Designing for Bicyclist Safety

Module C

INTERSECTION DESIGN TREATMENTS

LEARNING OUTCOMES

- Understand intersection design options and features
- Select appropriate design feature for a bikeway in a given context

KEY SAFETY FACTORS

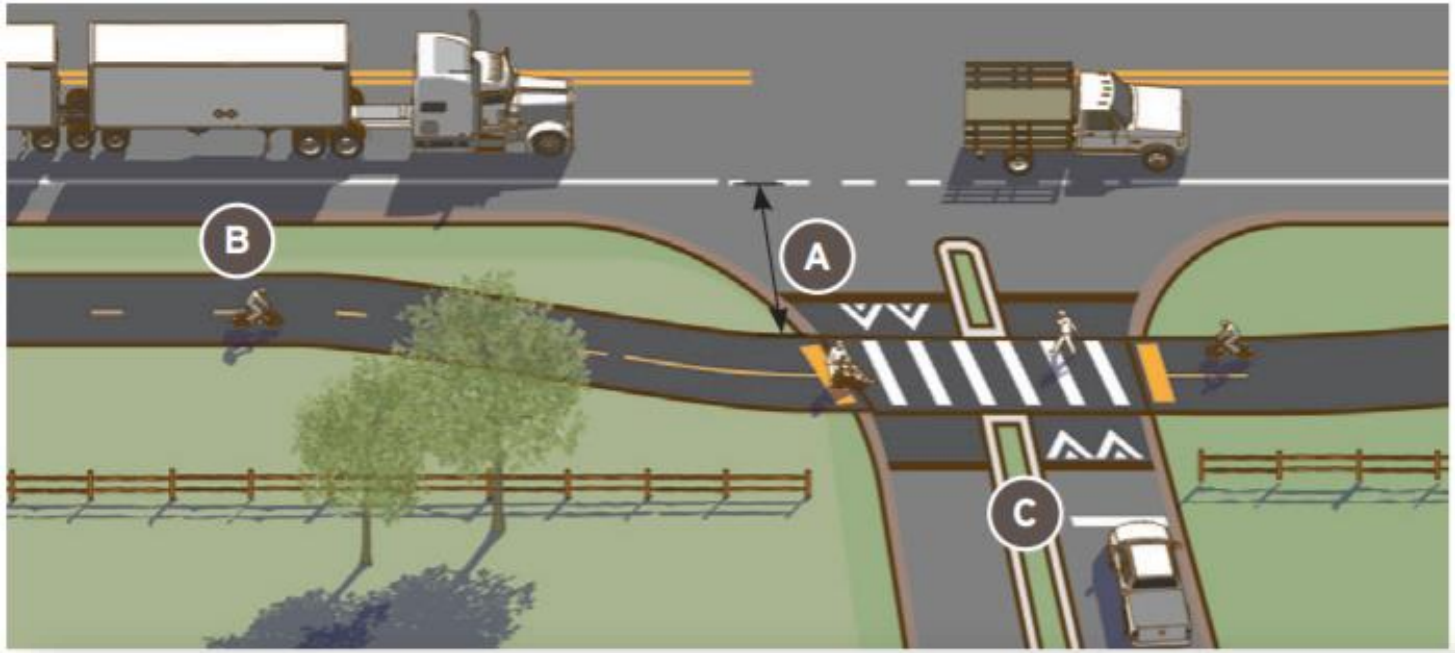
Important Message

- Speed
- Number of lanes
- Visibility
- Traffic volume & composition
- Conflict points
- Proximity
- Bike control
- Connectivity

Designing for Bicyclist Safety

SHARED-USE PATH CROSSINGS

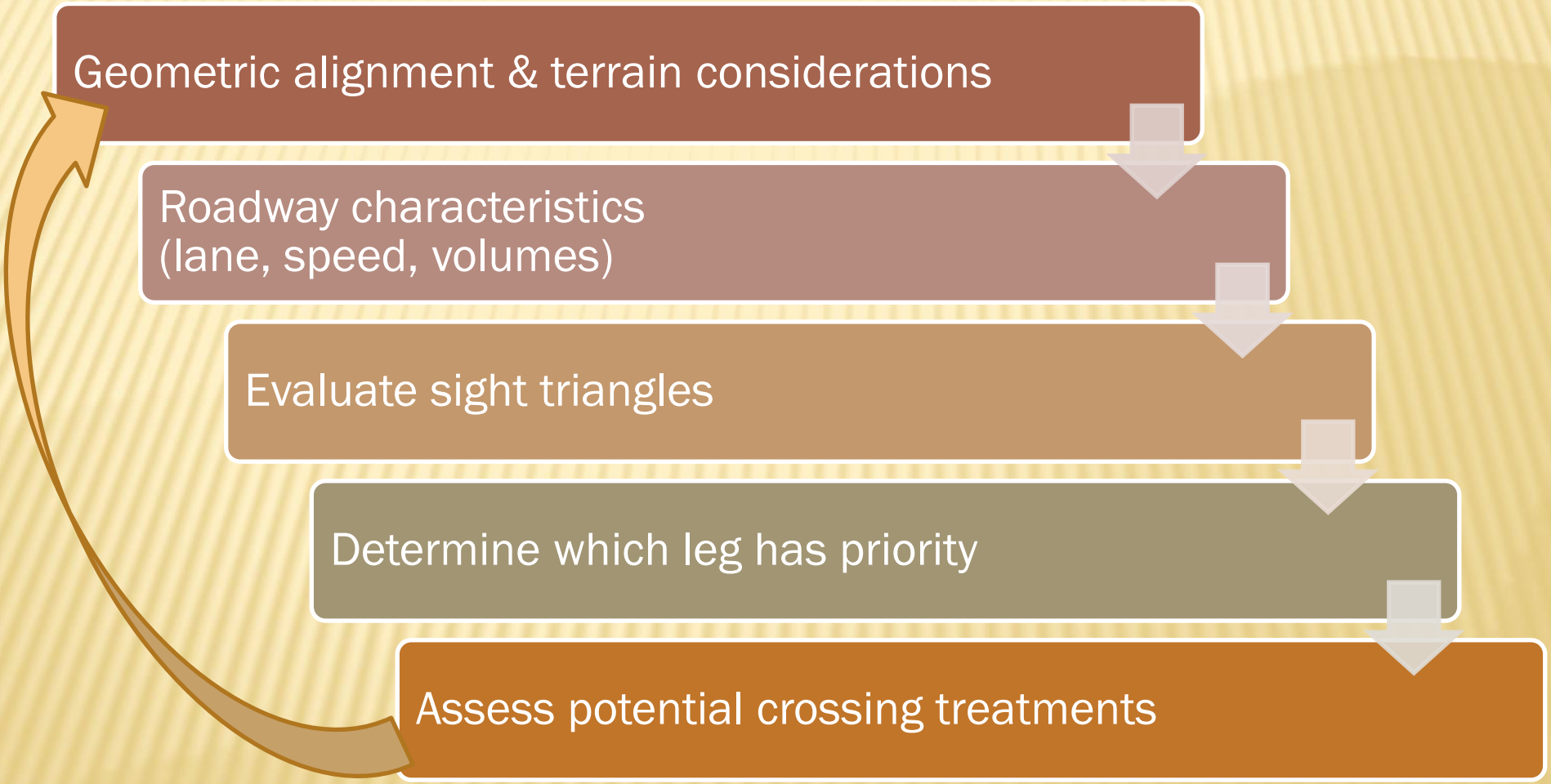
SIDE-STREET CROSSINGS



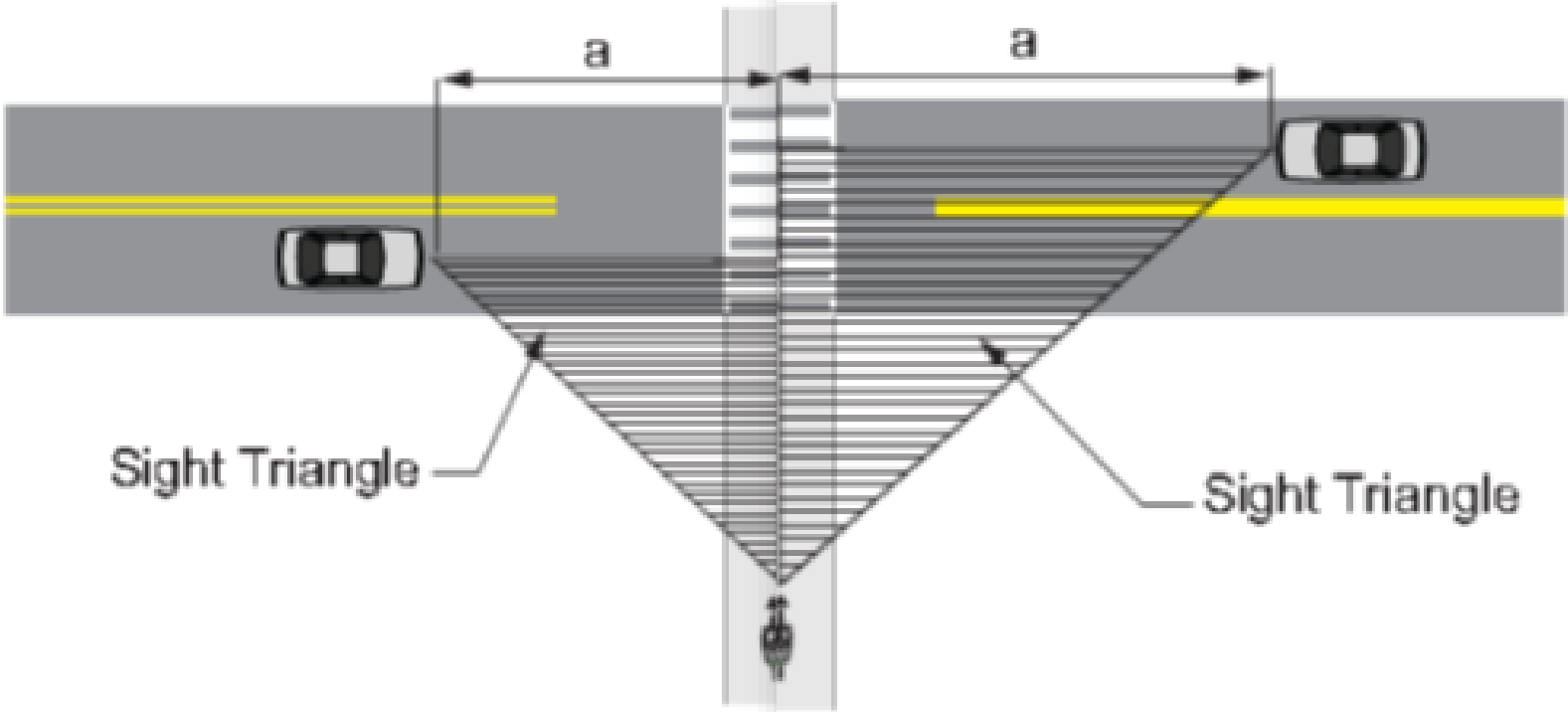
Adjacent Road Speed Limit (Mi/h)	Recommended Sidepath Separation Distance at Crossings
< 25 mi/h	6.5 ft (2.0 m)
35–45 mi/h	6.5–16.5 ft (2.0–5.0 m)
≥ 55 mi/h	16.5–24 ft (5.0–7.0 m)

**Separation distance may vary in response to available right of way, visibility constraints and the provision of a right turn deceleration lane.*

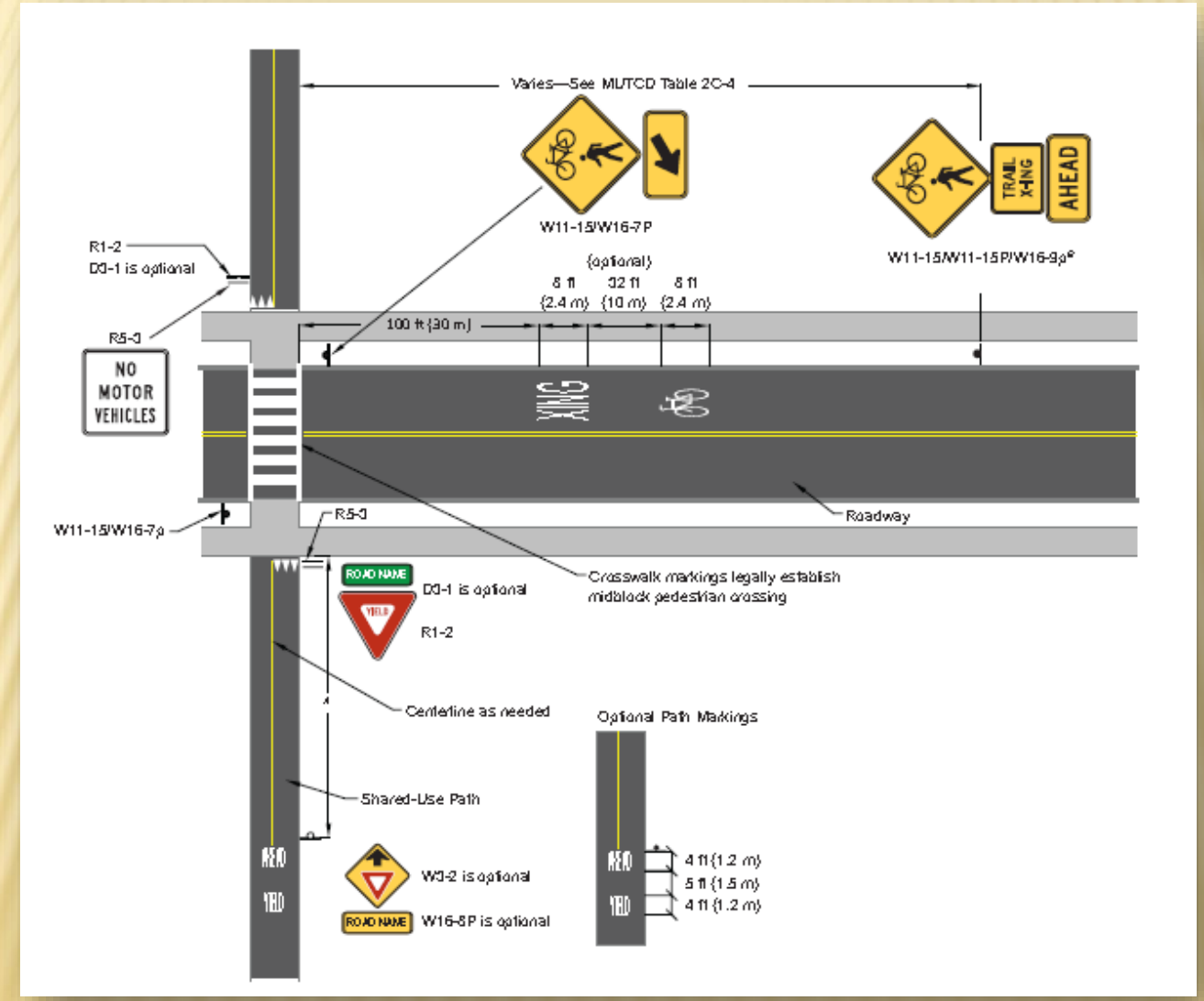
MID-BLOCK CROSSING DESIGN PROCESS



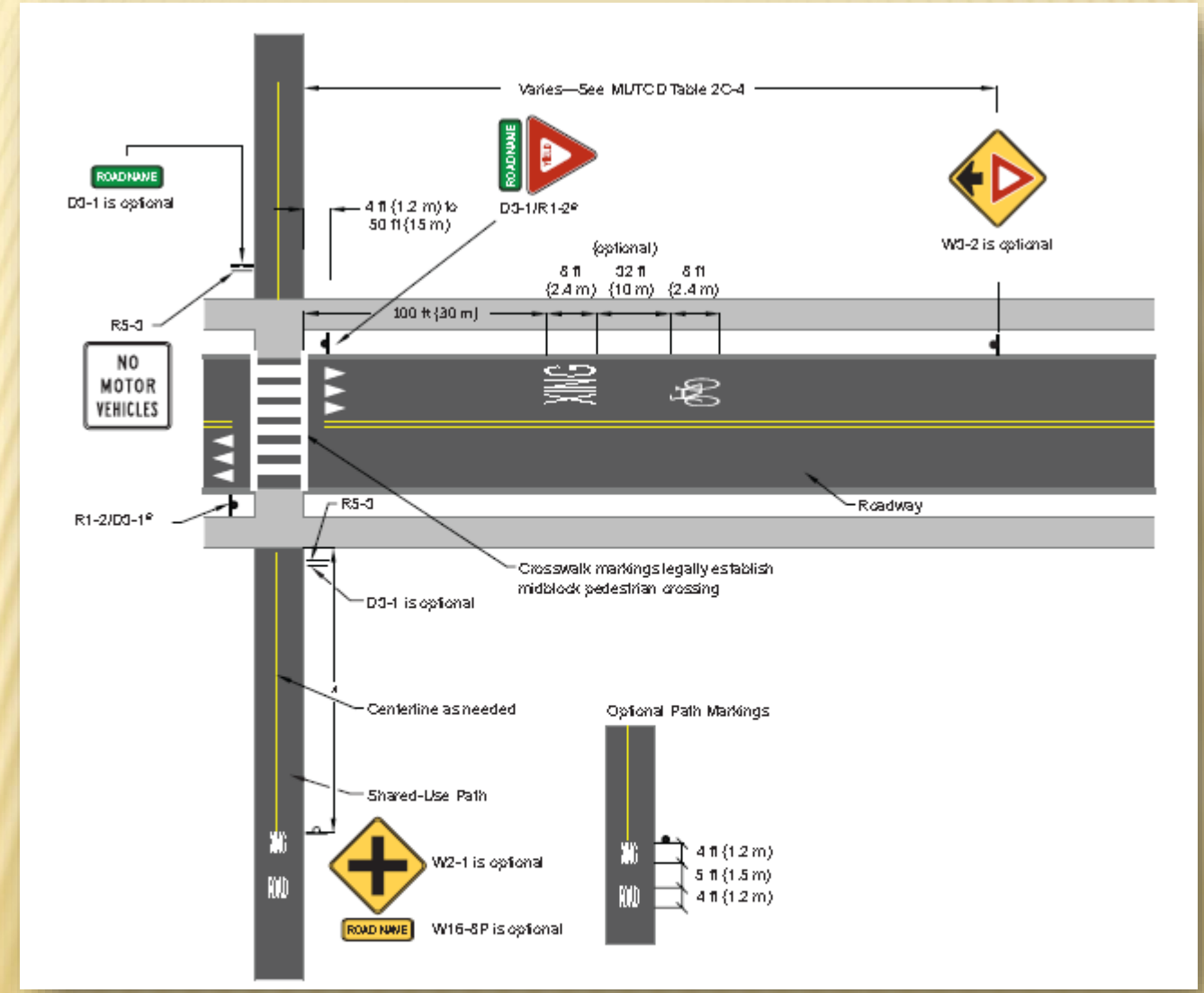
SIGHT TRIANGLES



PATH YIELDS TO ROADWAY



ROAD YIELDS TO PATHWAY

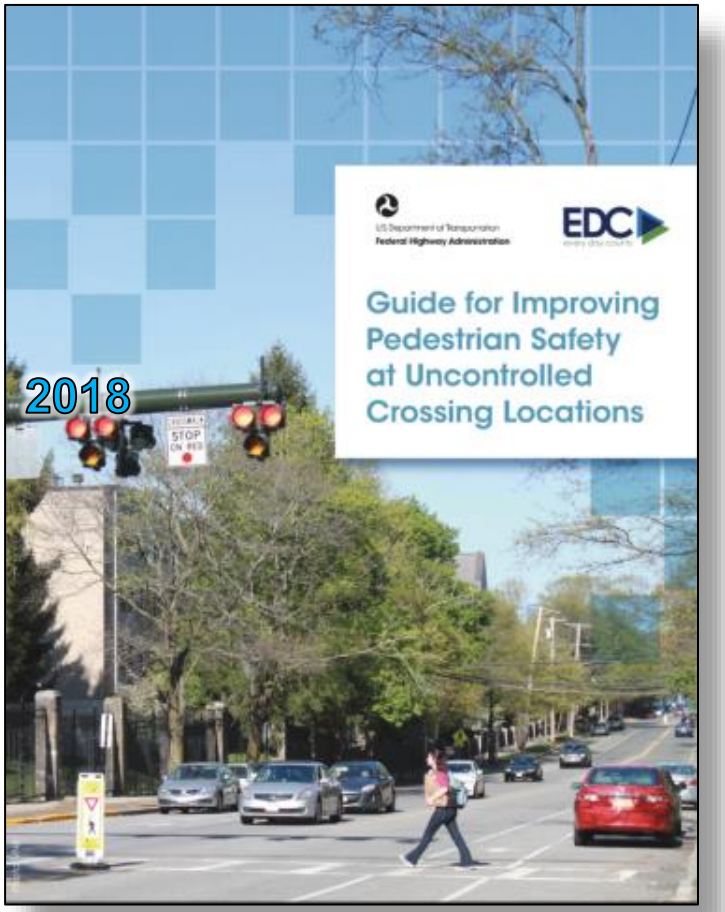


Crossing Countermeasures

- Advance warning signs
- Advance yield/stop line
- Raised island/crossing
- RRFB/PHB

Spectacular Seven

- Crosswalk Visibility Enhancements
- Raised Crosswalks
- Pedestrian Refuge Island
- RRFB
- PHB
- Road Diets
- LPI



https://safety.fhwa.dot.gov/ped_bike/step/docs/STEP_Guide_for_Improving_Ped_Safety_at_Unsig_Loc_3-2018_07_17-508compliant.pdf

Table 1. Application of pedestrian crash countermeasures by roadway feature.

Roadway Configuration	Posted Speed Limit and AADT								
	Vehicle AADT <9,000			Vehicle AADT 9,000–15,000			Vehicle AADT >15,000		
	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph
2 lanes (1 lane in each direction)	● 2 4 5 6	● 5 6 7 9	○ 5 6 ● 9	● 4 5 6	● 5 6 7 9	○ 5 6 ● 9	● 4 5 6 7 9	○ 5 6 7 9	○ 5 6 ● 9
3 lanes with raised median (1 lane in each direction)	● 2 3 4 5 7 9	● ● 5 7 9	○ ● 5 ● 9	○ 3 4 5 7 9	○ ● 5 ● 9	○ ● 5 ● 9	○ ● 4 5 7 9	○ ● 5 ● 9	○ ● 5 ● 9
3 lanes w/o raised median (1 lane in each direction with a two-way left-turn lane)	● 2 3 4 5 6 7 9	● ● 5 6 7 9	○ ● 5 6 ● 9	○ 3 4 5 6 7 9	○ ● 5 6 ● 9	○ ● 5 6 ● 9	○ ● 4 5 6 7 9	○ ● 5 6 ● 9	○ ● 5 6 ● 9
4+ lanes with raised median (2 or more lanes in each direction)	● ● 5 7 8 9	● ● 5 7 8 9	○ ● 5 8 ● 9	○ ● 5 7 8 9	○ ● 5 ● 8 9	○ ● 5 8 ● 9	○ ● 5 ● 7 8 9	○ ● 5 8 ● 9	○ ● 5 8 ● 9
4+ lanes w/o raised median (2 or more lanes in each direction)	● ● 5 6 7 8 9	○ ● 5 ● 6 7 8 9	○ ● 5 6 8 ● 9	○ ● 5 ● 6 7 8 9	○ ● 5 6 ● 8 9	○ ● 5 6 8 ● 9	○ ● 5 6 ● 7 8 9	○ ● 5 6 8 ● 9	○ ● 5 6 8 ● 9

Given the set of conditions in a cell,

- # Signifies that the countermeasure is a candidate treatment at a marked uncontrolled crossing location.
- ● Signifies that the countermeasure should always be considered, but not mandated or required, based upon engineering judgment at a marked uncontrolled crossing location.
- ○ Signifies that crosswalk visibility enhancements should always occur in conjunction with other identified countermeasures.*

The absence of a number signifies that the countermeasure is generally not an appropriate treatment, but exceptions may be considered following engineering judgment.

1 High-visibility crosswalk markings, parking restrictions on crosswalk approach, adequate nighttime lighting levels, and crossing warning sign
2 Raised crosswalk
3 Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line
4 In-Street Pedestrian Crossing sign
5 Curb extension
6 Pedestrian refuge island
7 Rectangular Rapid-Flashing Beacon (RRFB)**
8 Road Diet
9 Pedestrian Hybrid Beacon (PHB)**

*Refer to Chapter 4, 'Using Table 1 and Table 2 to Select Countermeasures,' for more information about using multiple countermeasures.
**The PHB and RRFB are not both installed at the same crossing location.


TRAIL X-ING
Burke-Gilman Trail
BUMP
BIKE SALE

BIKE “HAWK” PHB

- First installation Tucson, AZ
- “BIKES WAIT”/”BIKES OK”

Designing for Bicyclist Safety

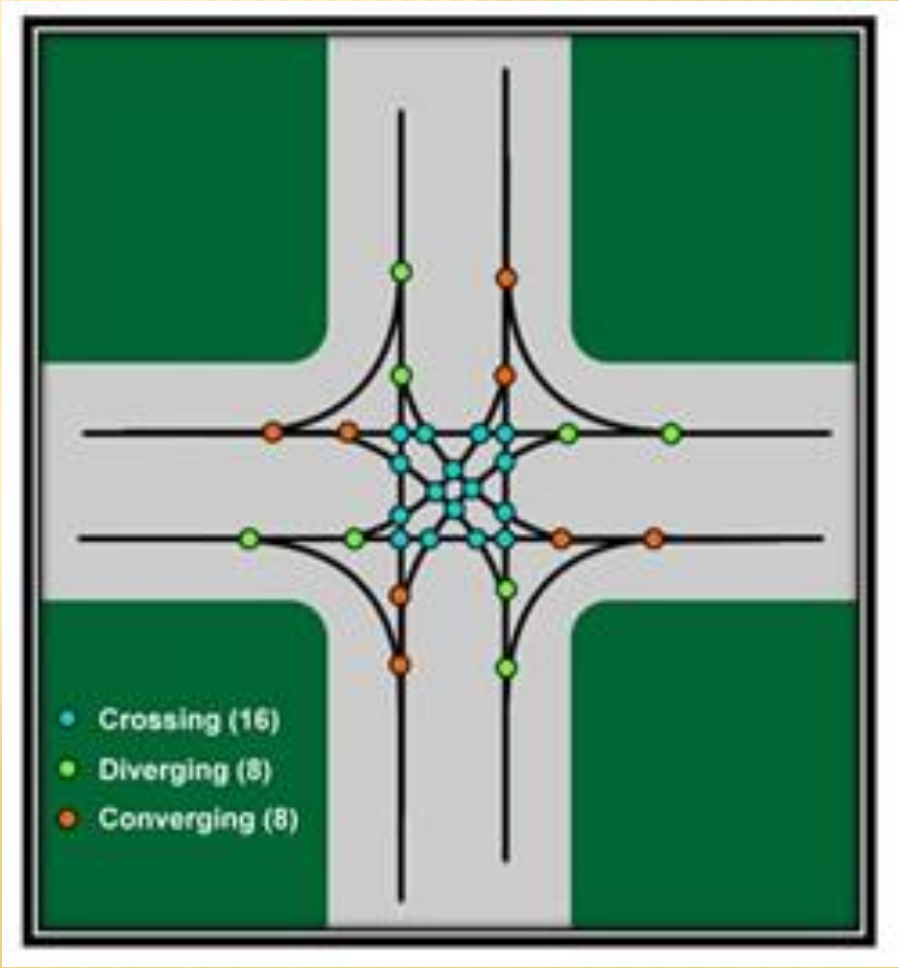
INTERSECTION DESIGN

INTERSECTION DESIGN PRINCIPLES

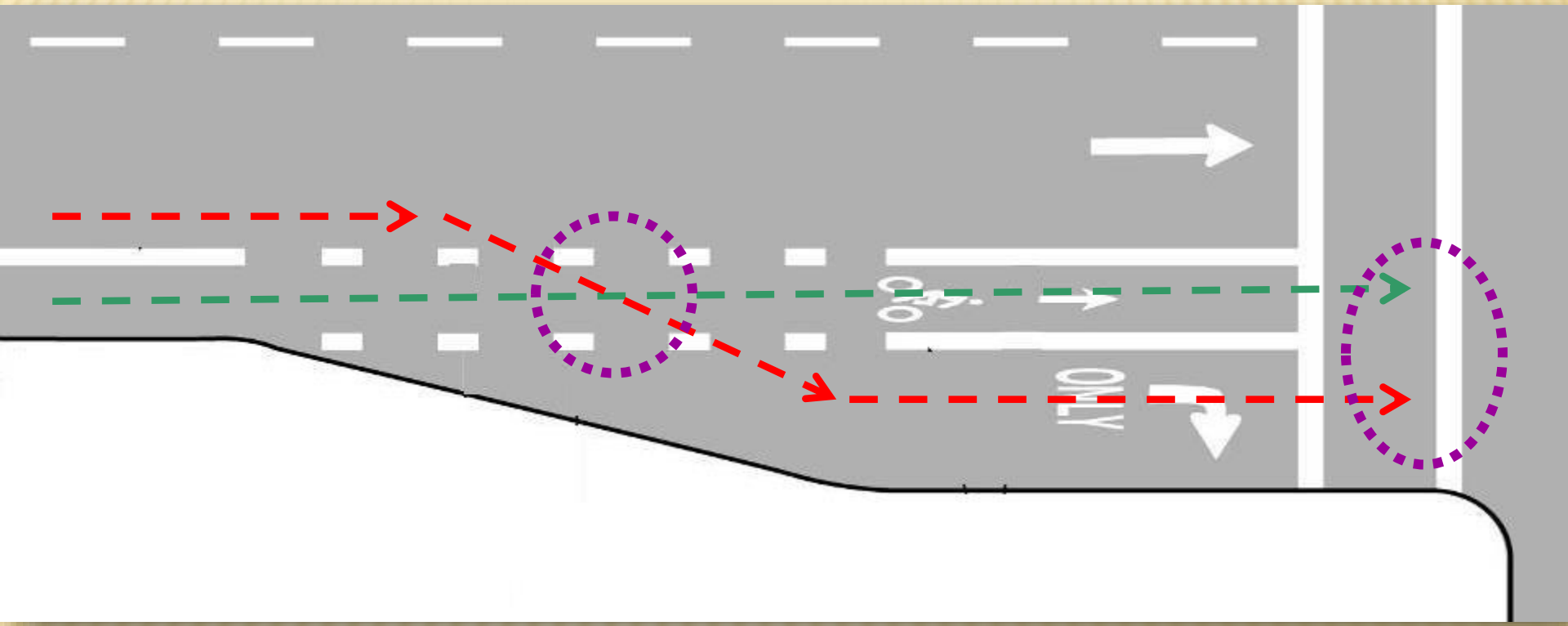
- Reduce speed
- Minimize exposure to conflicts
- Communicate right-of-way priority
- Provide adequate sight distance

INTERSECTION CONFLICTS

- Typical conflicts for both pedestrians and motorists, plus:
  - Right-turn/thru movement
  - Weaving to left turn



RIGHT-TURN/THRU CONFLICT



WOULD YOU DARE?

WOULD YOU DARE?

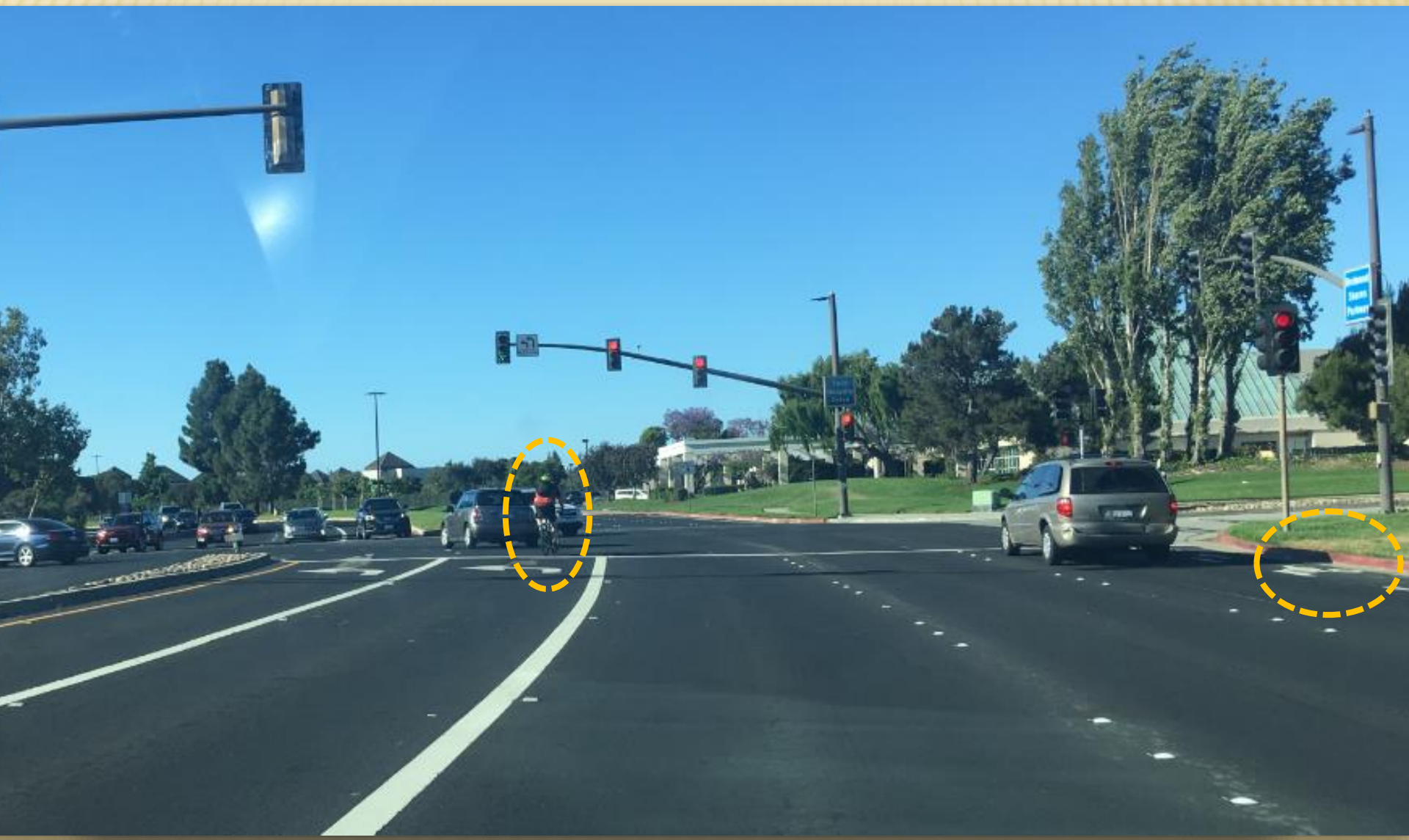
WOULD YOU DARE?

WOULD YOU DARE?

WOULD YOU DARE?

LEFT-TURN CONFLICT

WOULD YOU DARE?

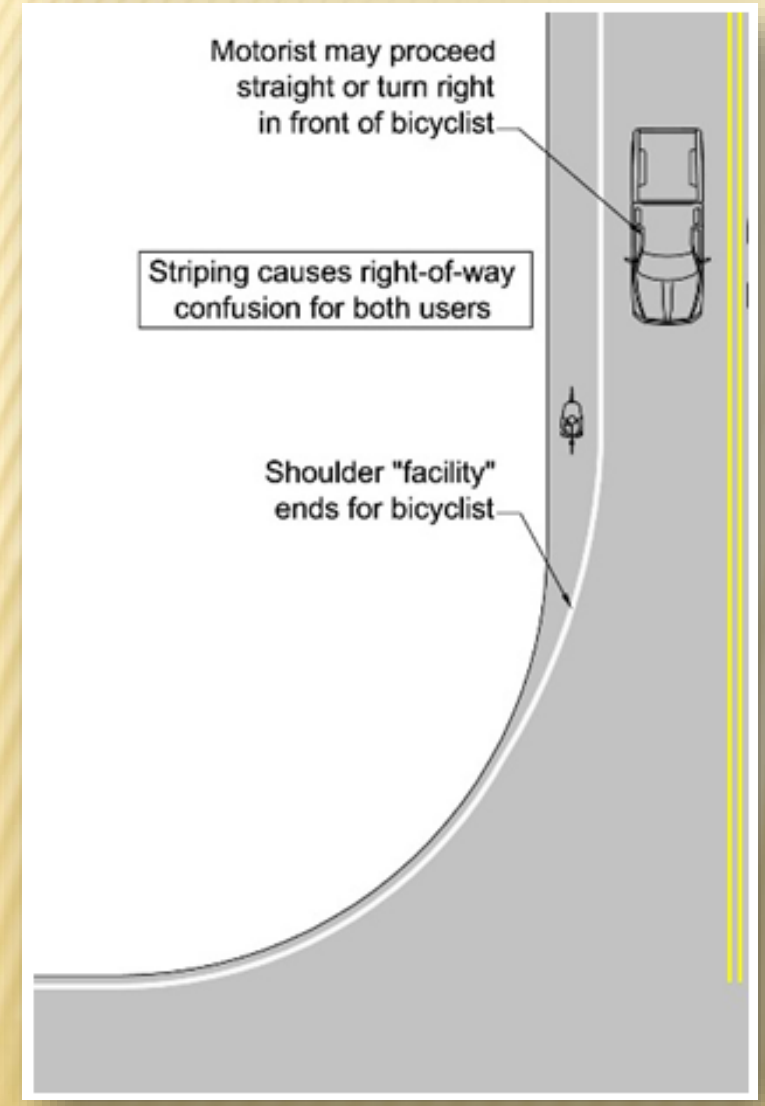


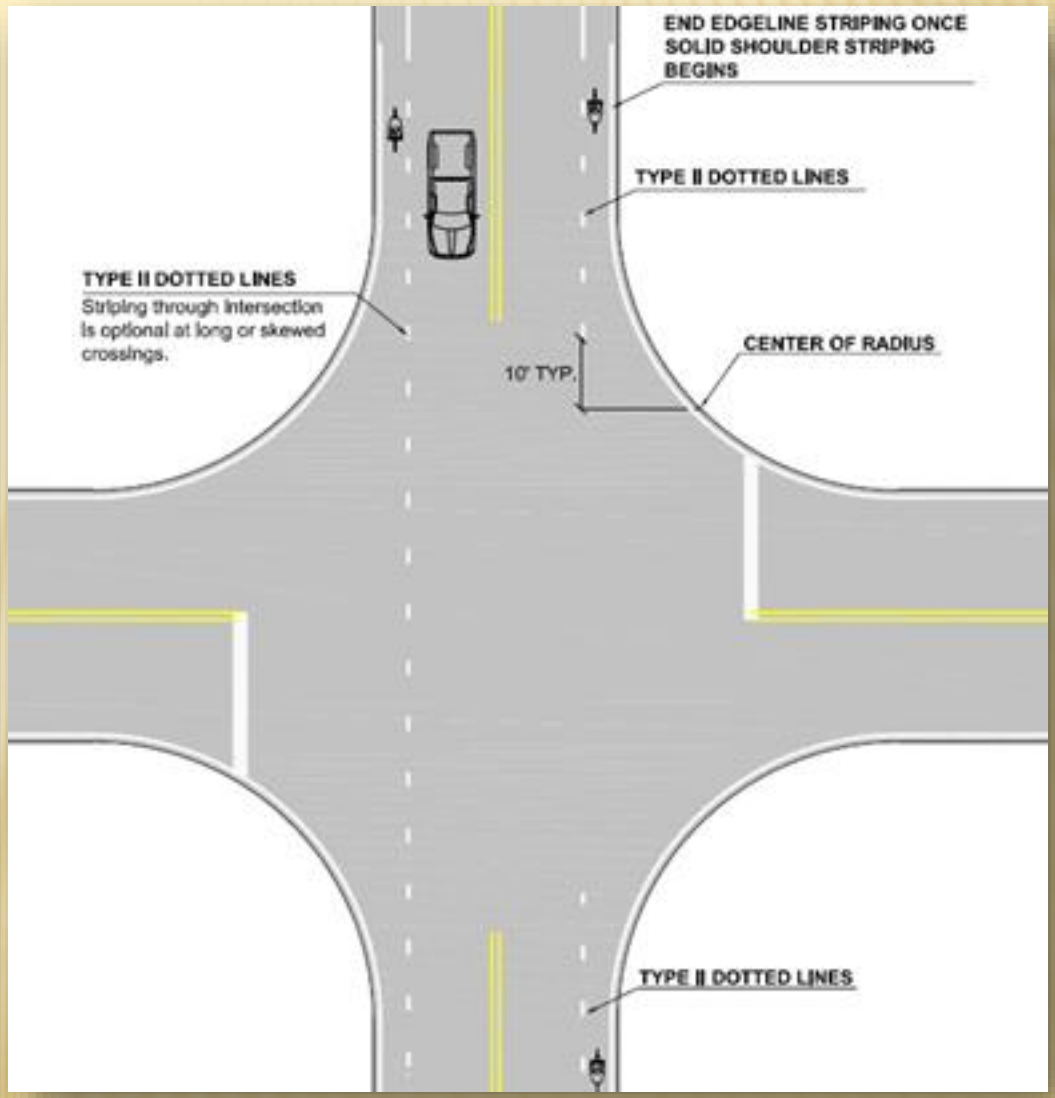
INTERSECTION COUNTERMEASURES

SHOULDER RIDING AT INTERSECTION

- Shoulder not a travel lane
- Modify shoulder striping
- Opportunity to switch to shared lanes **OR**
- Add bike lane thru intersection

SHOULDER STRIPING

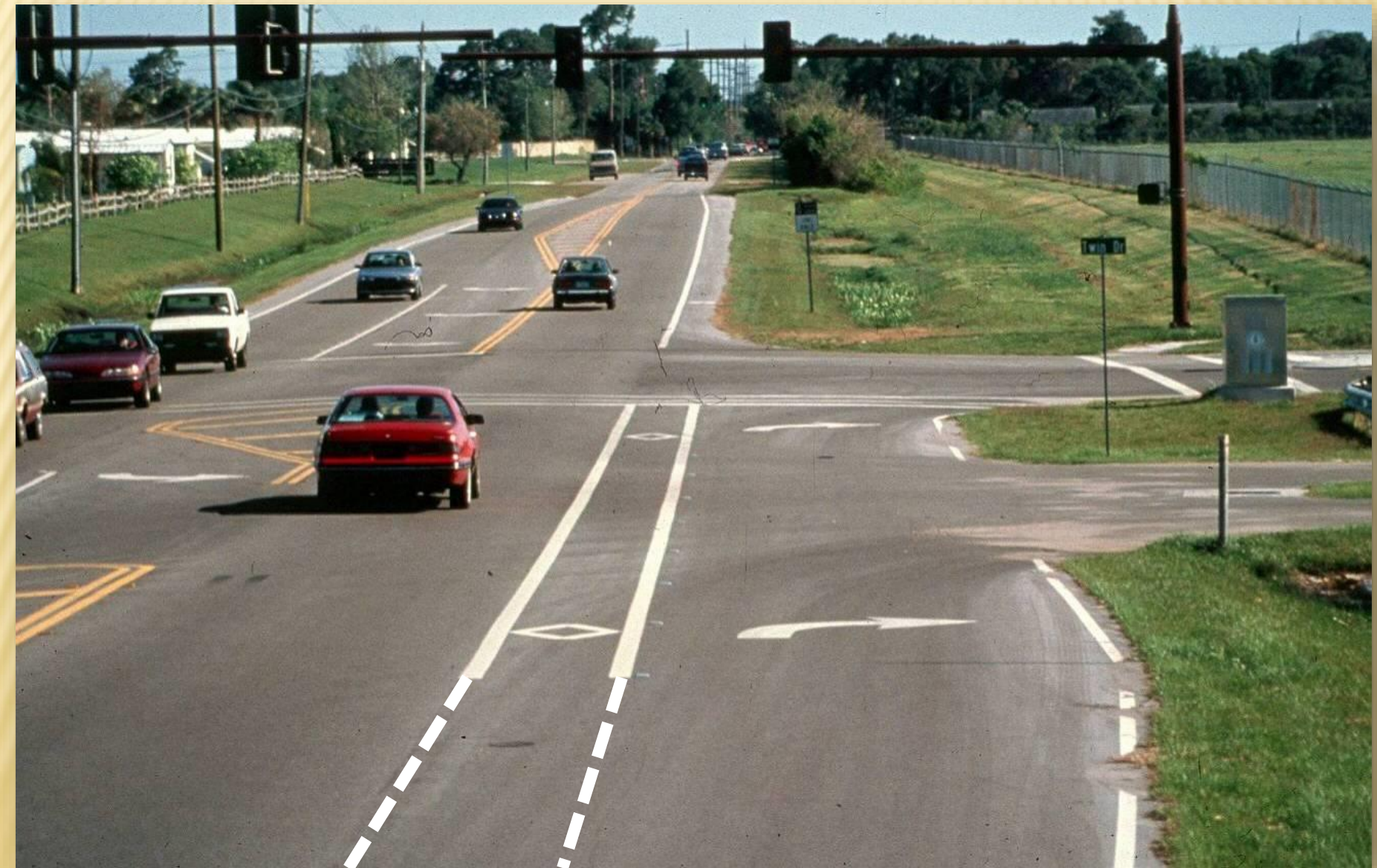




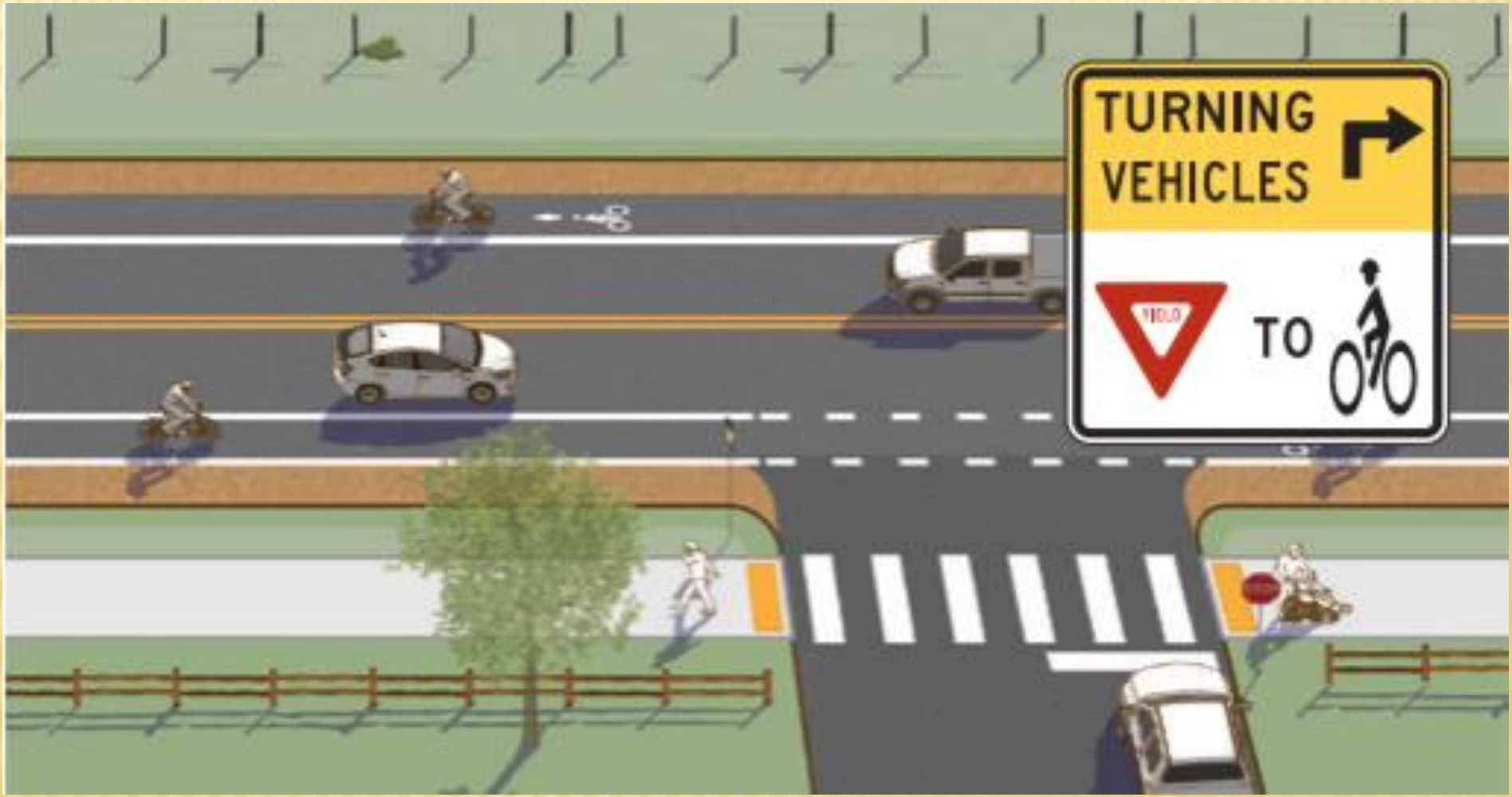
INTERSECTION WITH SHARED LANES

- Additional/all lanes are shared at intersection

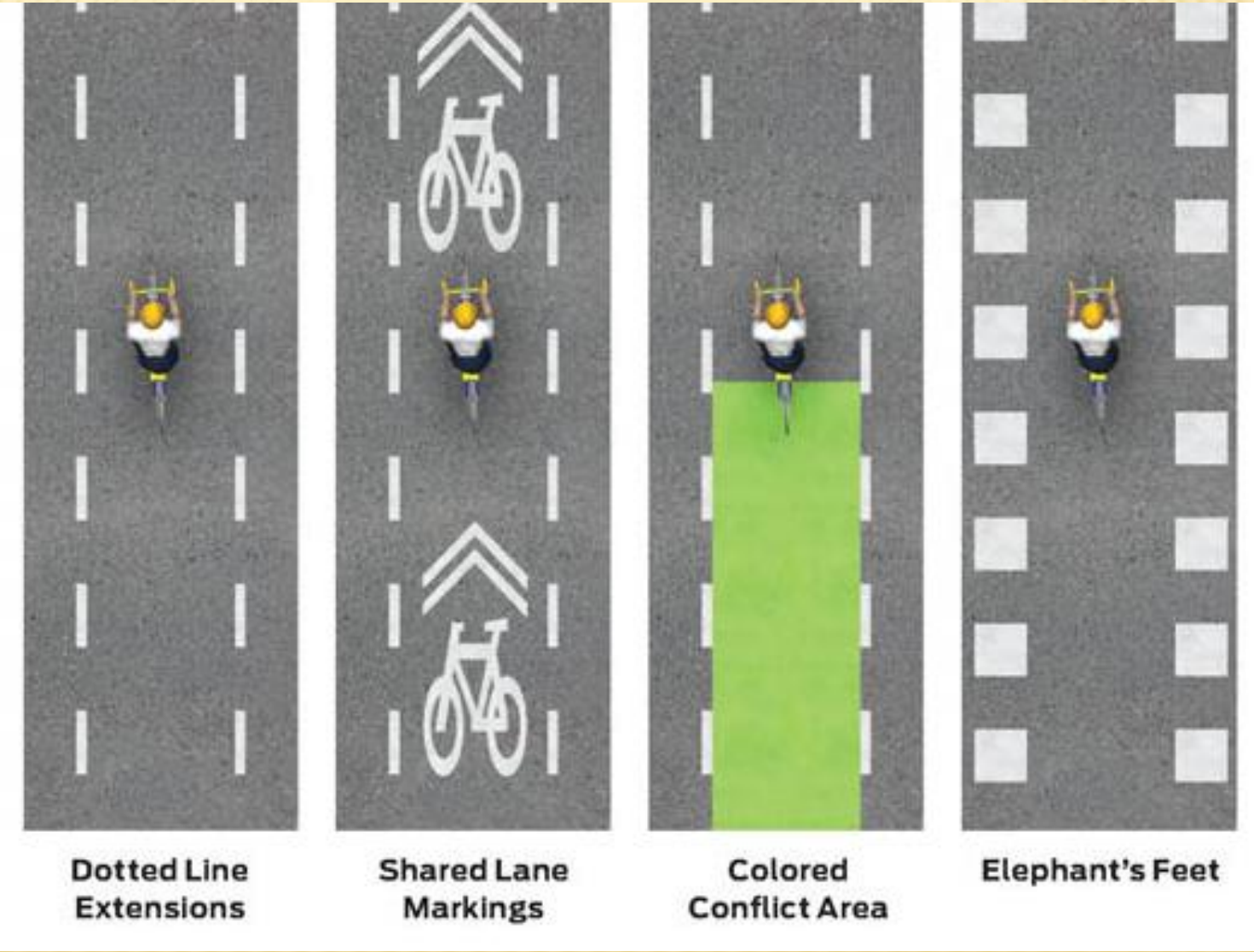
BIKE LANE THRU INTERSECTION



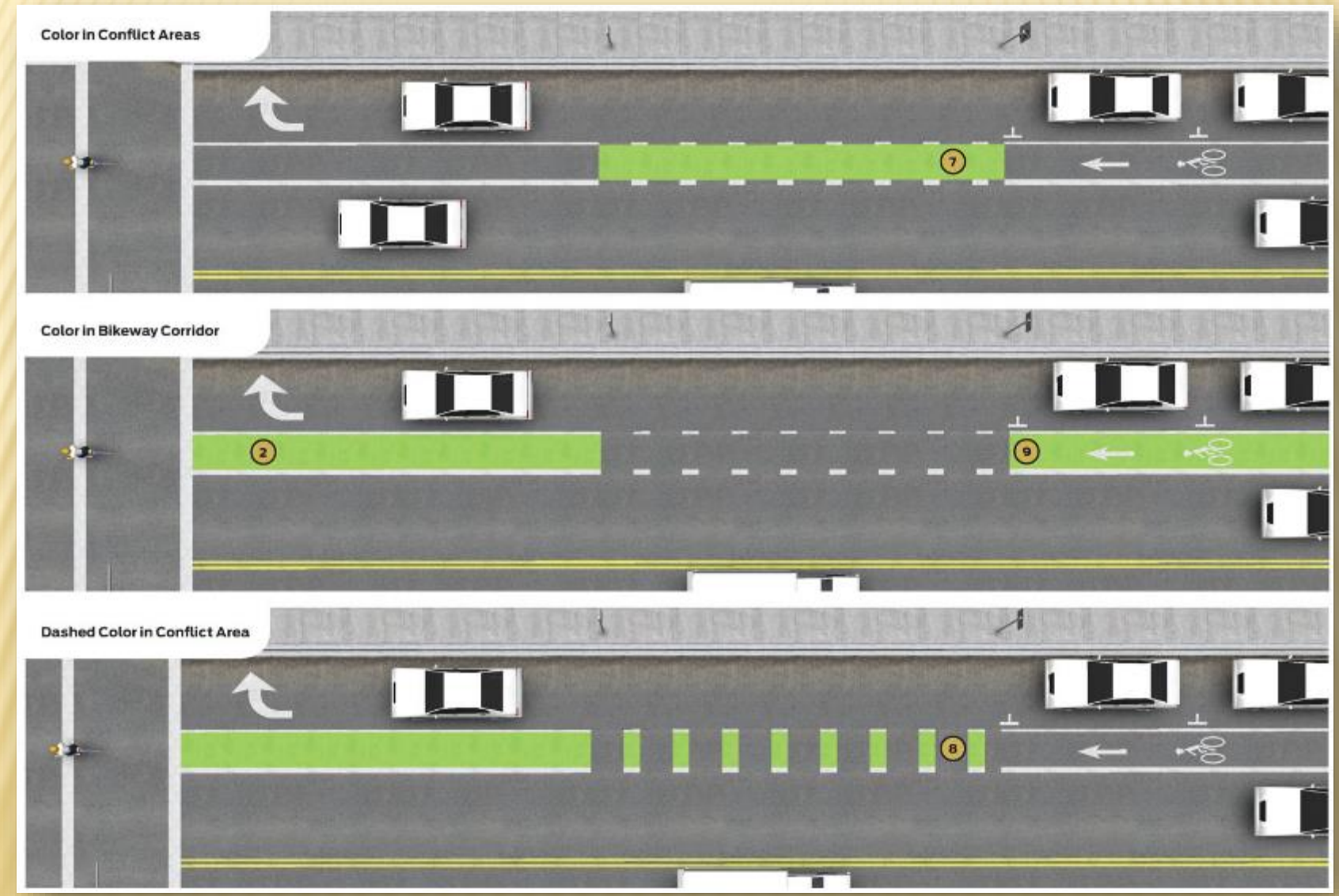
BIKE LANE THRU INTERSECTION



HIGHLIGHT CONFLICT ZONE



HIGHLIGHT CONFLICT ZONE



Urban Example—Orange Blossom Trail

Map data: Google © 2022 Landsat / Copernicus, Maxar Technologies

Urban Example—Orange Blossom Trail

Map data: Google © 2022 Landsat / Copernicus, Maxar Technologies

Urban Example—Orange Blossom Trail

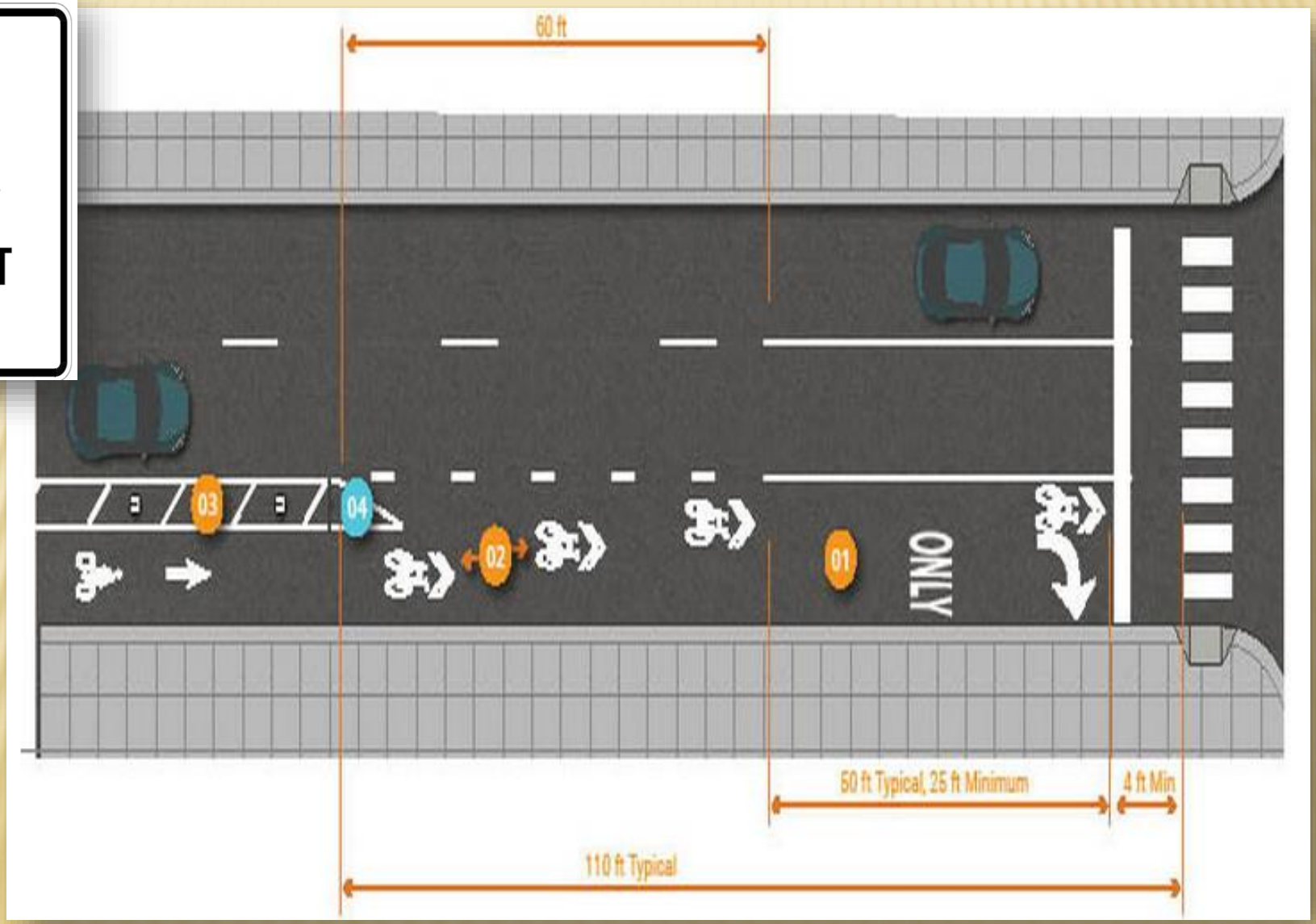
Urban Example—Orange Blossom Trail

BIKE LANE THRU INTERSECTION

BIKE LANE THRU INTERSECTION

BIKE LANE THRU INTERSECTION

RIGHT TURN SHARED LANE



TWO-STAGE TURN BOX

TWO-STAGE TURN BOX

- Required design elements include:
  - Bicycle symbol
  - Turn or through arrow
  - Turn on red prohibition
  - Passive detection of bicycles
- Size to prevent conflicts

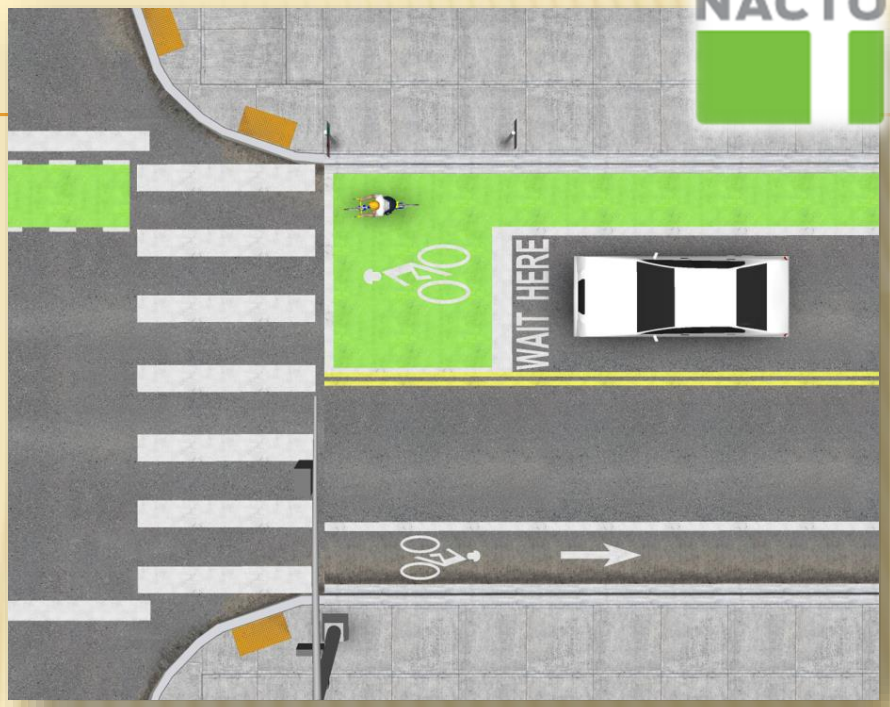
SALT LAKE CITY, UT (PHOTO: SALT LAKE CITY PUBLIC WORKS)

BIKE BOX

BIKE BOX

- Reduced conflicts between bicyclists and turning vehicles
- Reduced avoidance maneuvers
- Reduced encroachment into crosswalks
- Use clearly understood by motorists and bicyclists

BIKE BOX



- Required elements:
  - Advance stop line at 10’
  - Bike symbol in the box
  - RTOR prohibited
  - Setback from crosswalk
  - 50 feet of bike lane on approach
  - STOP HERE ON RED (R10-6/R10-6a) with EXCEPT BICYCLE text plaque
  - Countdown ped signal if box crosses multiple lanes
  - Yellow change & red clearance
- Green pavement is optional

SIGNAL STRATEGIES

SAFER SIGNALS FOR BICYCLISTS

- Bikes start-up and travel slower than cars
  - Differentiating bike detection to optimize signals
  - Set initial and gap times to accommodate bikes
- Leading Bike Interval
- Segregate Conflicting Movements

Bicycle Signals

Common Applications

- Poor bicycle/driver compliance with traffic control devices
- Leading bicycle intervals (LBI)
- Thru bike lane to right of right turn lane
- Contra flow bike facilities
- Increased bicyclist safety through phase separation.

Seattle, WA

Photo credit: SDOT

Bicycle Signal General Conditions

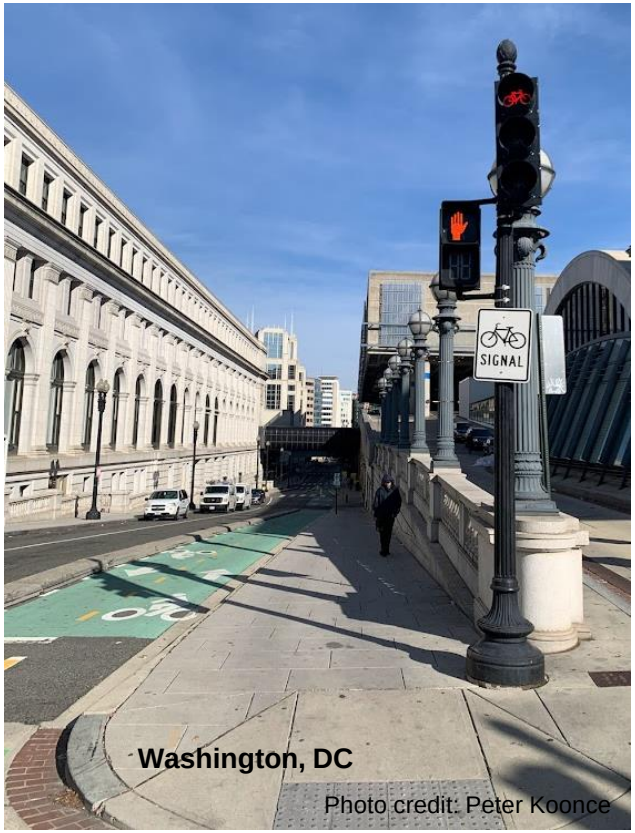
- The use of a bicycle signal face is optional
- **Shall be limited to situations where bicycles moving** on a green or yellow signal indication in a bicycle signal face **are not in conflict with any simultaneous motor vehicle movement** at the signalized location, including right (or left) turns on red.

Columbus, OH

Photo credit: Peter Koonce

Placement of Bicycle Signals

- A minimum of one primary bicycle signal face shall be provided
- Bicycle signal face shall have either 8-inch or 12-inch signal indications, even if it is located at the near side of the signal controlled location.
- When the primary bicycle signal face is >120 feet from beyond the stop line, a supplemental nearside bicycle signal face shall be provided.



Washington, DC

Photo credit: Peter Koonce

Bicycle Signal Indica

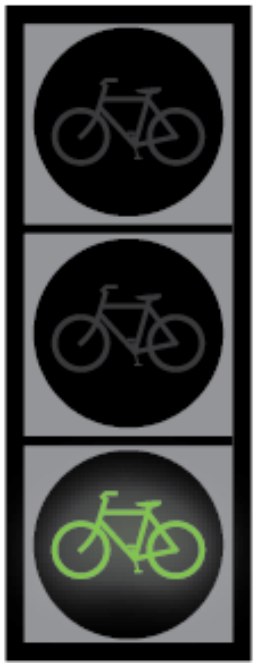
- Bicycle signal faces should be placed such that visibility is maximized for bicyclists

- Consideration should be given to using visibility limited bicycle signal faces

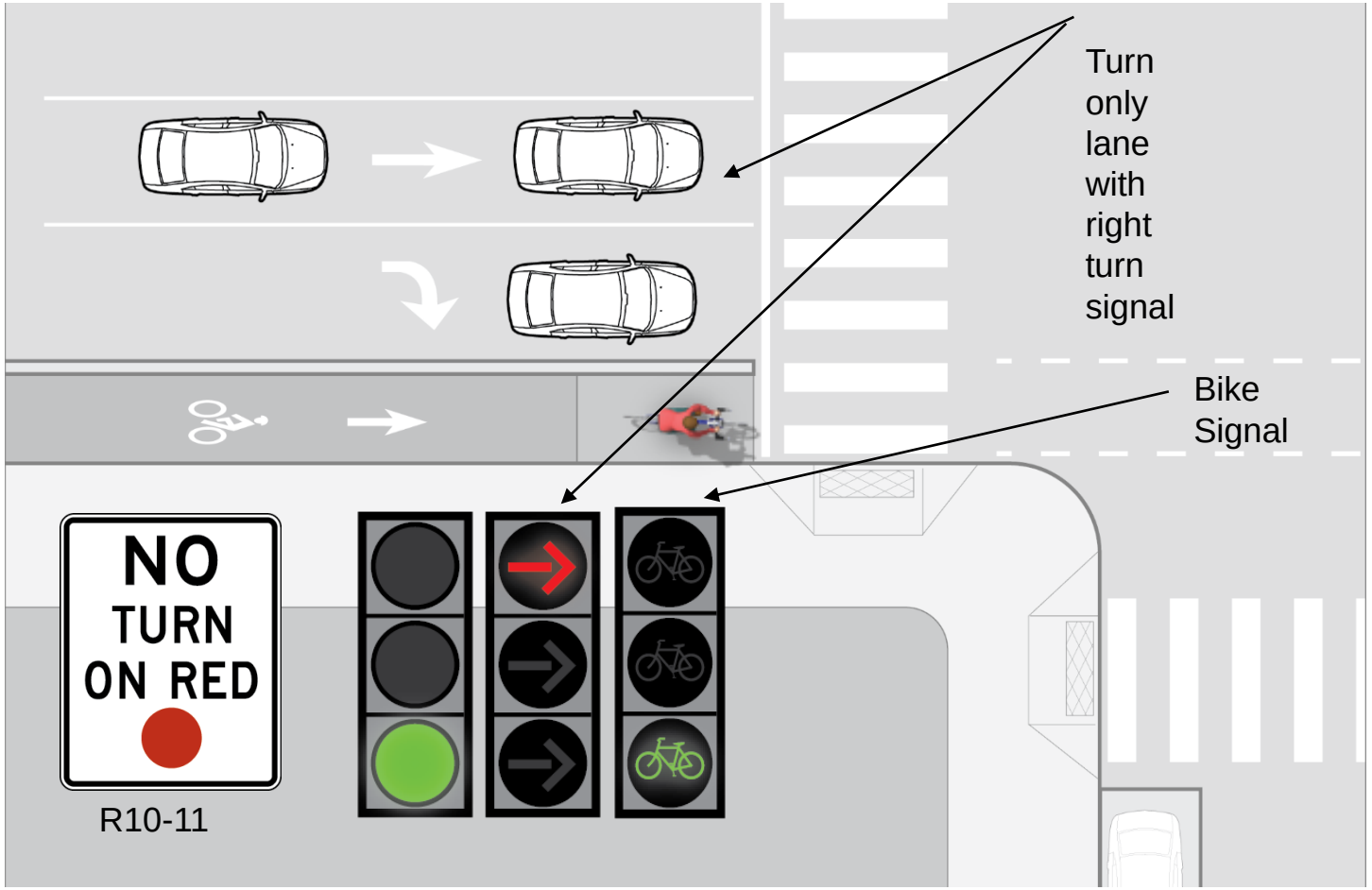
Honolulu, HI Photo credit: Peter Koonce

Bicycle Signals – Interim Approval

- No conflicts of any kind with vehicle movements
- No bicycle scrambles
- No use with hybrid beacons
- Must have bike lane, no shared lane approaches



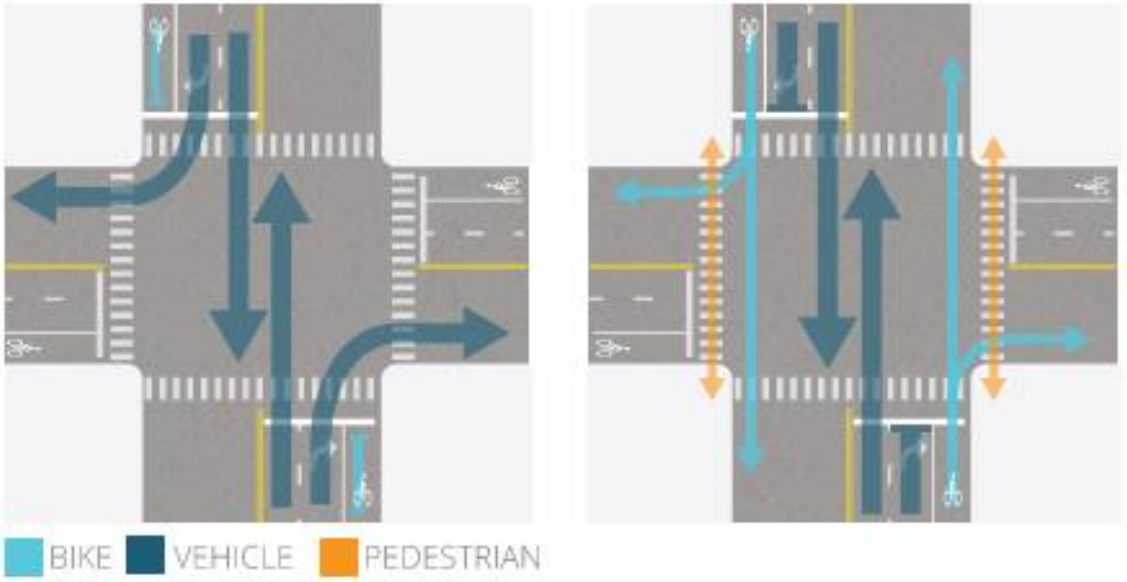
Bicycle Signals



Source Alta Planning and Design

Bicycle Signal Phasing – Protected Signal Phasing

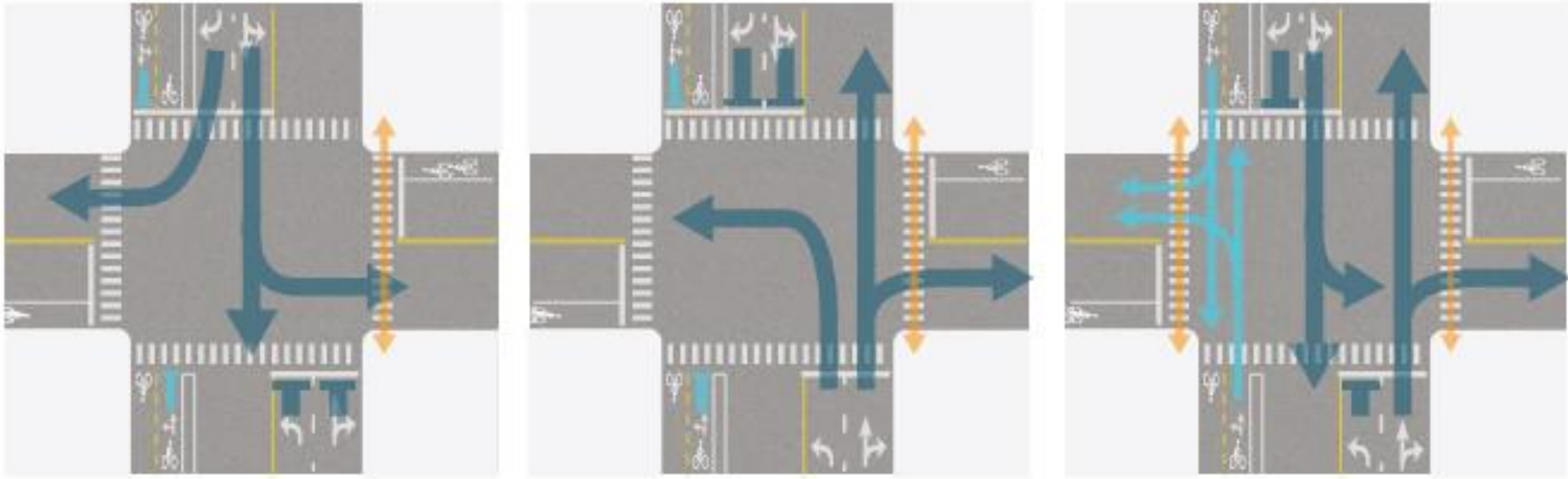
Bicycle movements can be separated from conflicting vehicle movements with automobile right-turn restrictions during the bicycle through movement, and bicycle signals stopping bikes while automobiles turn right.



Source: FHWA

Bicycle Signal Phasing – Two-Way Separated Bikeway

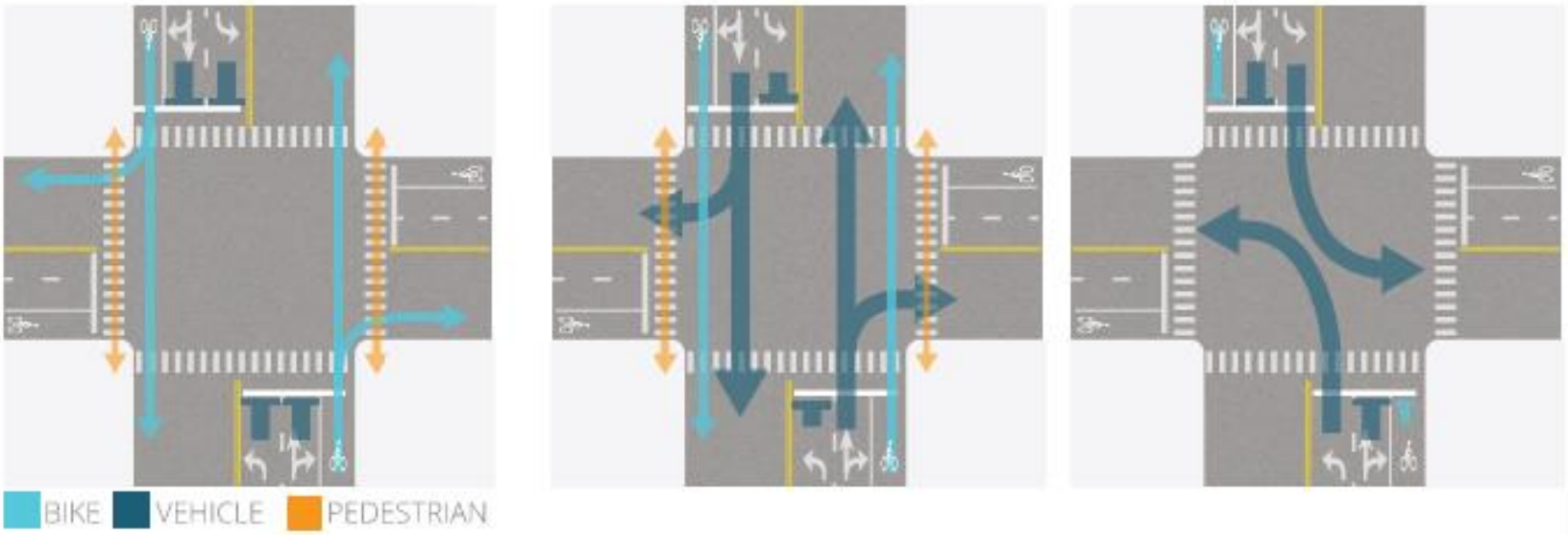
A two-way separated bike lane adds complexity to signal phasing at two-way intersections. Importantly, the separated bike lane movement should be separated from conflicting vehicle turning movements.



Source:
FHWA

Bicycle Signal Phasing – Leading Bicycle Interval

In low vehicle traffic situations with separated bike lanes, a dedicated bicycle movement should be considered. The interim approval for bicycle signals (IA-16) does not permit a "bicycle scramble" (where bicycle movements are permitted from all four directions simultaneously).



Source: FHWA

Use: Separate from Turn Lanes

Most beneficial with multiple turn lanes and/or high turning volumes

Portland

Photo credit: NACTO

Use: Diagonal Trail Crossing

Separate movement for people on bicycles through the signal

Milwaukie, OR

Photo credit: Peter Koonce

Use: Contra-Flow Movements

Example:

Two-way bikeway and turning vehicle conflict

Interim Approval prohibits any conflicting movements

Use: Low Volume Street Crossings

"Toucan crossing" combines bike signal with traffic diversion

Fort Collins CO

Photo credit: Joe Gilpin

Use: Transitions

Aurora, CO

Use: Reduce Delay for Other Users

- Bicyclist speeds higher than pedestrian speeds
- Clearance times shorter
- This signal can be actuated
  - by peds (longer crossing time) or
  - bikes (shorter crossing time)
  - Passively through technology

Portland

Photo credit: Google Streetview

Volume of Bikes vs Turns

- MassDOT Separated Bike Lane Planning & Design Guide Exhibit 6A
- Denver:
  - Mixing Zone <100 turns/hr
  - Bike Signal >150 turns/hr
- Salt Lake City:
  - Mixing Zone <75 turns/hr
  - Through bike lane 75-100 turns/hr

Separated Bike Lane Operation	Motor Vehicles per Hour Turning across Separated Bike Lane			
	Two-way Street			One-way Street
	Right Turn	Left Turn across One Lane	Left Turn across Two Lanes	Right or Left Turn
One-way	150	100	50	150
Two-way	100	50	0	100

EXHIBIT 6A: Considerations for Time-separated Bicycle Movements

Source: MassDOT Separated Bike Lane Planning and Design Guide

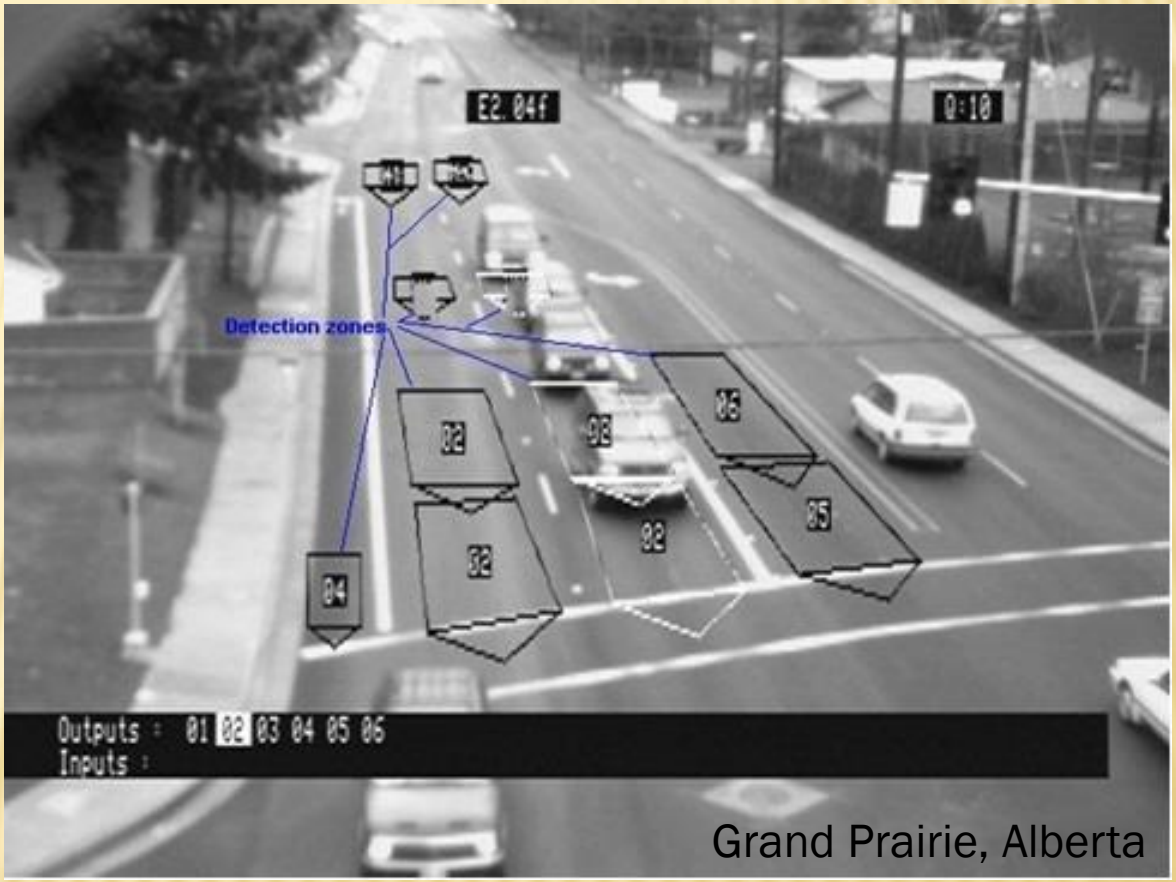
Bicycle Signals

Bikes Use Ped Signal (R9-5) sign may be used to provide guidance without bicycle signal head

What minimum green do they need?
Are they being detected?

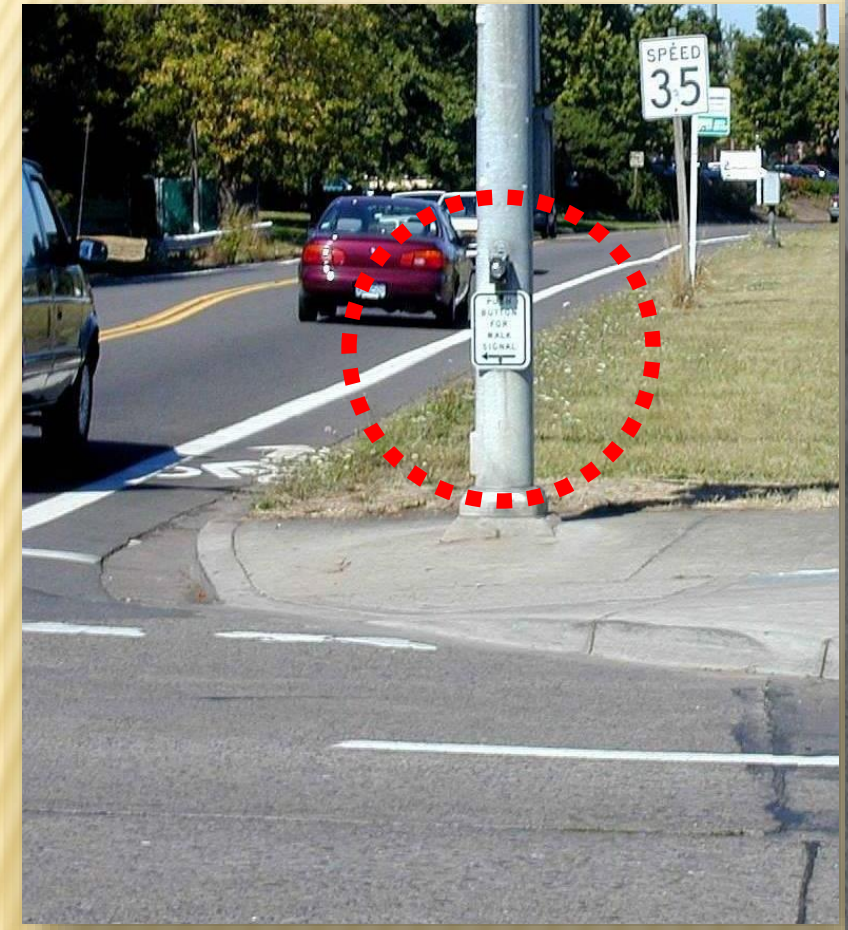
BICYCLE DETECTION

- Buttons
- Loops
- Video
- Microwave
- Radar
- Infrared

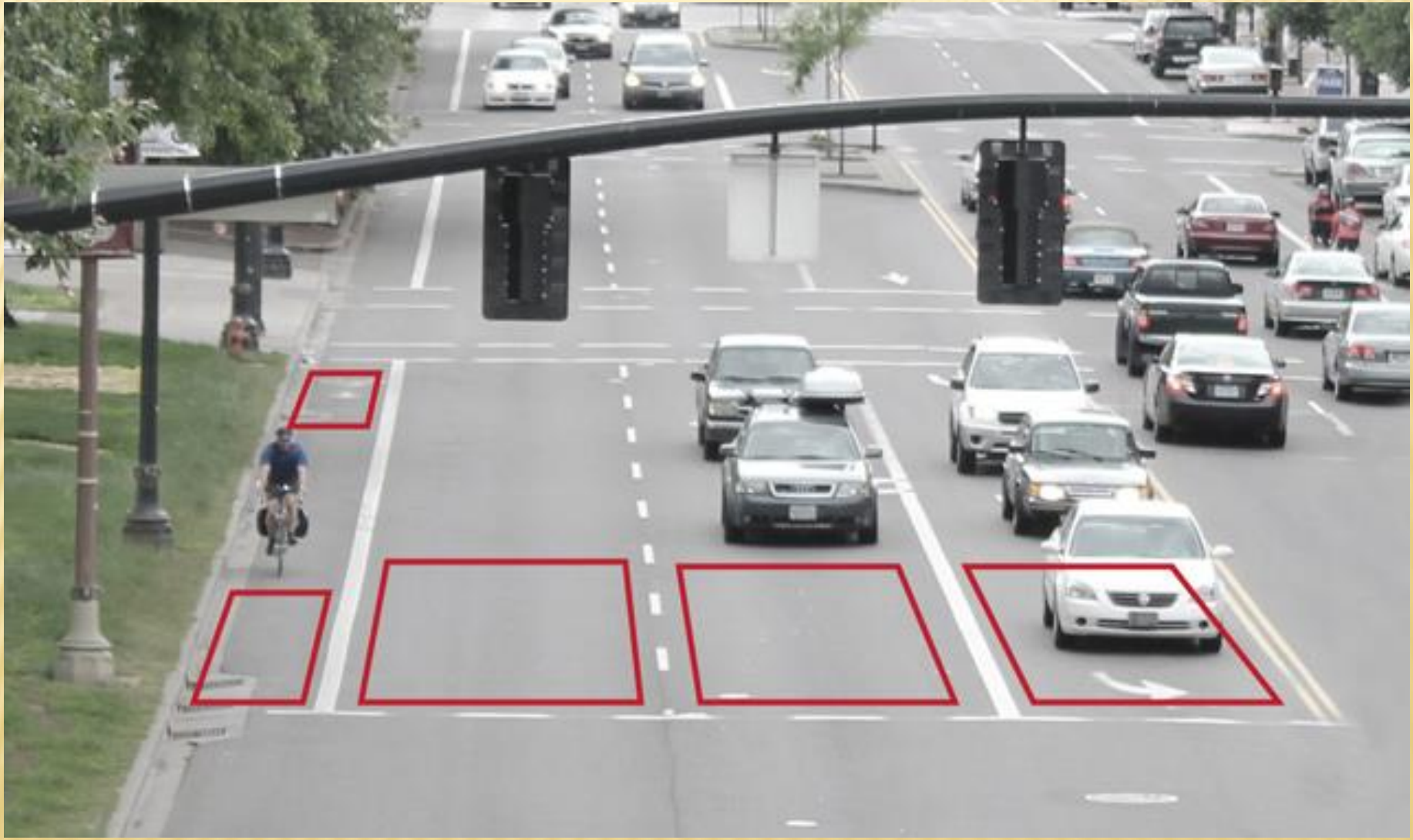


Grand Prairie, Alberta

PUSH BUTTONS



PASSIVE DETECTION



Detection & Actuation

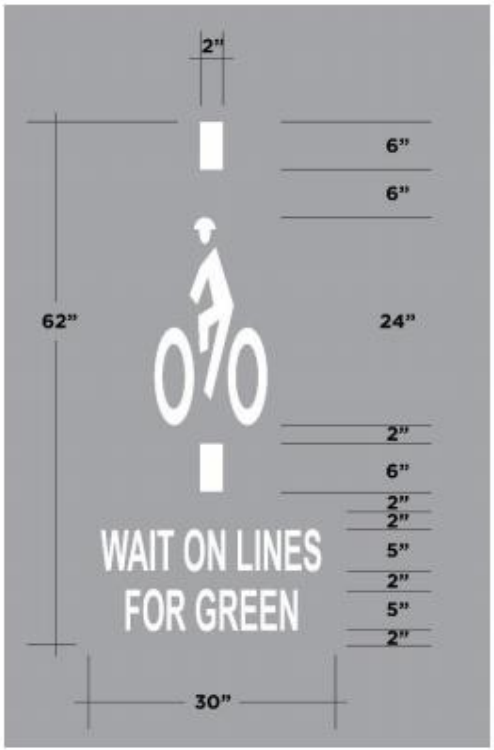
Inductive Loops

Image Source: NACTO

Photo credit: Richard Masoner

- Thermal better than video in Denver evaluation
- Video may make false detections
- Many jurisdictions find the best results with loops, but maintenance concerns
- Upstream bike lane detection should be considered to improve overall signal operation

Bicycle Detector Marking New 9C-7B options



Detection Zone Locations

- Detection zones should cover the entire bicycle facility approach
- Traditionally placed at stop line
- Advanced detection should be considered to reduce unnecessary stops of both bicyclists and conflicting turning traffic to make signal more responsive
- Can also be placed in bike box and TSBTB to call cross-street phase or activate an LBI

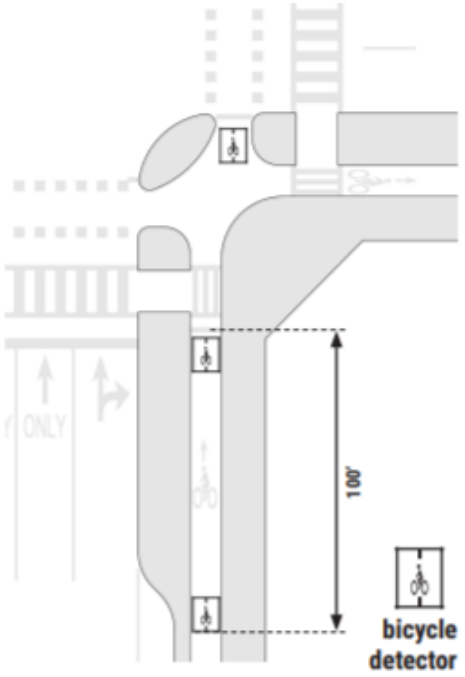


EXHIBIT 6F: Typical Bicycle Detector Locations

Source: MassDOT Separated Bike Lane Planning & Design Guide

Bicycle Green Wave

SFMTA has set reduced traffic signal speeds using the following criteria:

- More than 3 signals
- On City bike network with bike lane
- Same signal cycle length
- Outside center city grid

Source: SFMTA

BICYCLISTS AT ROUNDABOUTS

MAKING ROUNDABOUTS WORK

- Slow speeds
  - Deflection
  - Truck apron
  - NO BIKE LANES
- Simple
  - Single lane
  - NO BIKE LANES
- Splitter islands
- Bike ramps

Bike lane ends at splitter island

Slower speeds and fewer conflict points

Slower speeds and fewer conflict points

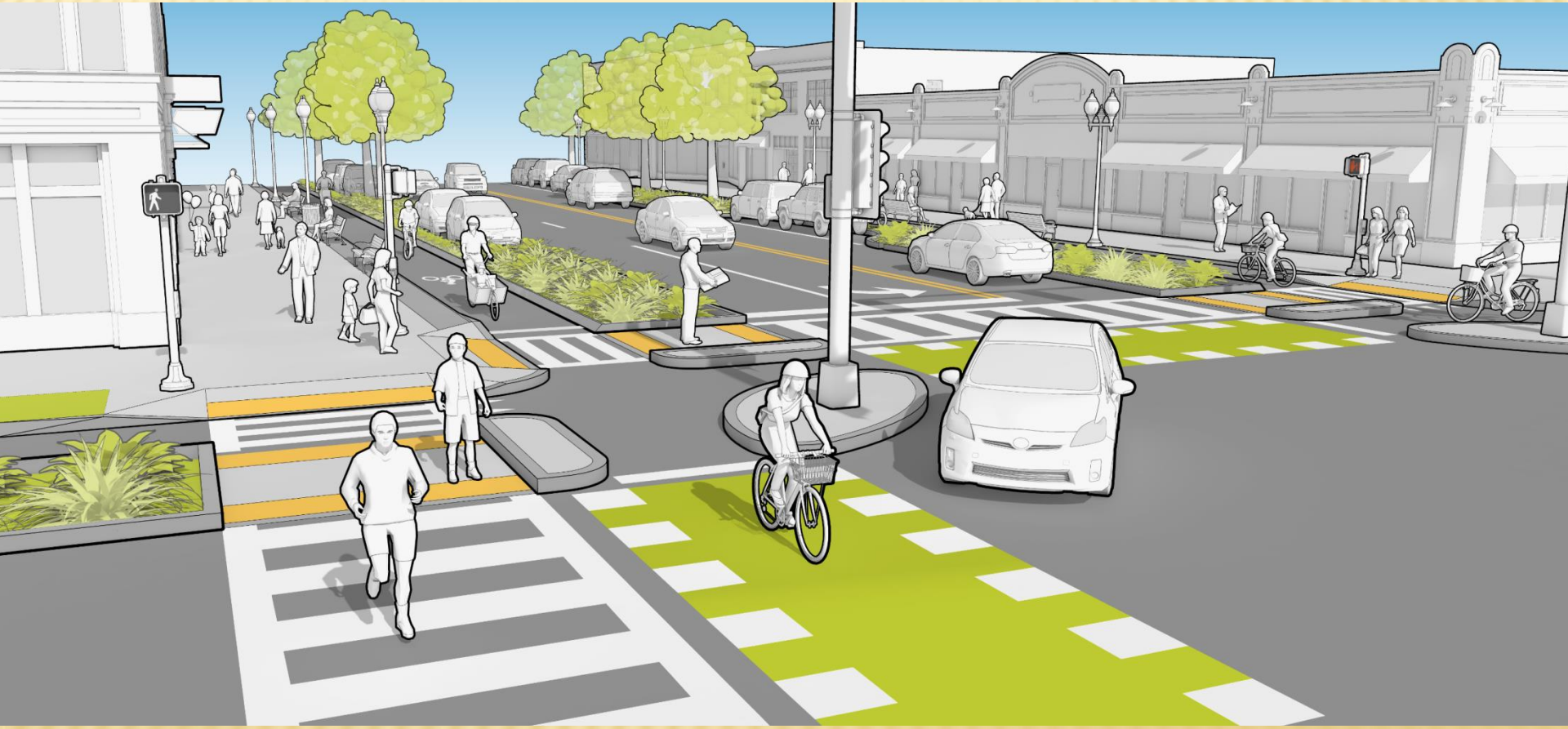
Bend, Oregon

Bike lane begins

Bike ramp

PROTECTED INTERSECTIONS

“PROTECTED” INTERSECTIONS



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“PROTECTED” INTERSECTIONS

Salt Lake City, UT

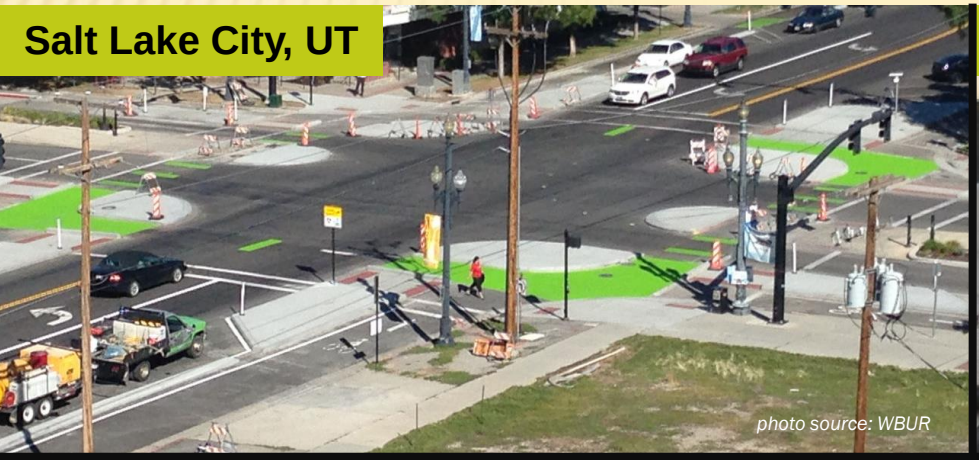


photo source: WBUR

Chicago, IL

photo source: Streetsblog

Austin, TX

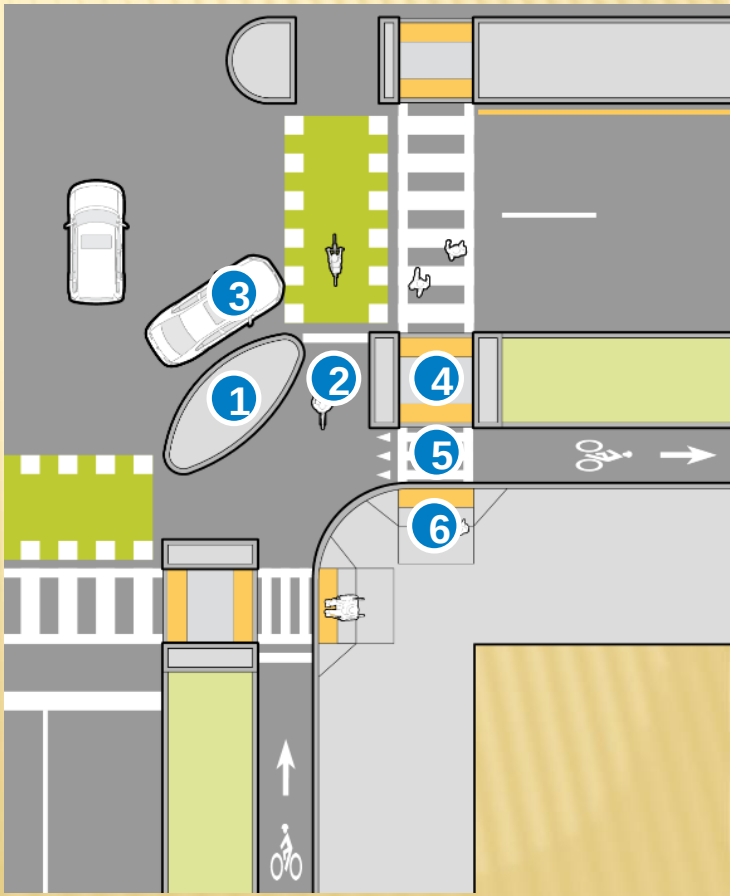
photo source: Google

Davis, CA

photo source: People for Bikes

PROTECTED INTERSECTIONS

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



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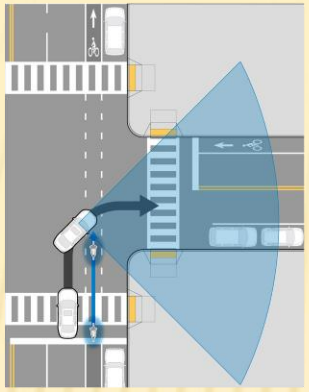
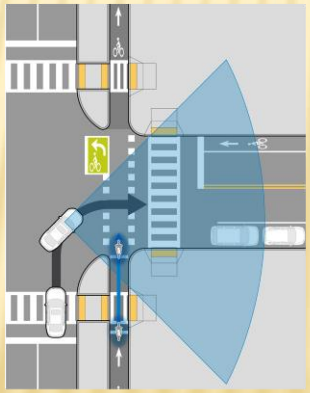
VISIBILITY AT CONFLICT POINTS

motorist's view at conventional bike lane

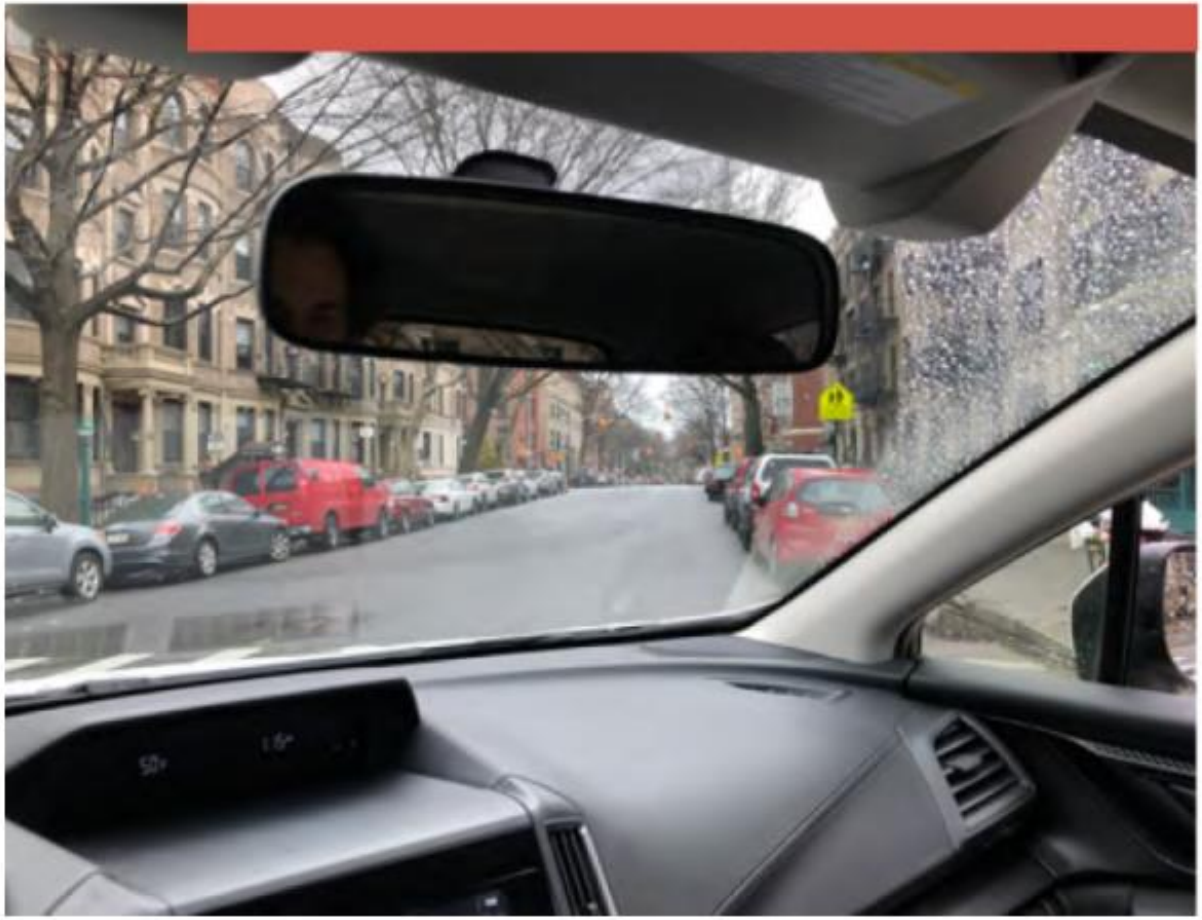


motorist's view at **separated bike lane**



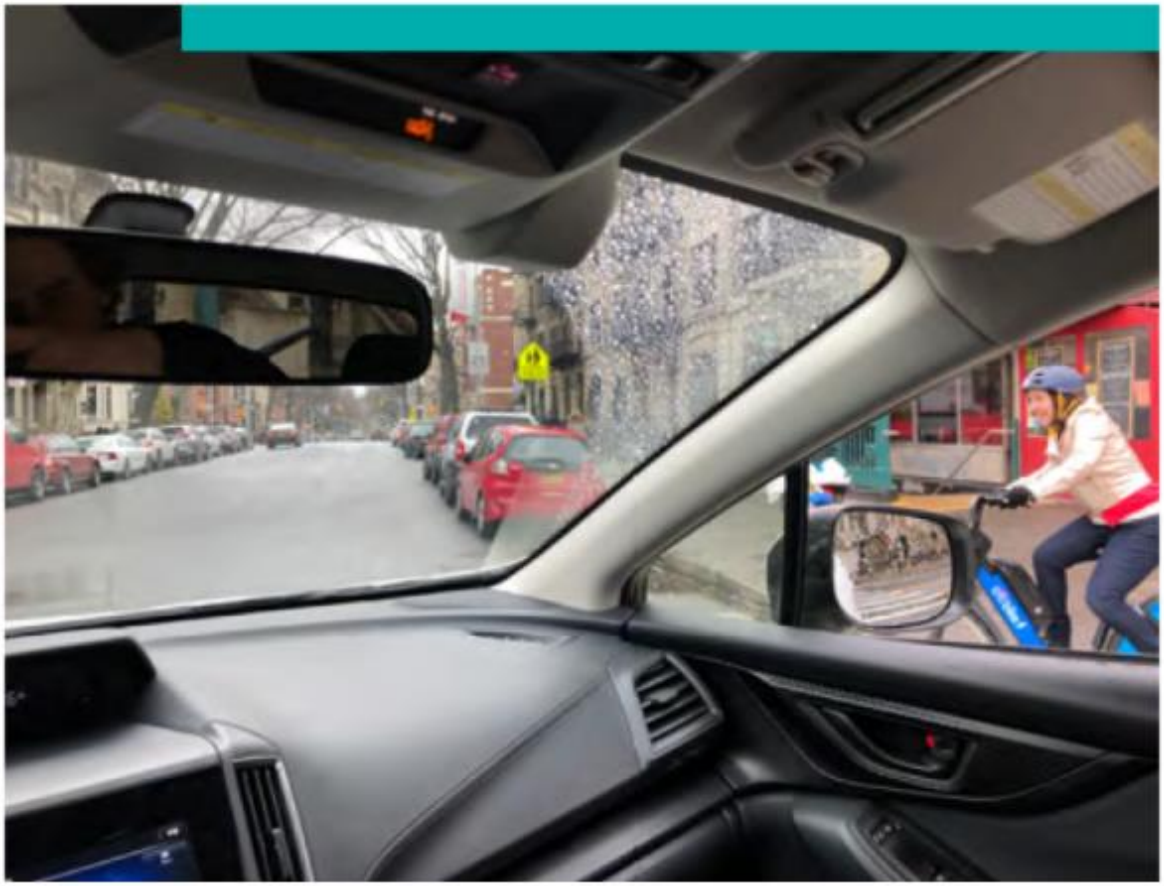
massDOT

VISIBILITY AT CONVENTIONAL INTERSECTION



At a conventional intersection, the bike rider is hidden from the driver's view as the driver makes the turn.

VISIBILITY AT PROTECTED INTERSECTION



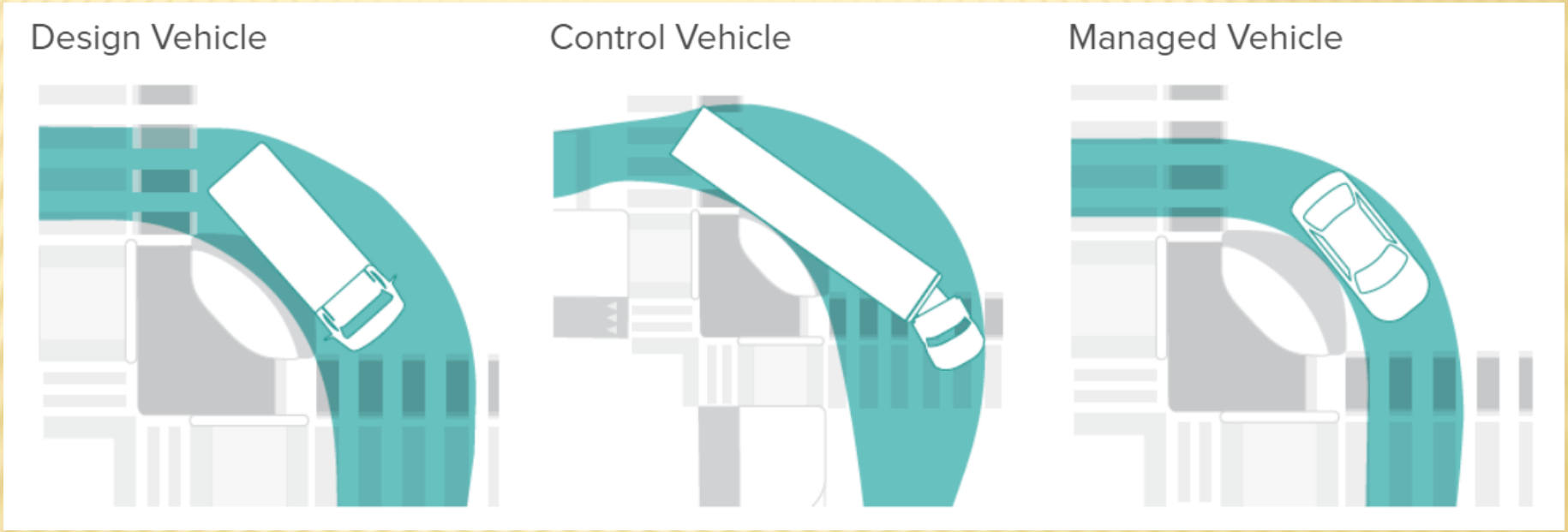
At a protected intersection, the bike lane is set back from the motor vehicle through/turn lane, so the bike rider is visible as the driver turns.

VISIBILITY AT CONFLICT POINTS

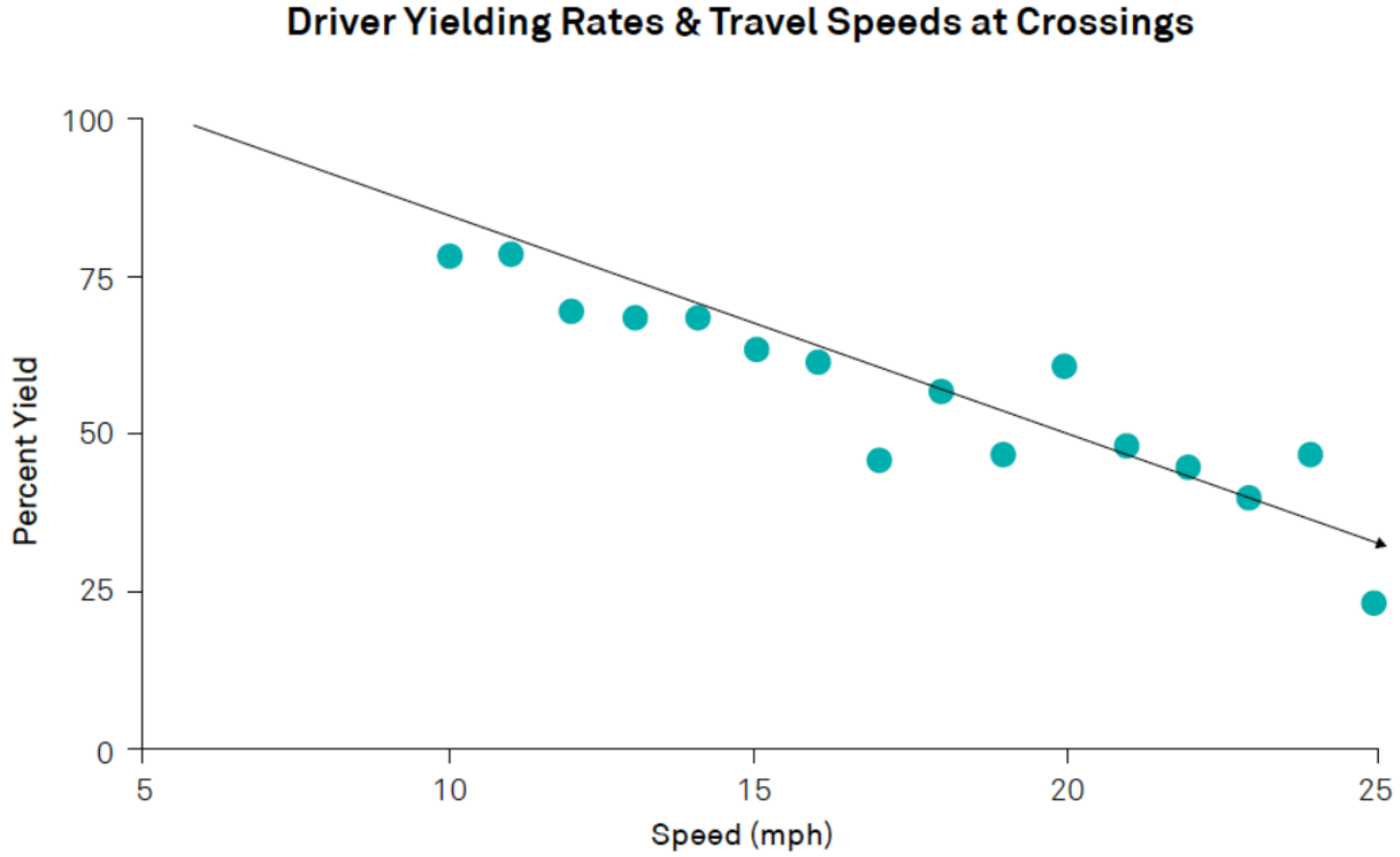
protected intersection

conventional bike lane

CORNER RADIUS



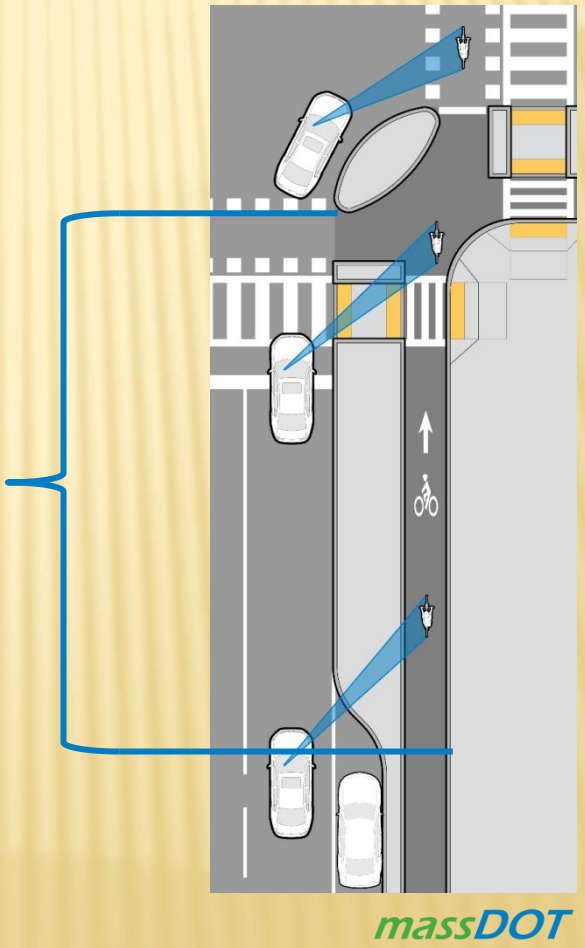
YIELDING RATE & TRAVEL SPEEDS



Lower speeds lead to higher driver yielding rates at urban roundabouts. Roundabouts share important geometric features with protected intersections. Graph source: Geruschat, D.R., Driver Behavior in Yielding to Sighted and Blind Pedestrians at Roundabouts. 2005.

APPROACH CLEAR SPACE

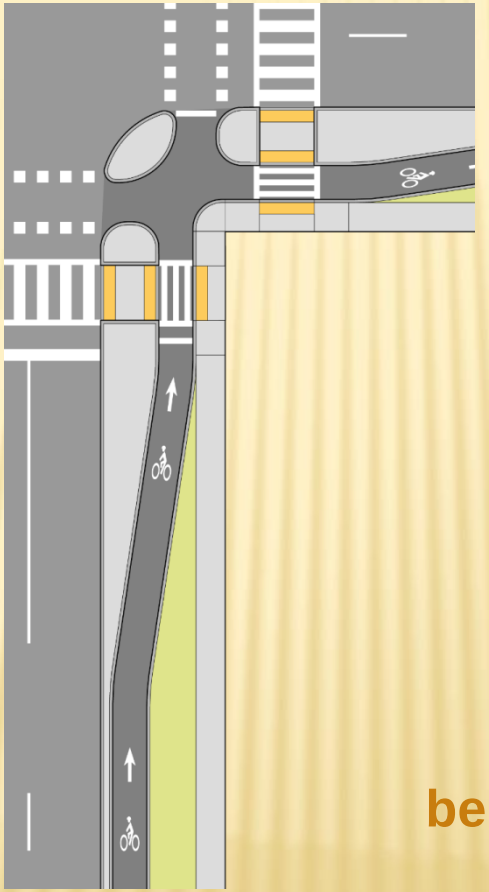
Vehicular turning design speed	Minimum approach clear space
<10 mph	20’
10 mph	40’
15 mph	50’
20 mph	60’



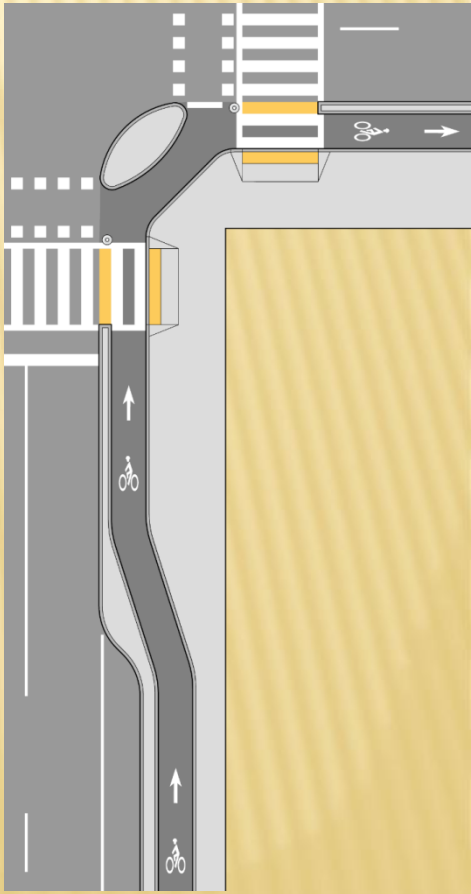
DEFLECTION

- Maximum taper **3:1**
- Bend-out preferred (motorist yield zone, bus stops, pedestrian refuge area, loading and parking)
- Separation increases sight distance
- Corner island affects motorist yield zone

bend-out



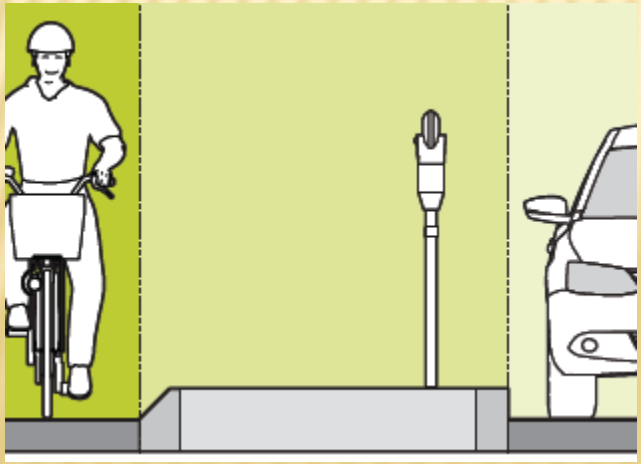
bend-in

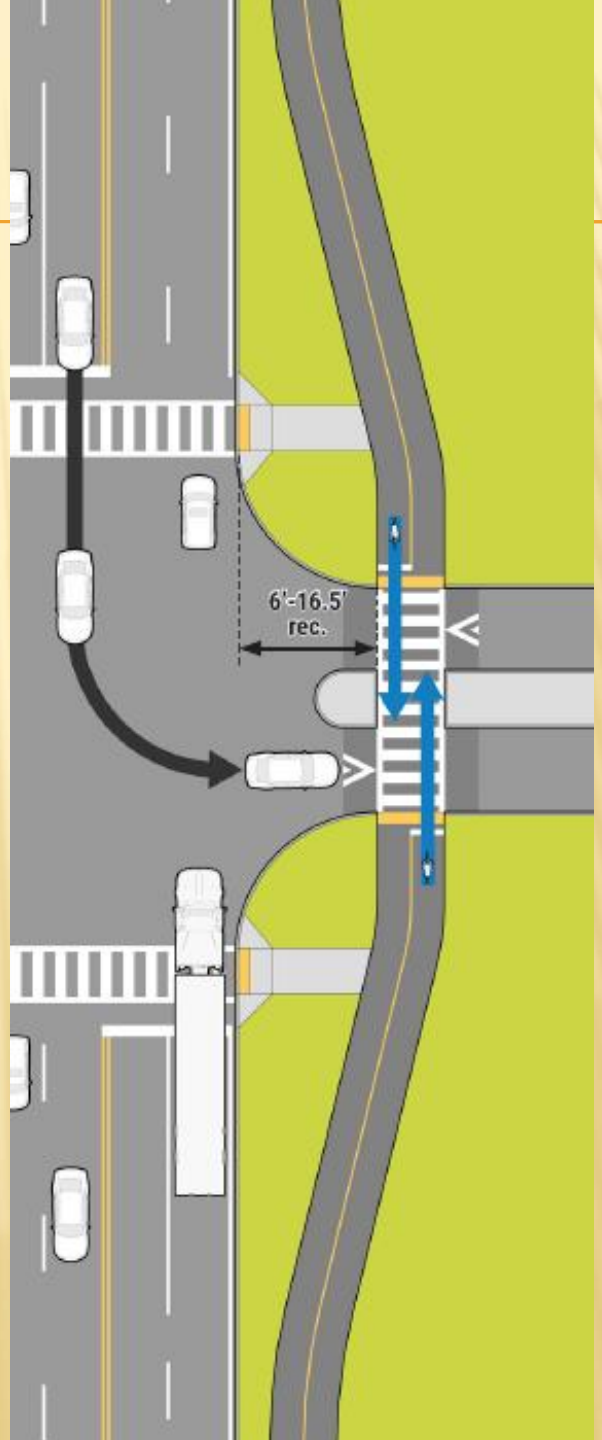


massDOT

STREET BUFFER WIDTH

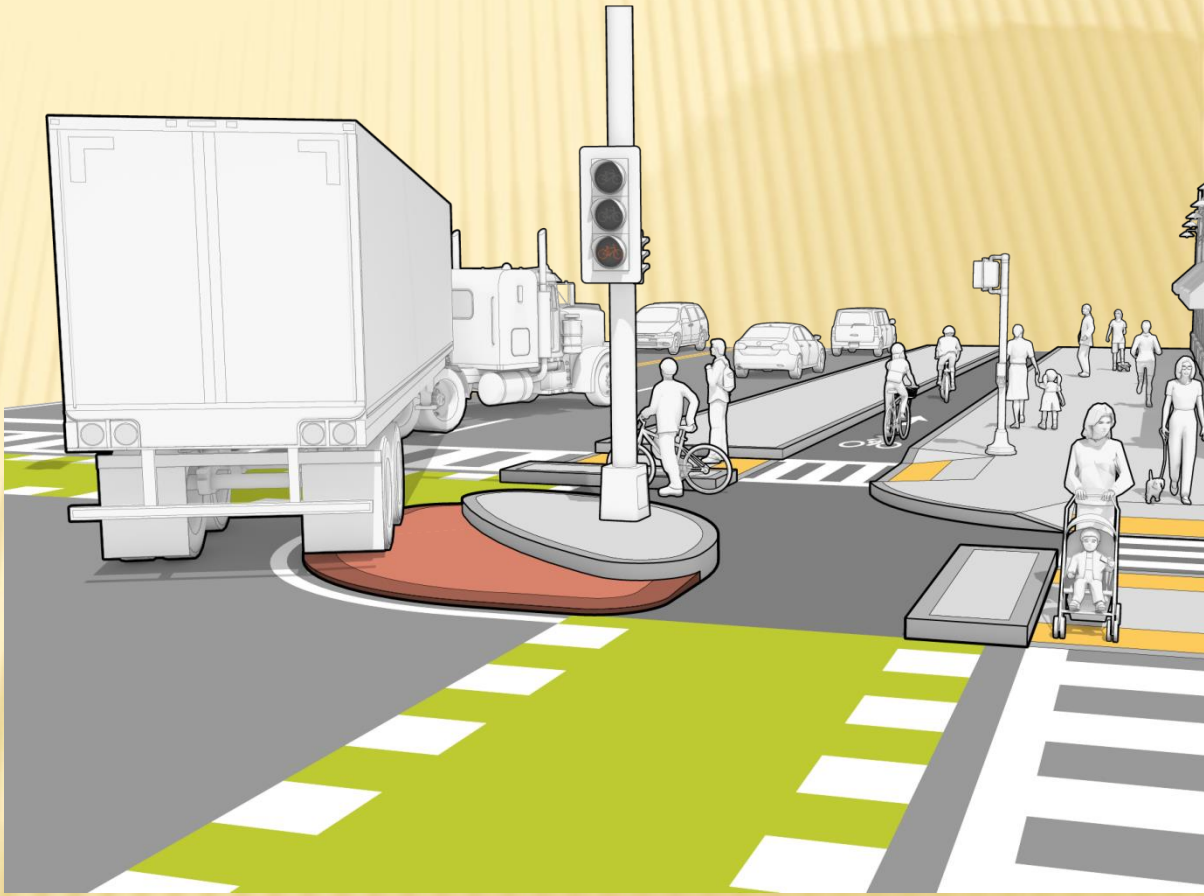
- 6’ preferred
- 2’ when constrained
- 1’ along raised SBL
- 6-16.5’ optimum for intersections





SLOW RIGHT TURNING SPEEDS

- Design for ≤**10 mph** vehicle turns
- Mountable truck apron
  - 3” max.
  - Visually distinct
- Large radii reduces bicycle, pedestrian queuing areas

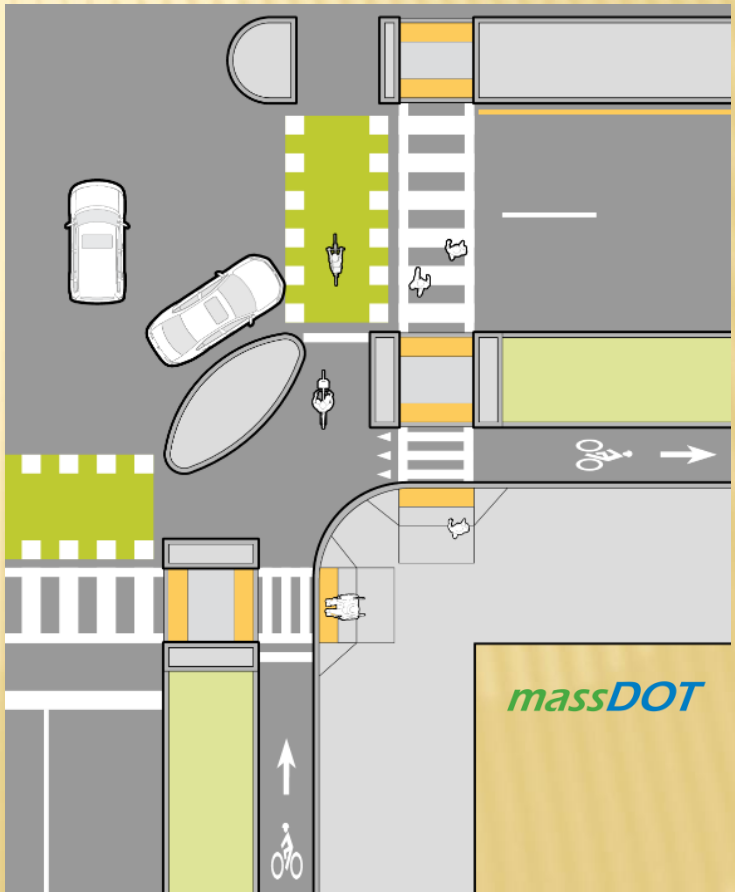


massDOT

ADA ISSUES

- PROWAG was written over 15 years ago
- Still a “draft” but widely used and enforceable
- Did not consider SBL’s
- Must be interpreted

NO EASY ANSWERS



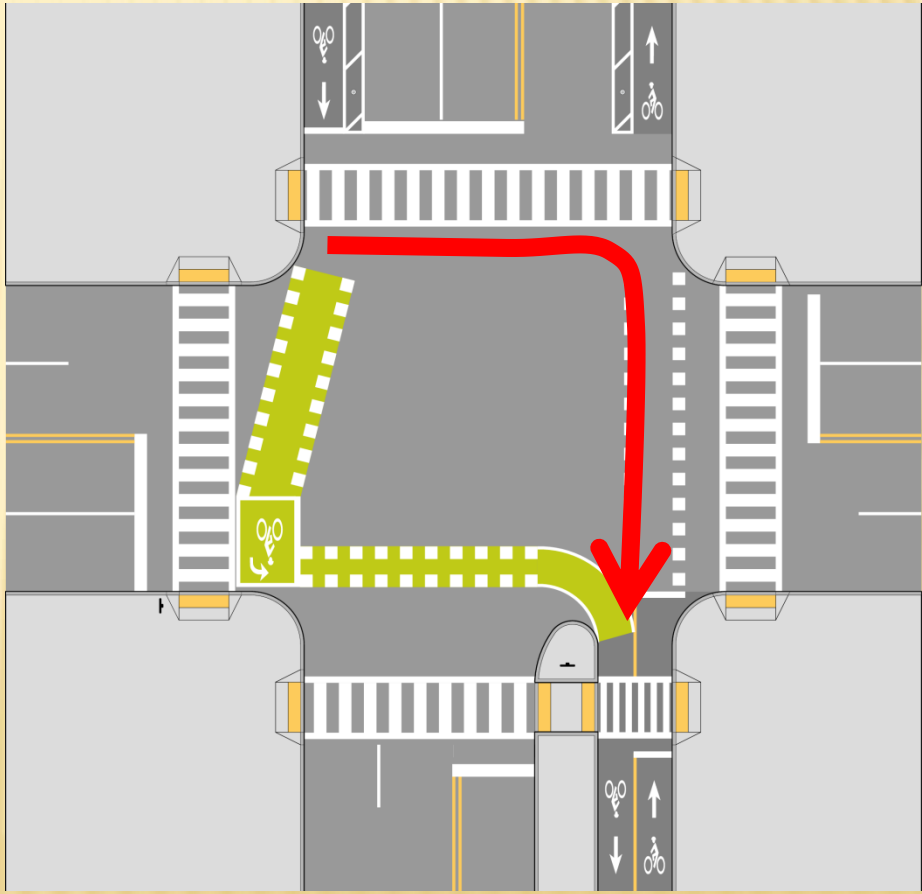
TRANSITIONS

CONSIDERATIONS

- What happens at termini?
- What happens when bicycle facility type changes?
- Have you stranded or created a barrier to the less confident user?
- How many stops will bicyclist have to make to traverse transition?

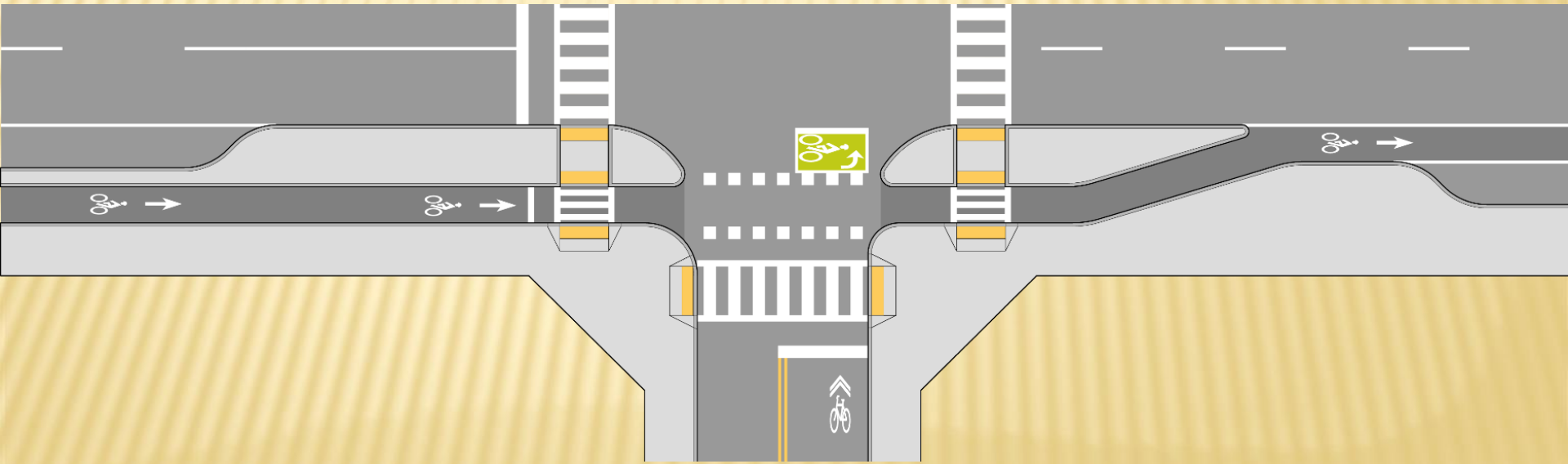
EXAMPLE TRANSITIONS

into a two-way separated bike lane



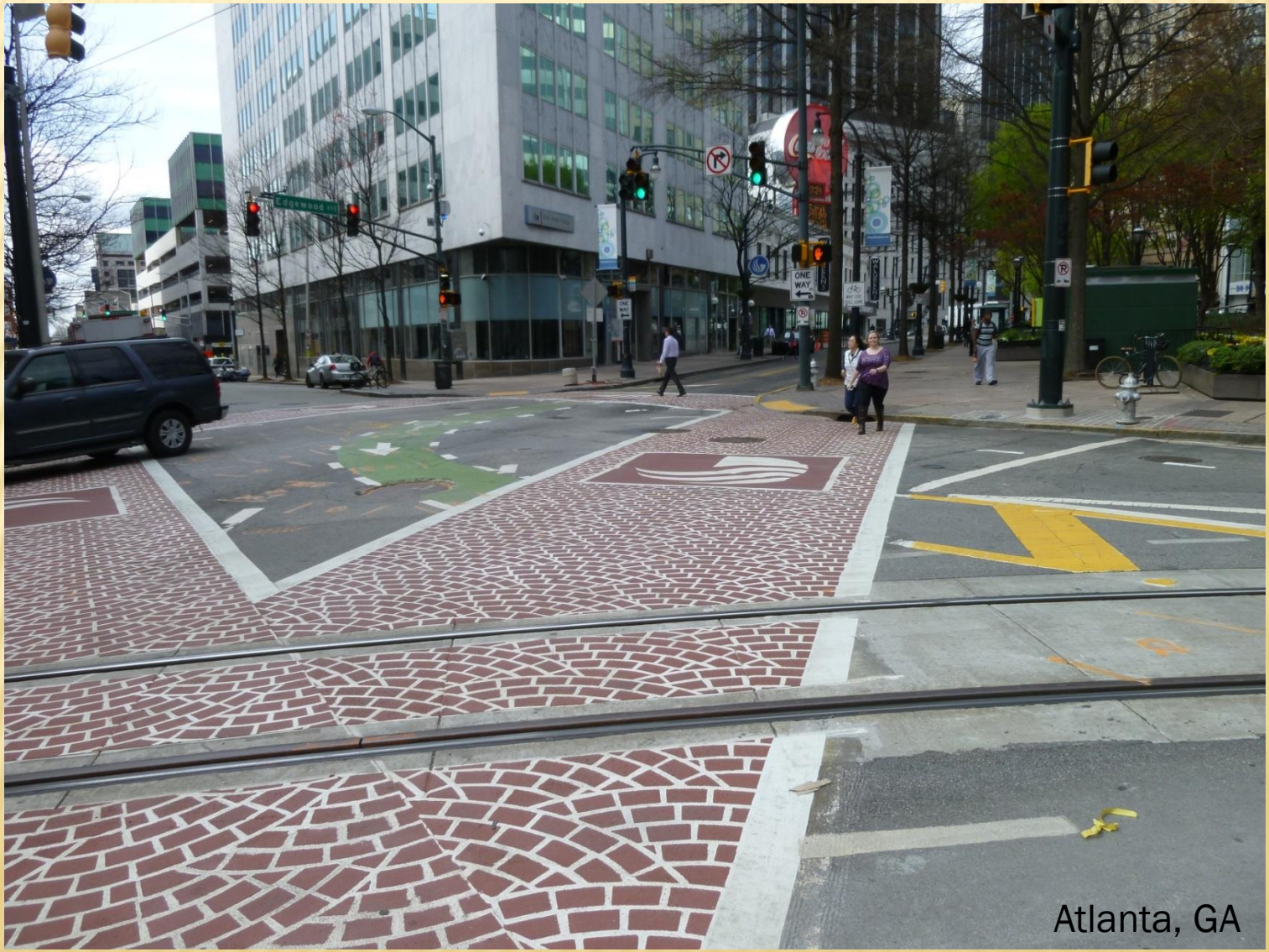
EXAMPLE TRANSITIONS

into a conventional bike lane



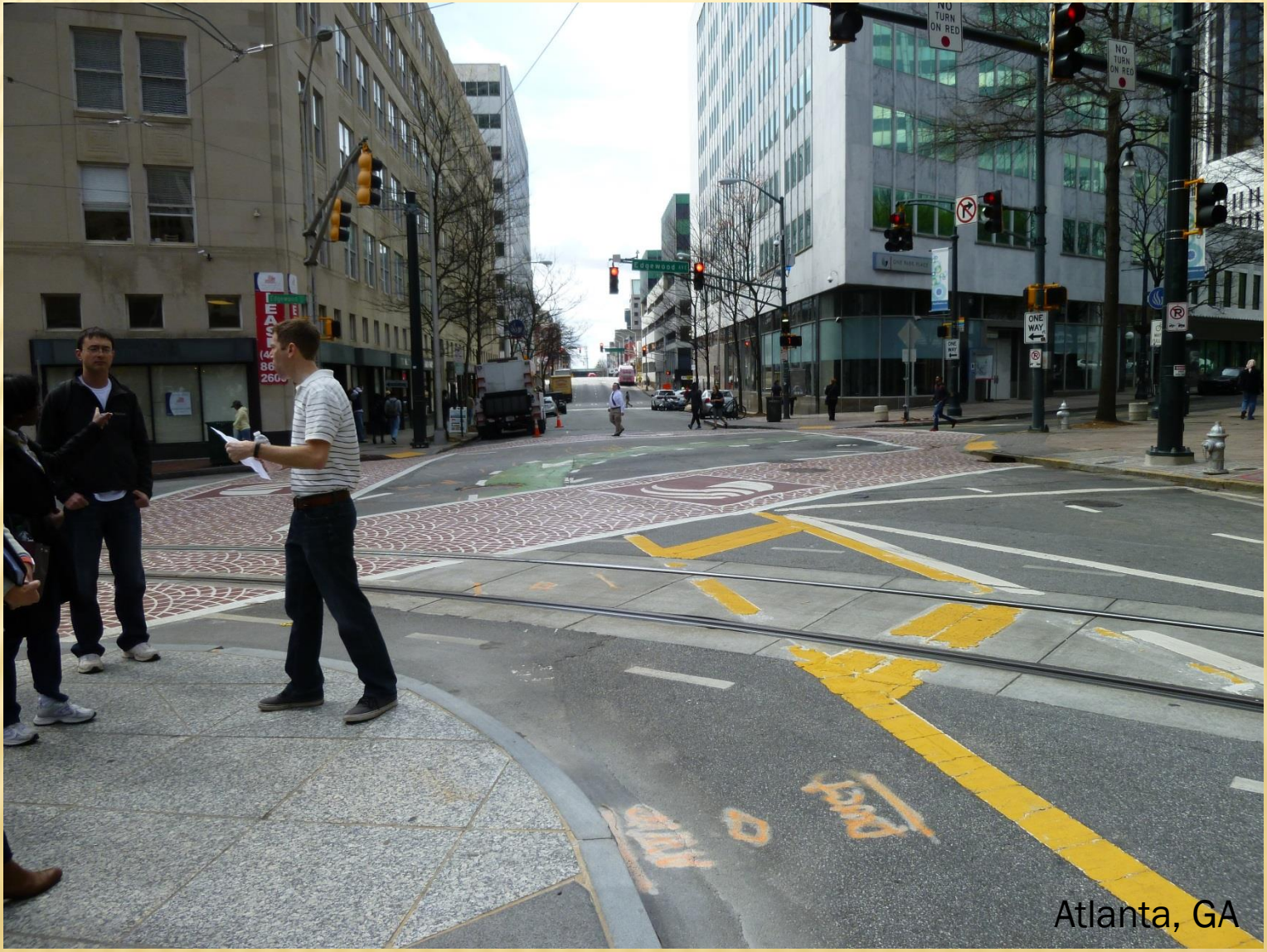
ACCESS TO/FROM SIDE STREET

ACCESS TO/FROM SIDE STREET



Atlanta, GA

ACCESS TO/FROM SIDE STREET



Atlanta, GA

ACCESS TO/FROM SIDE STREET

Atlanta, GA

STEEP GRADE TO INTERSECTION

Atlanta, GA

STEEP GRADE TO INTERSECTION

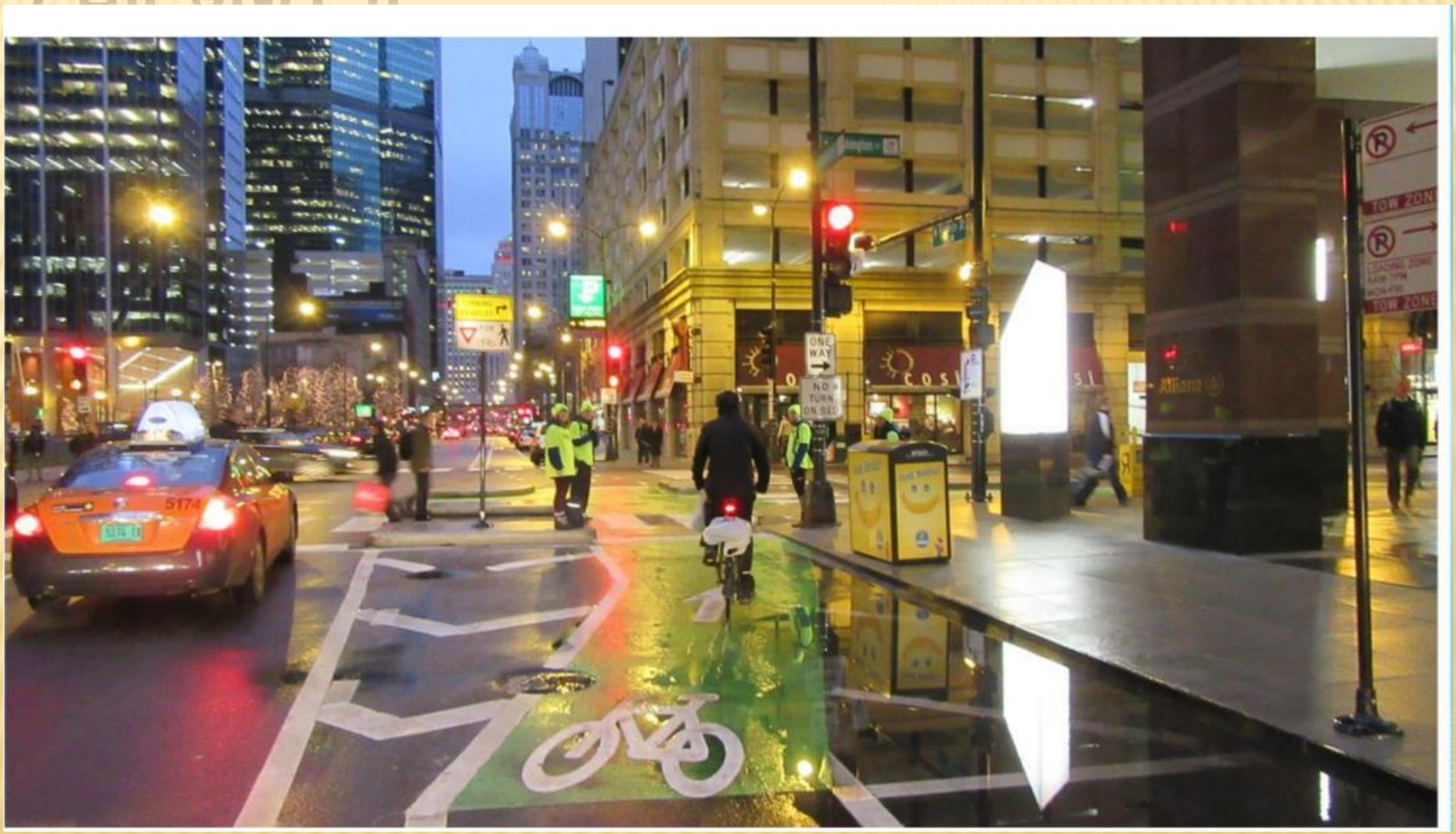
Atlanta, GA

Designing for Bicyclist Safety

SUMMARY THOUGHTS

CHICAGO, IL

CHICAGO, IL



CHICAGO, IL

LEARNING CHECK

- What options do you have to mitigate a right-turn conflict at an intersection?

LEARNING CHECK

- What options do you have to mitigate a right-turn conflict at an intersection?
  - Dashed bike lane pavement marking
  - Green pavement

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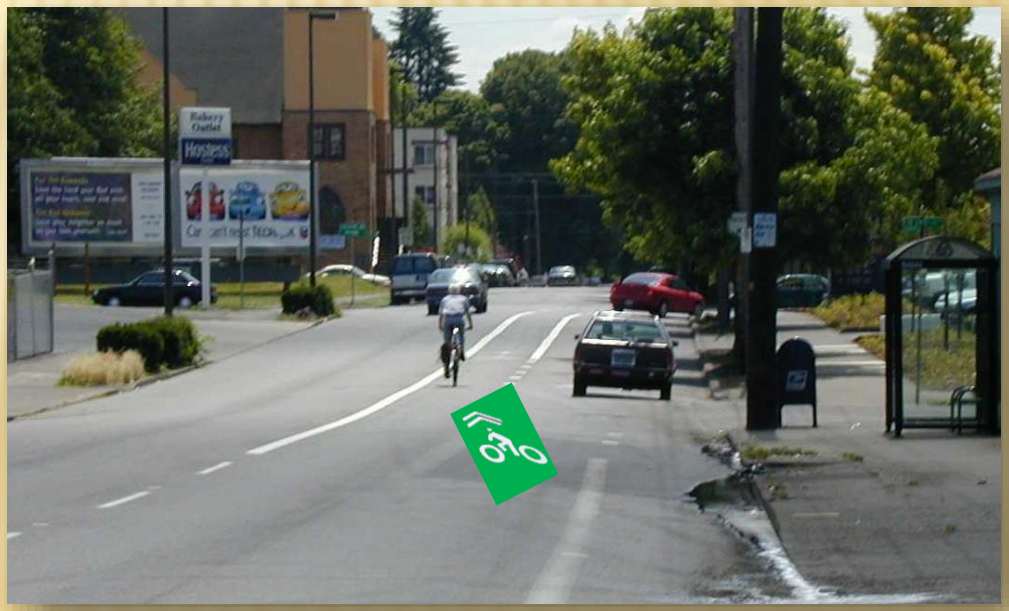
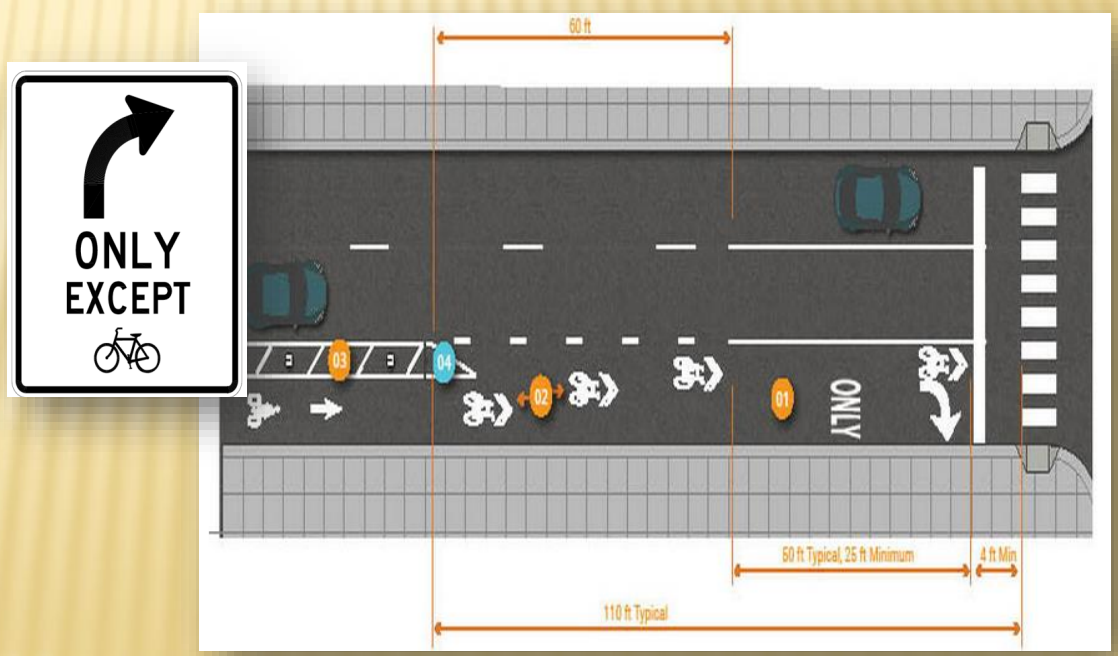


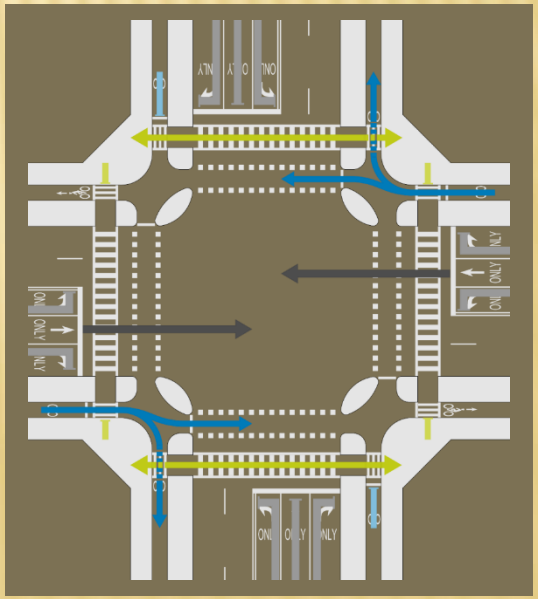
LEARNING CHECK

- What options do you have to mitigate a right-turn conflict at an intersection?
  - Shared-lane markings in the right turn/through lane
  - Right-turn-only-except-bikes



LEARNING CHECK

- What options do you have to mitigate a right-turn conflict at an intersection?
  - No turn on red for motorists
  - Bike signal face for bike through movement

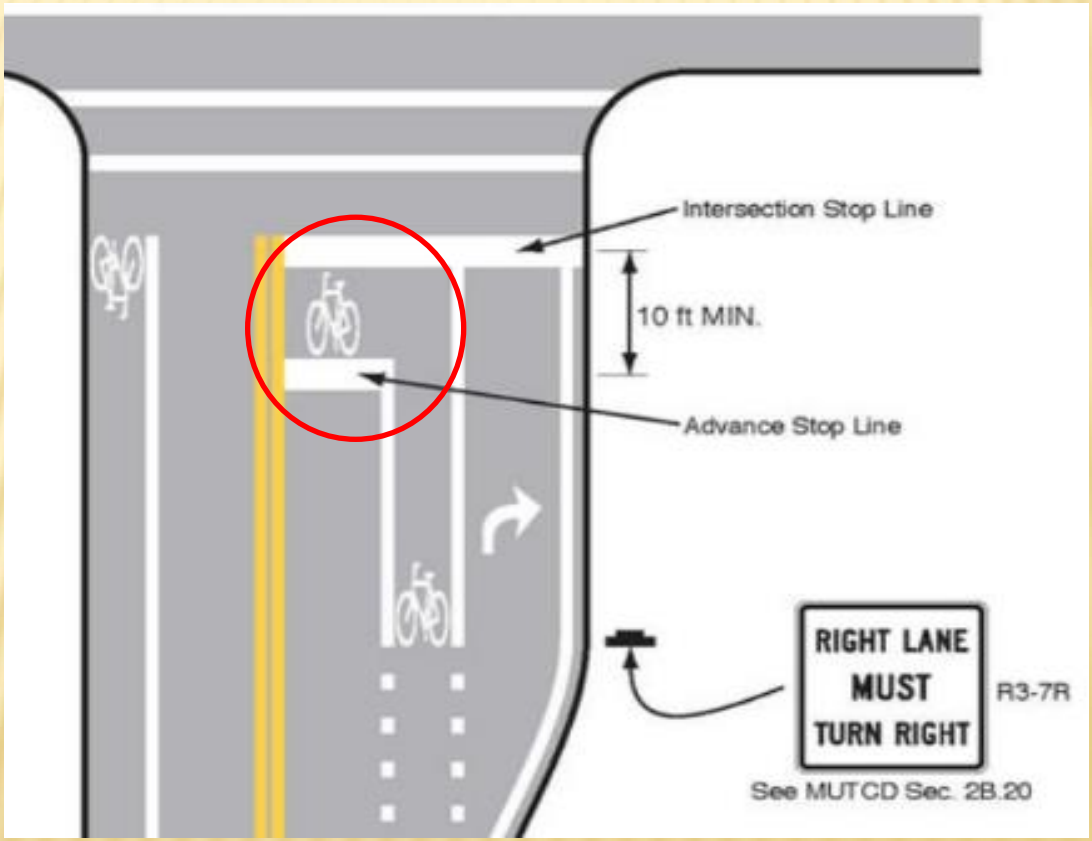


LEARNING CHECK

- What options do you have to mitigate a right-turn conflict at an intersection?
  - Bike ramps at roundabout
  - Shared lane markings at roundabout

LEARNING CHECK

- Identify the traffic control device.



LEARNING CHECK

- Identify the traffic control device.

Designing for Bicyclist Safety

QUESTIONS