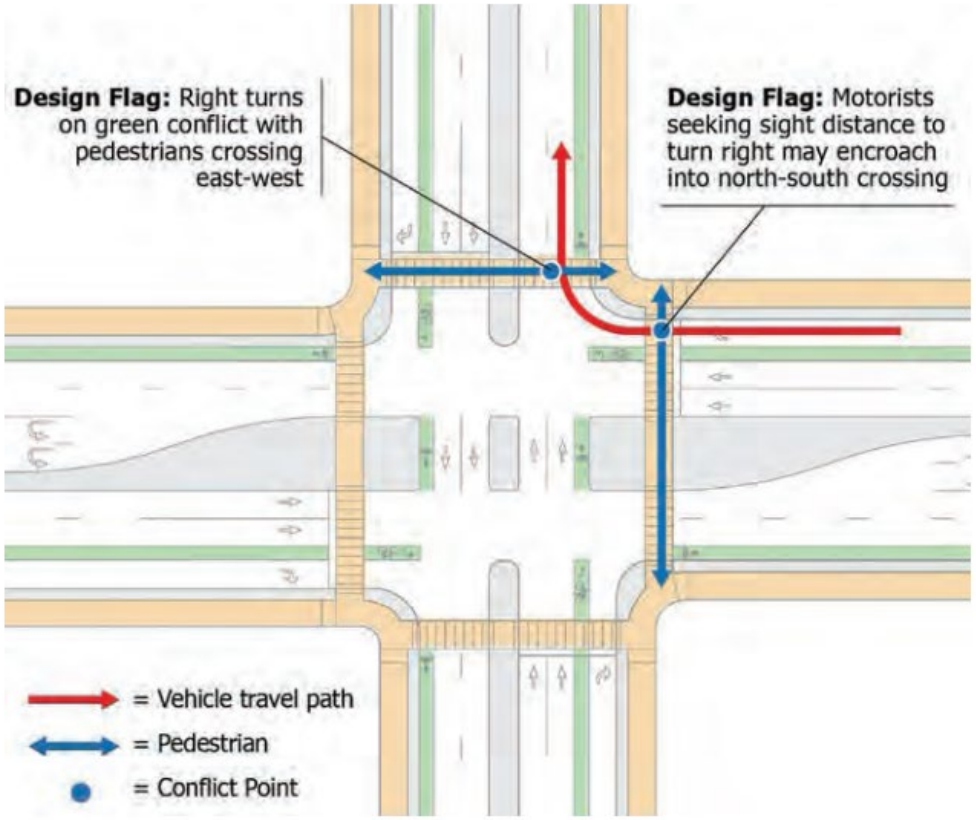


Exhibit 4-9. Design Flag 1 – Motor vehicle right-turns.

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

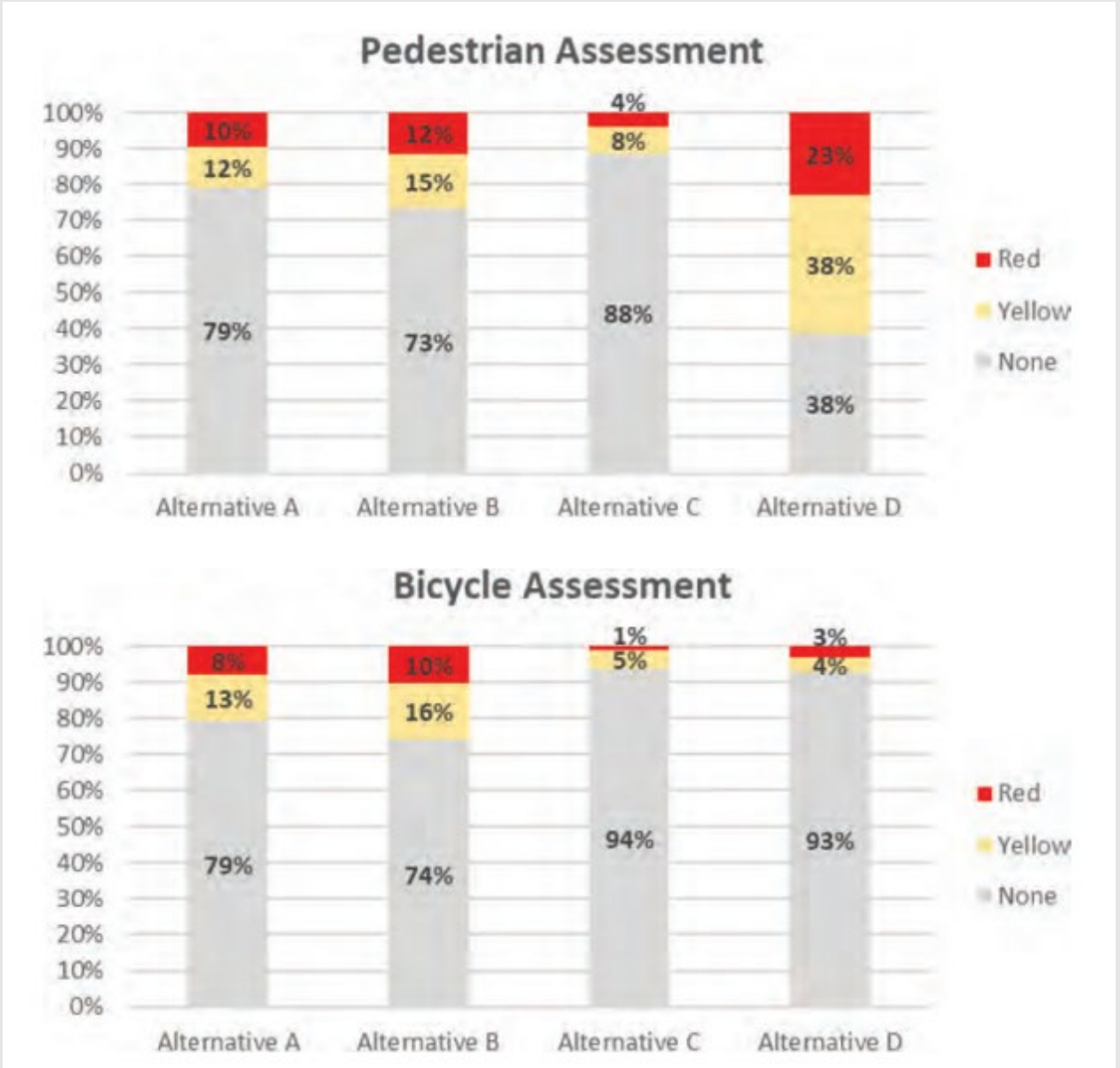
Exhibit 4-5. Summary of design flags pedestrian and bicycle assessment.

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

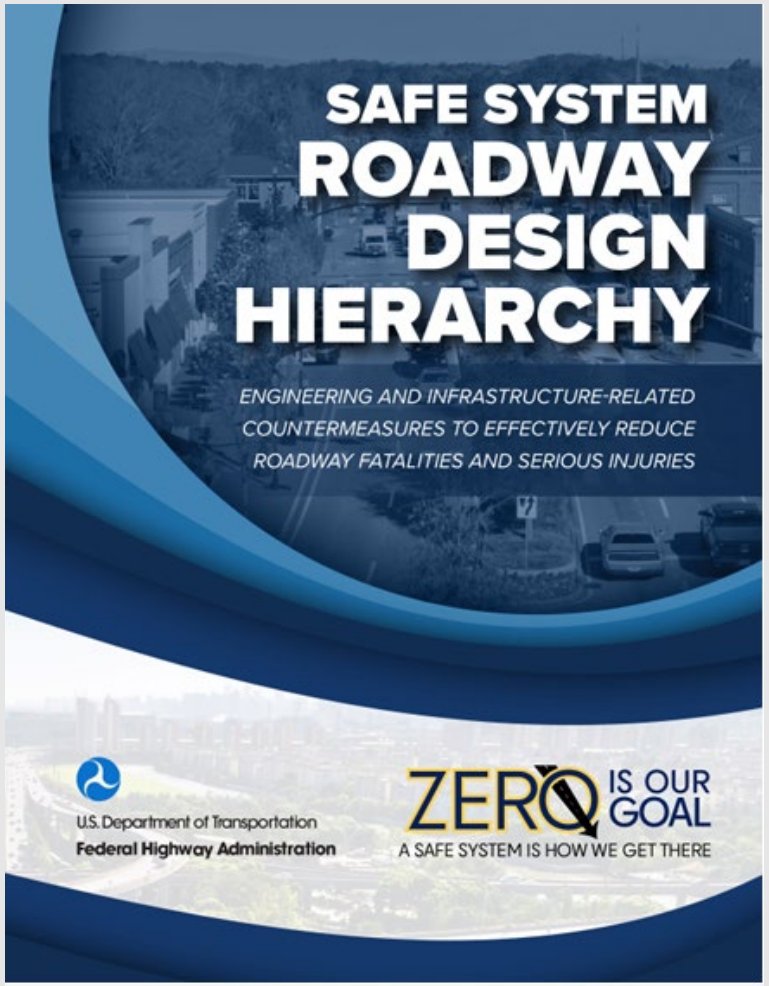
Source: NCHRP 948

20 Flags

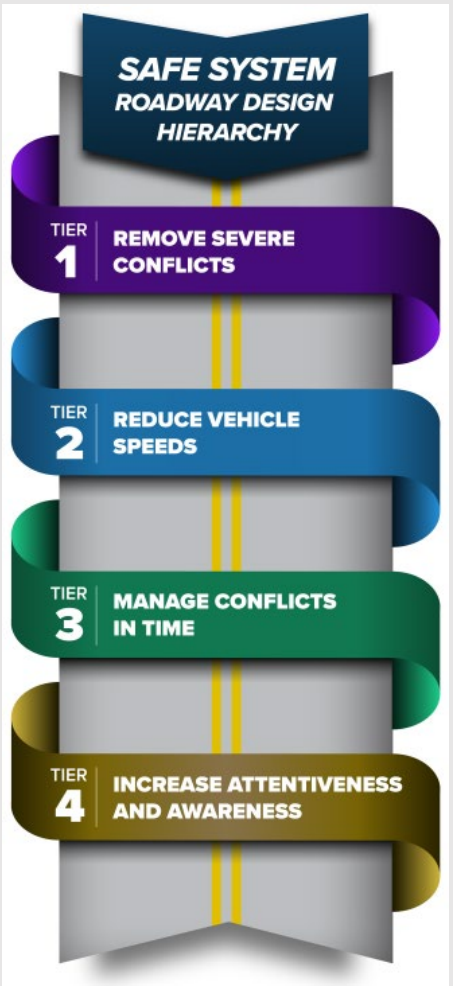


Source: NCHRP 948

Safe System Roadway Design Hierarchy



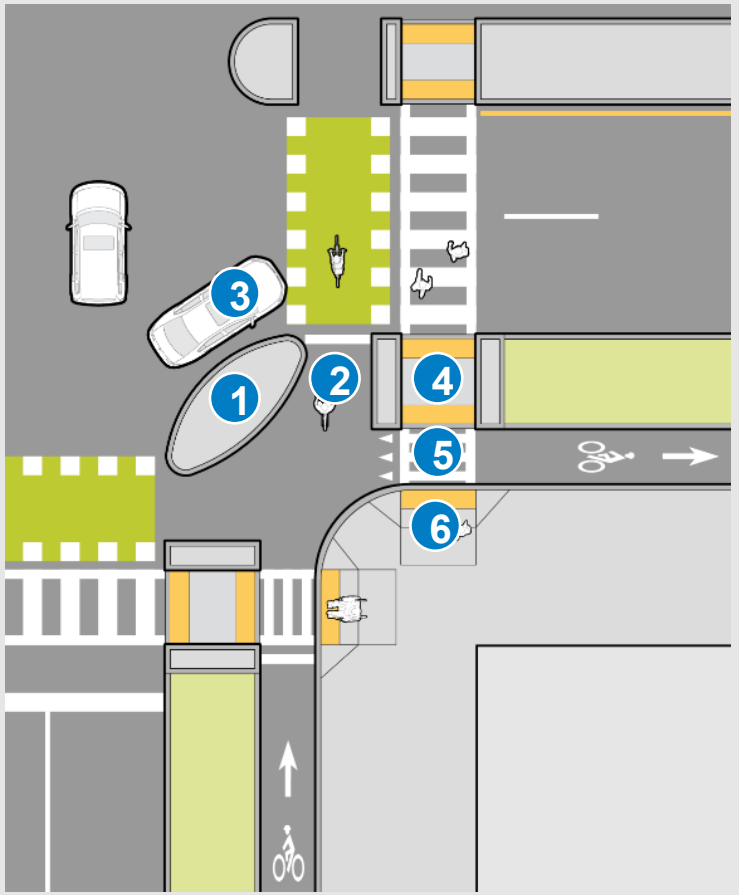
"The purpose of the hierarchy is to help transportation agencies and practitioners identify and prioritize countermeasures and strategies when developing transportation projects."



TIER 1 REMOVE SEVERE CONFLICTS

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

TIER 1 REMOVE SEVERE CONFLICTS

Protected Intersections

Salt Lake City, UT

photo source: WBUR

Chicago, IL

photo source: Streetsblog

Austin, TX

photo source: Google

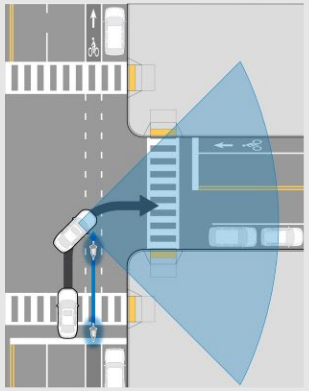
Davis, CA

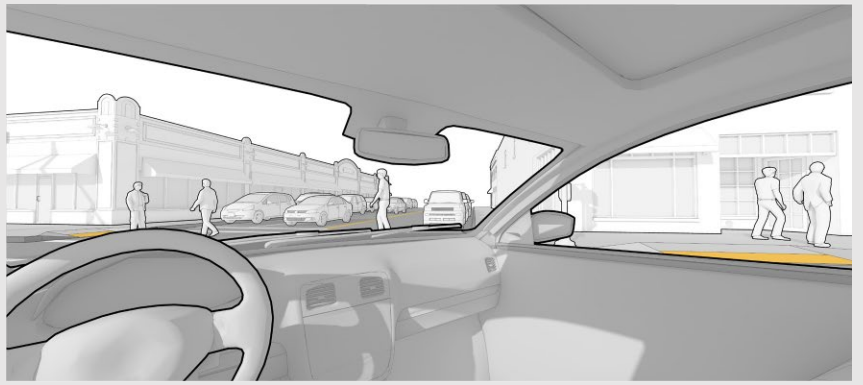
photo source: People for Bikes

TIER 1 REMOVE SEVERE CONFLICTS

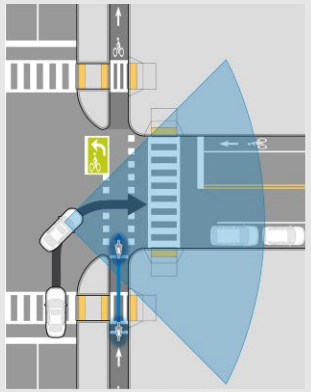
Visibility at Conflict Points

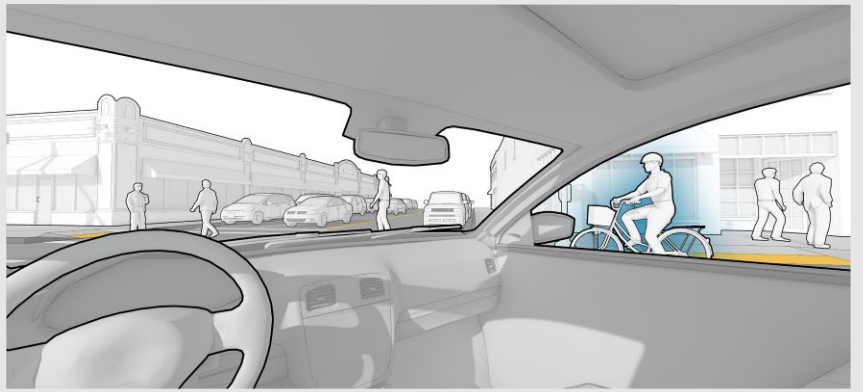
motorist's view at conventional bike lane





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





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TIER 1 REMOVE SEVERE CONFLICTS

Visibility at Conflict Points

protected intersection

photo source: Jonathan Maus

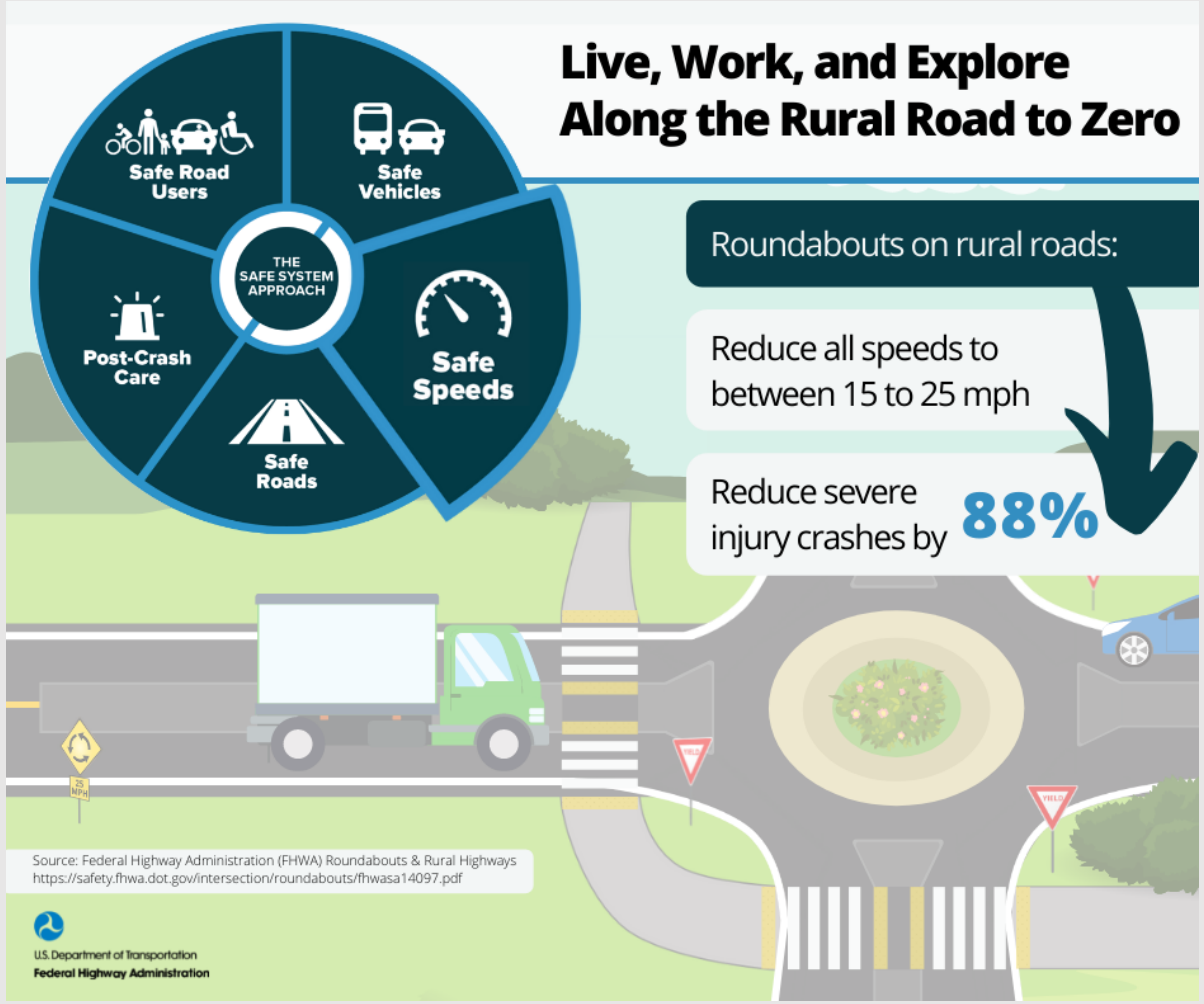
conventional bike lane

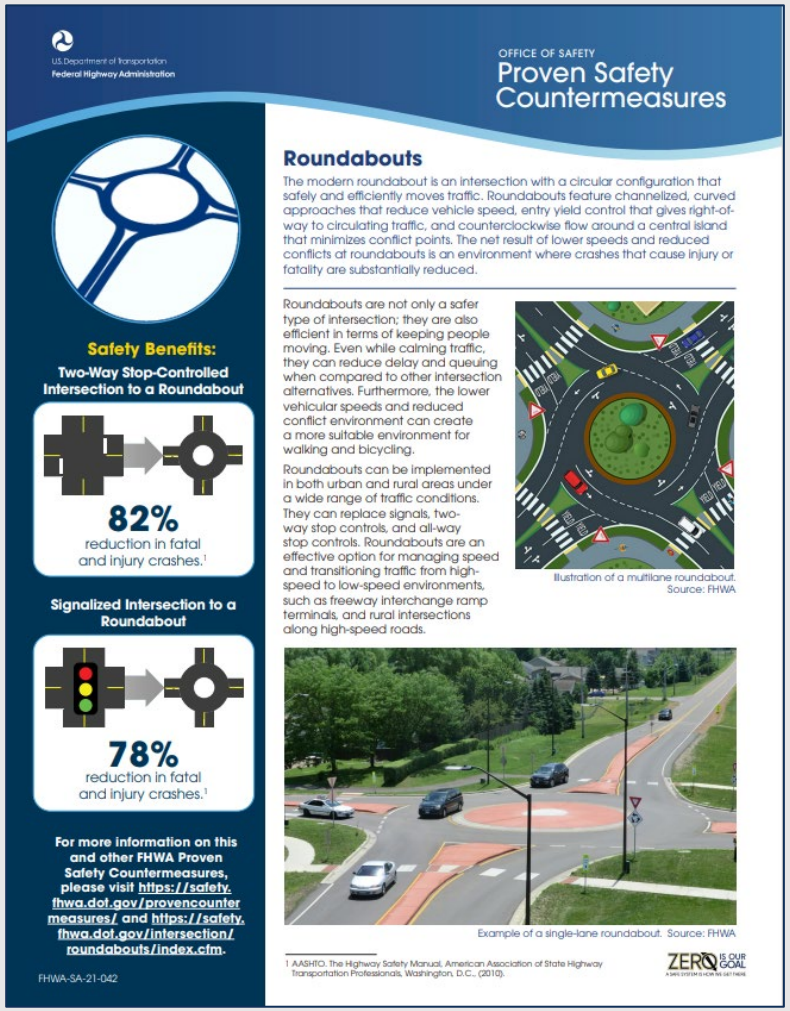
- Yielding increased from 34% to 38%
- Right-turn speeds reduced 2.6 mph

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

TIER 2 | REDUCE VEHICLE SPEEDS

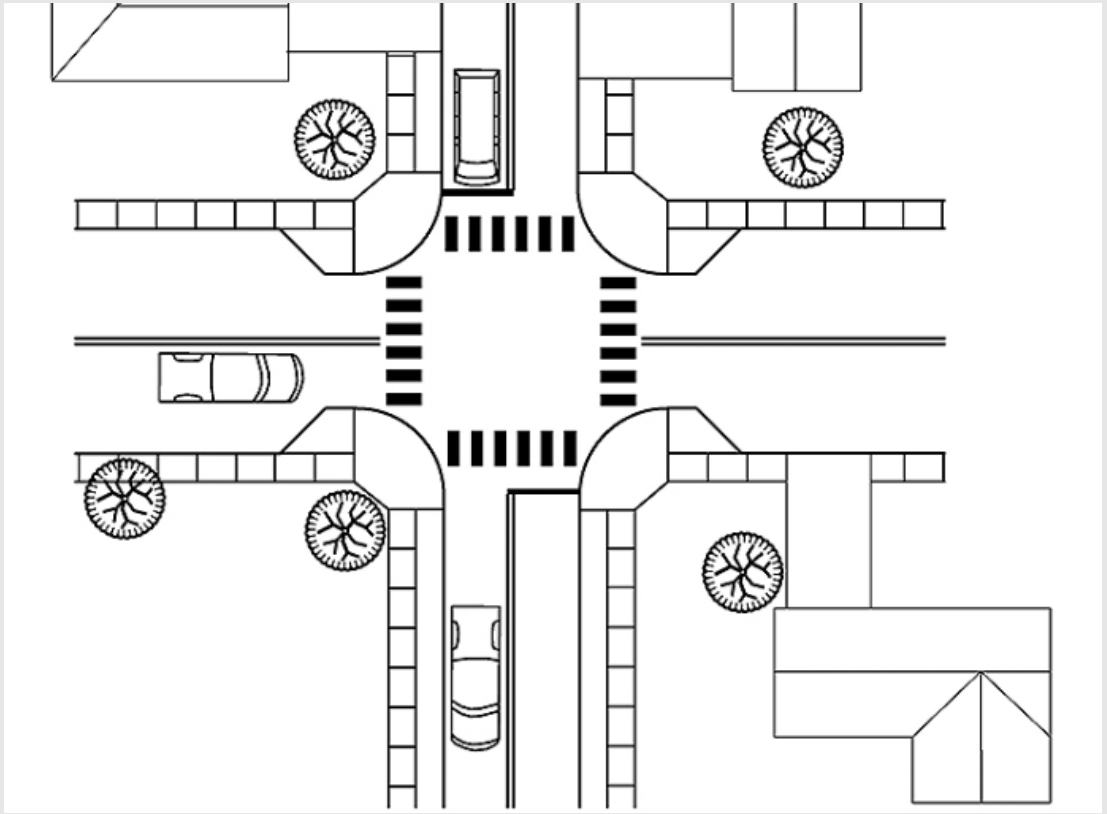
Roundabouts Save Lives!





TIER 2 | REDUCE VEHICLE SPEEDS

Corner Extensions



Source: Delaware DOT

Source: Hillary Orr

TIER 3 MANAGE CONFLICTS IN TIME

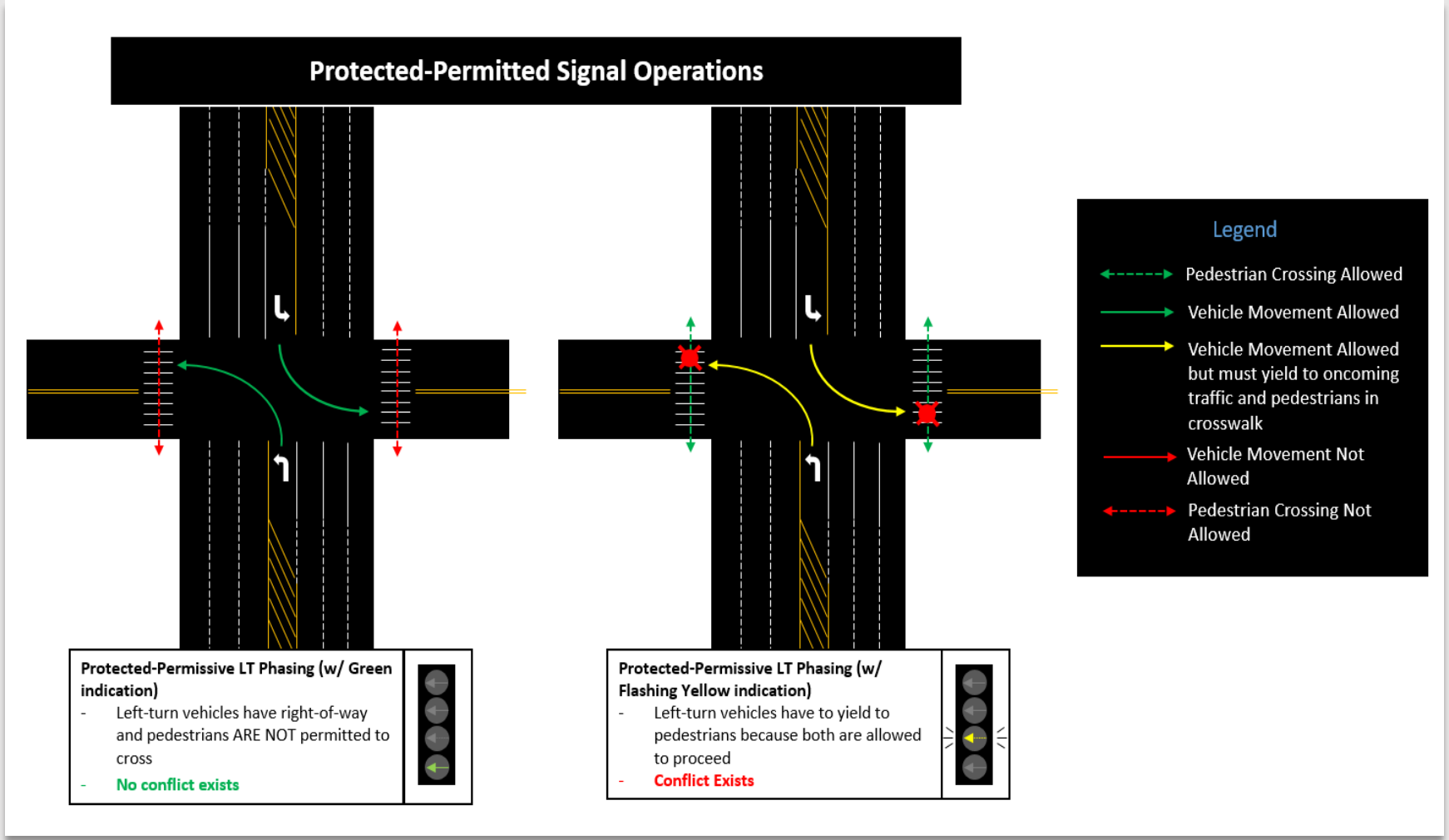
Leading Pedestrian Interval (LPI)

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

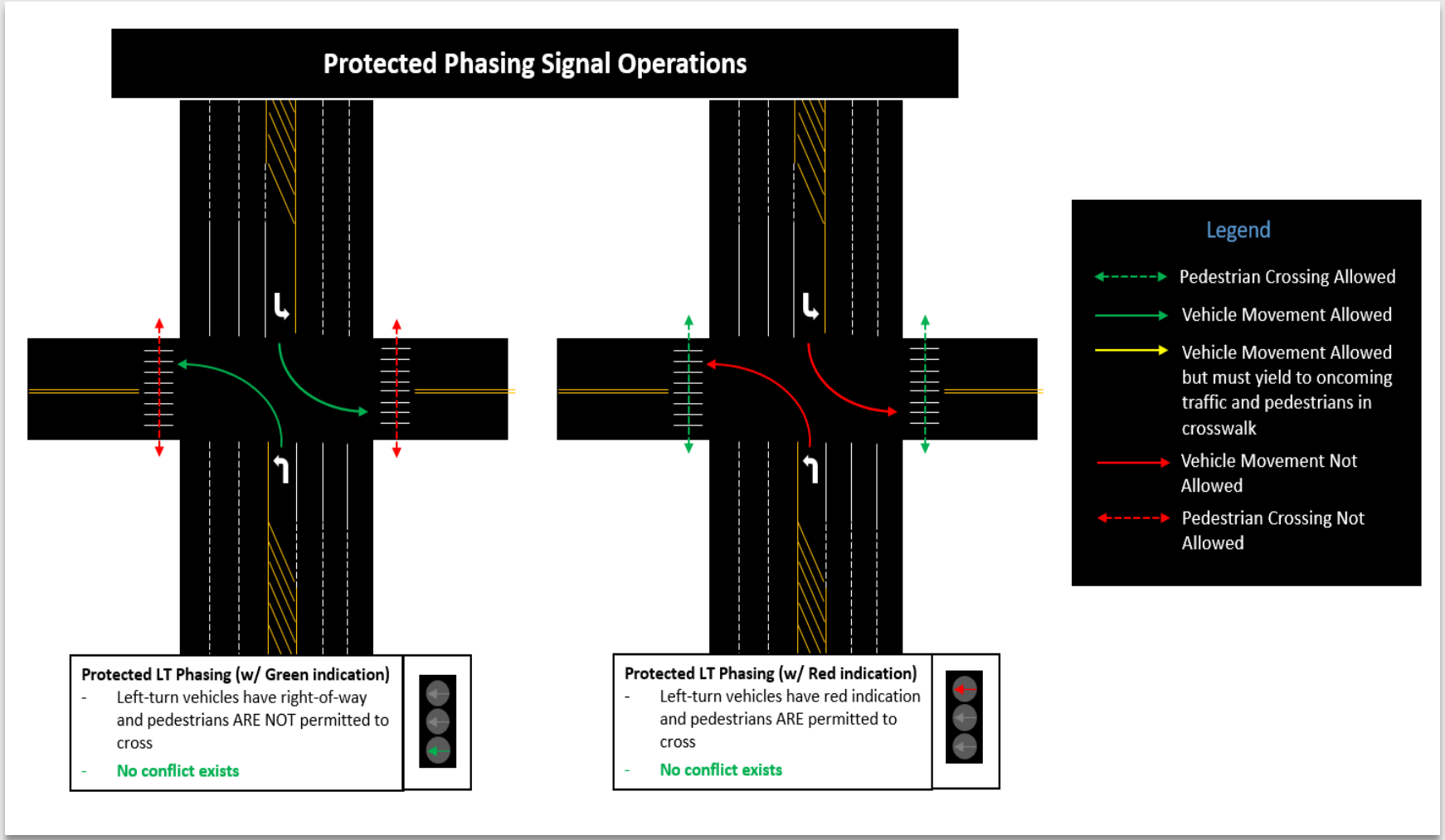
Manage Conflicts in Time



Source: FHWA.

TIER 3 MANAGE CONFLICTS IN TIME

Manage Conflicts in Time



Source: FHWA.

TIER 3 MANAGE CONFLICTS IN TIME

Pedestrians vs Permissive Lefts

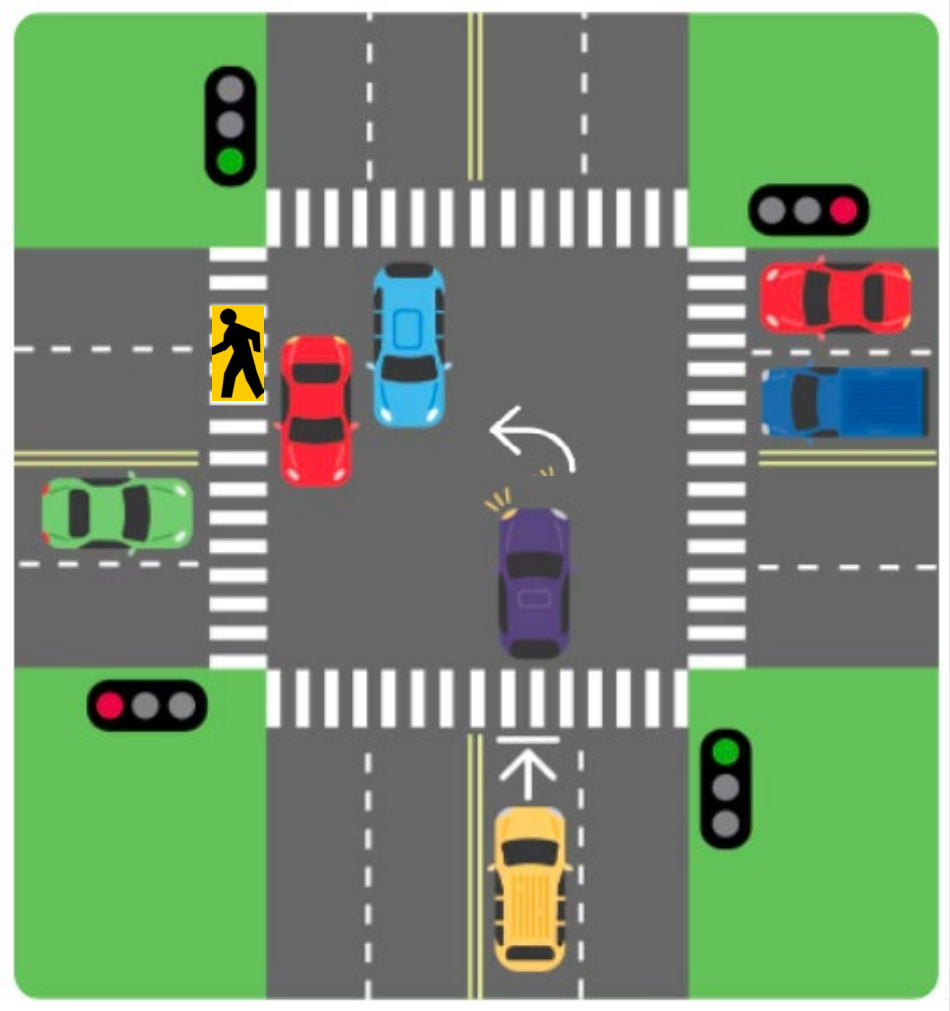
Source: FHWA.

- 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.

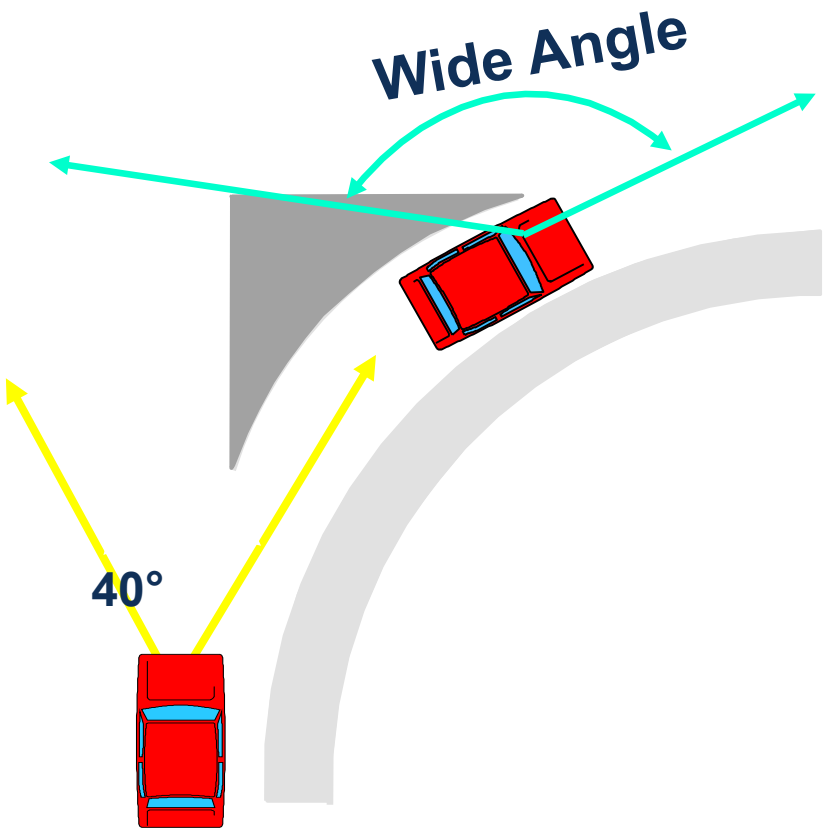
Protected Only Left Turn Signals

Consider:

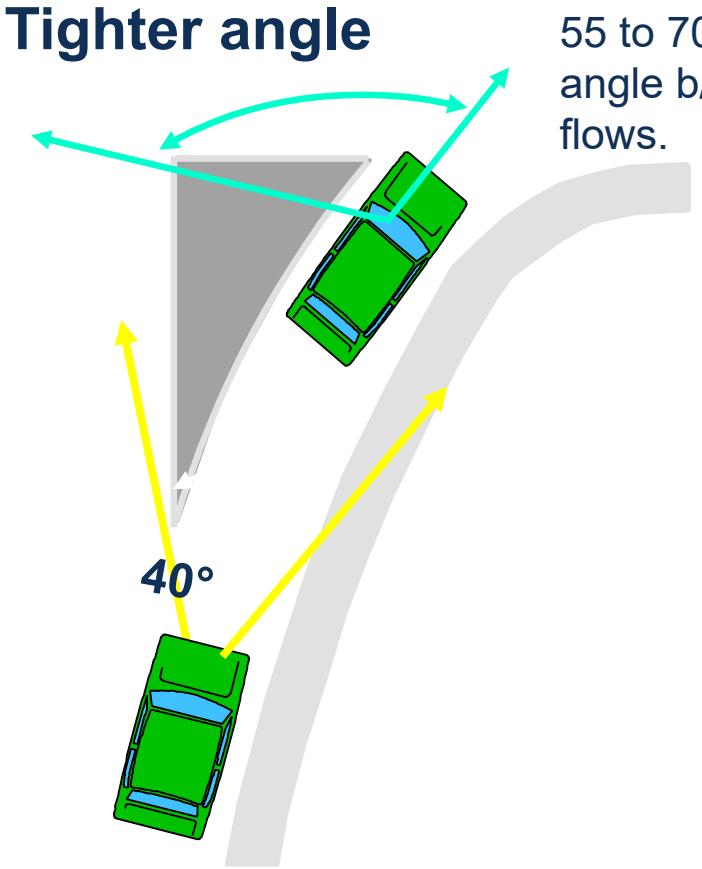
- Protected only left turn signal phasing; or
- Flashing Yellow Arrow to omit permissive movement when there is a pedestrian call



Right-Turn Slip Lanes: Design for Pedestrians

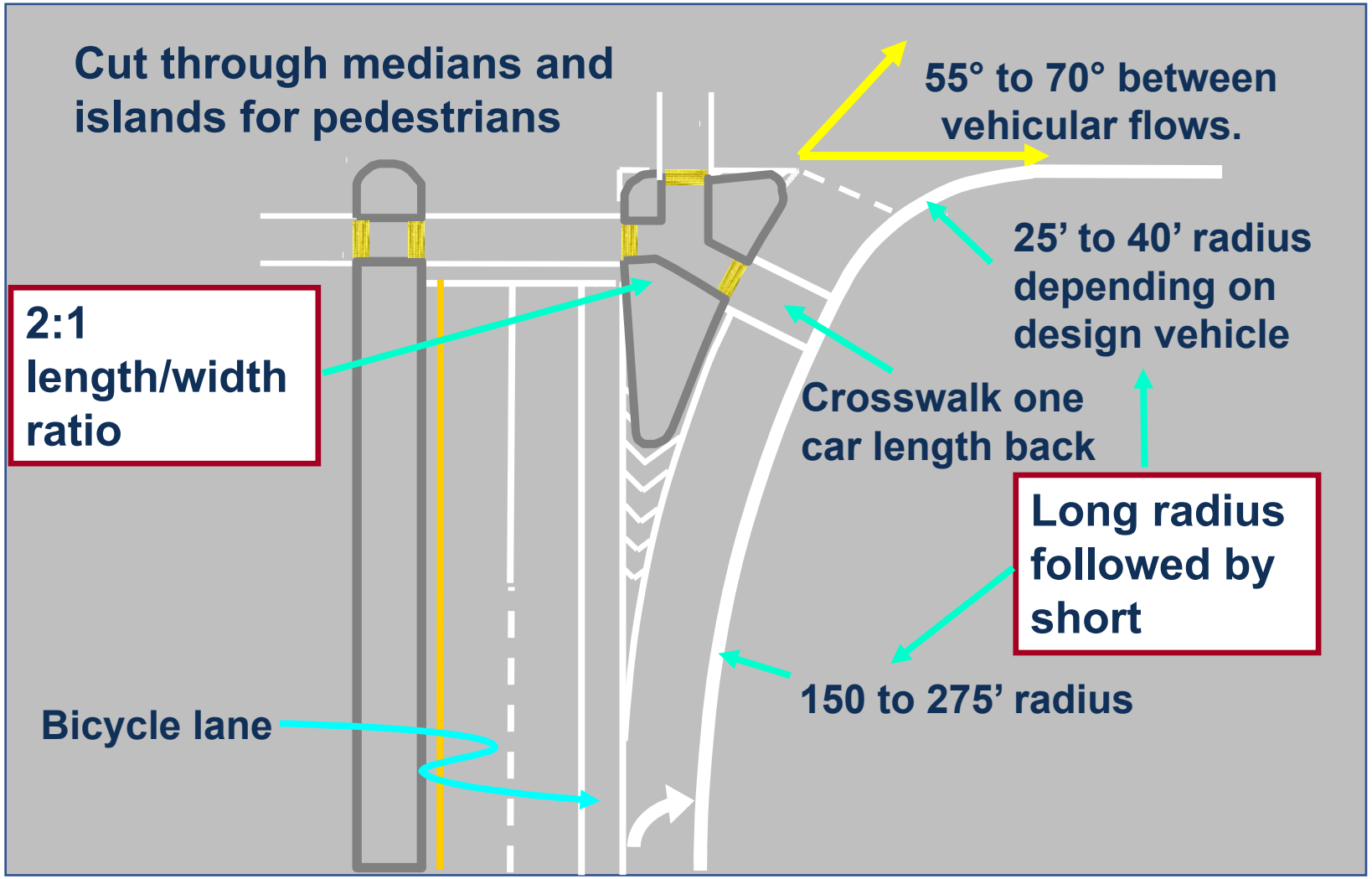


High speed, head turner = low visibility of pedestrians



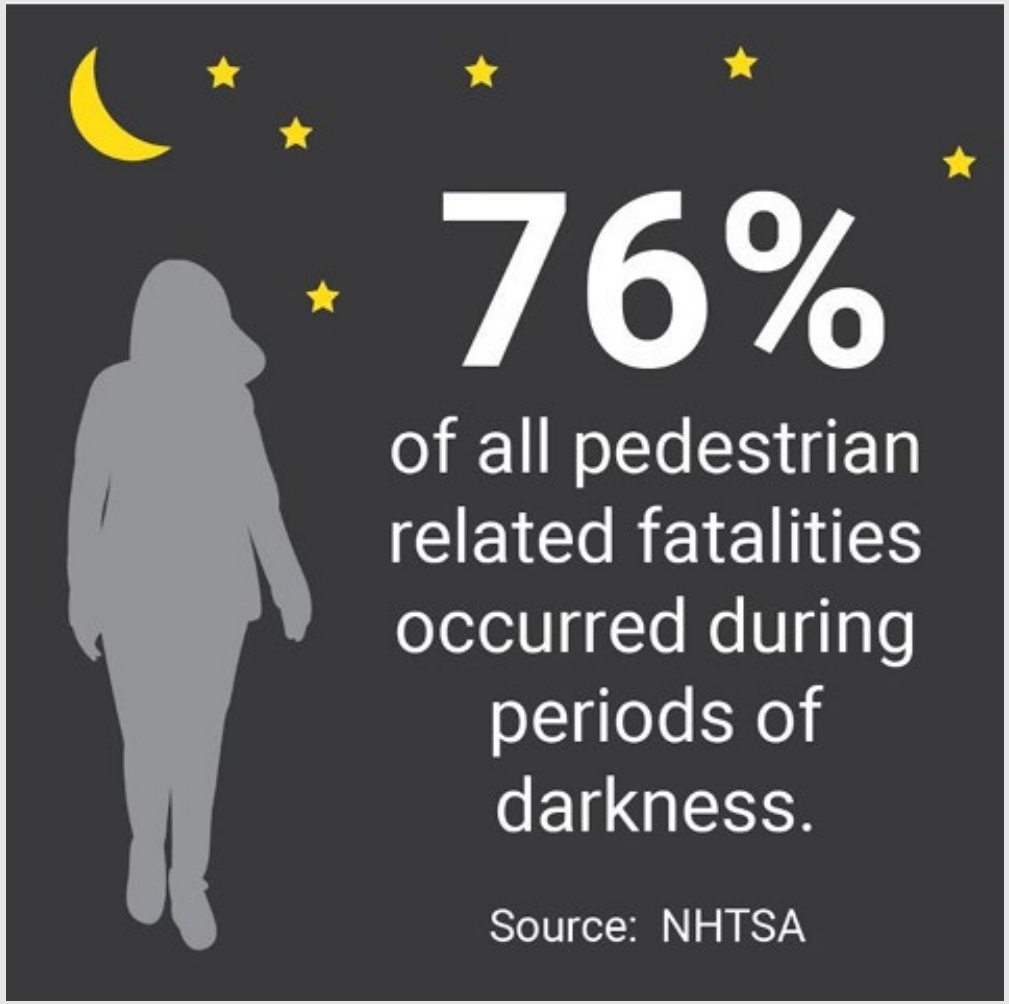
Slow speed, good angle = good visibility of pedestrians

Right-Turn Slip Lanes: Design for Pedestrians



TIER 4 INCREASE ATTENTIVENESS AND AWARENESS

Nighttime Visibility



Contact Us

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