Observations of Pedestrian Behavior and Facilities at Diverging Diamond Interchanges

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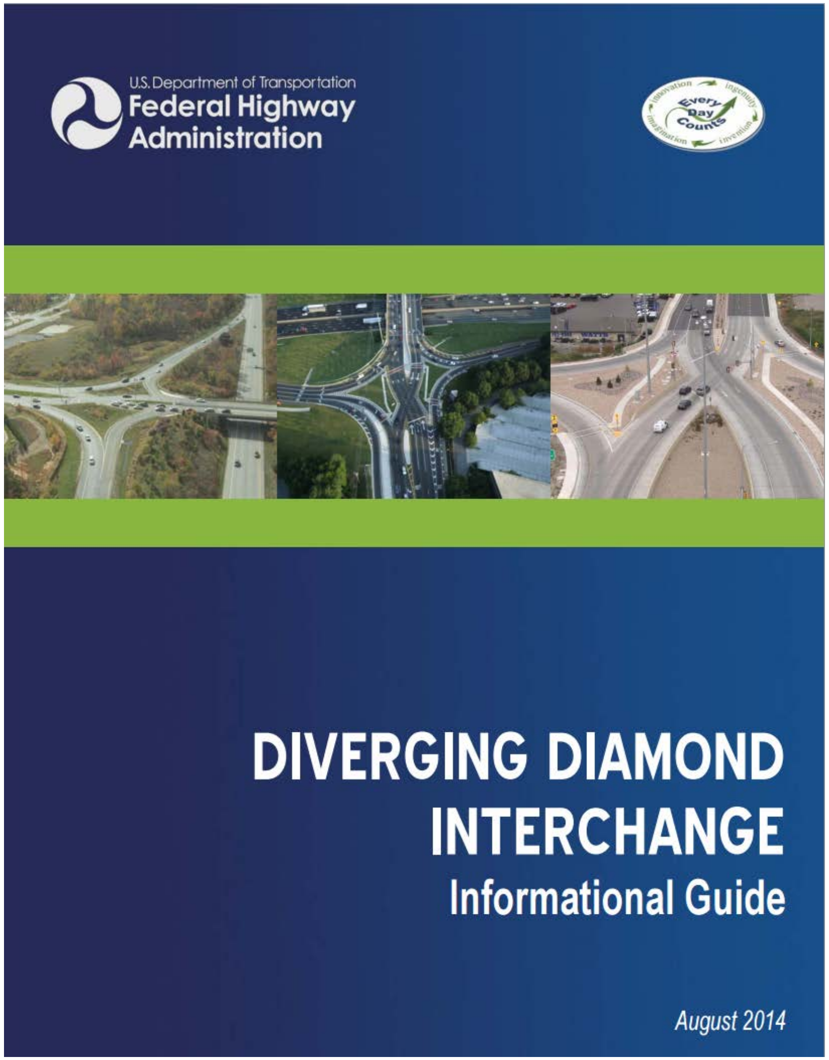
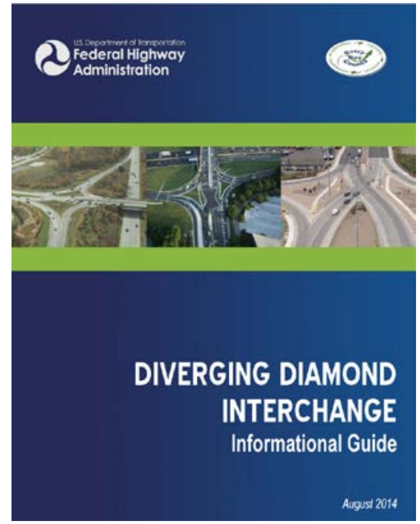
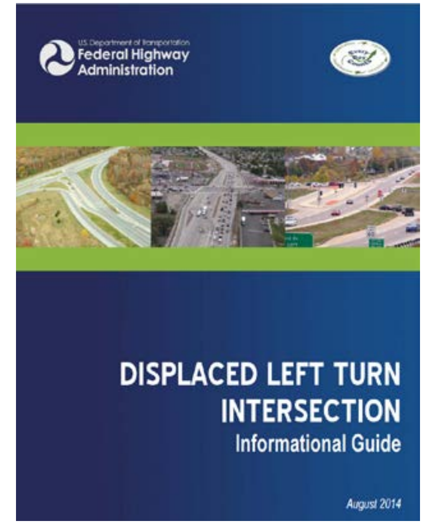
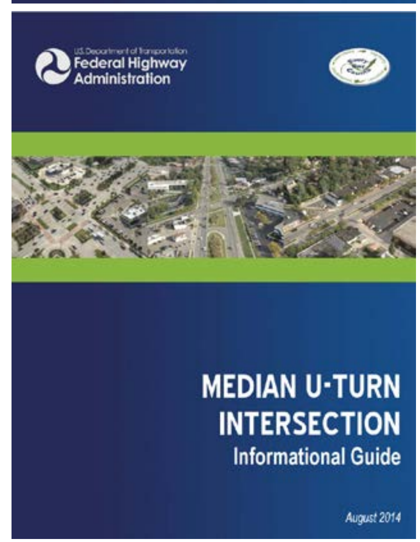
ITRE at N.C. State University

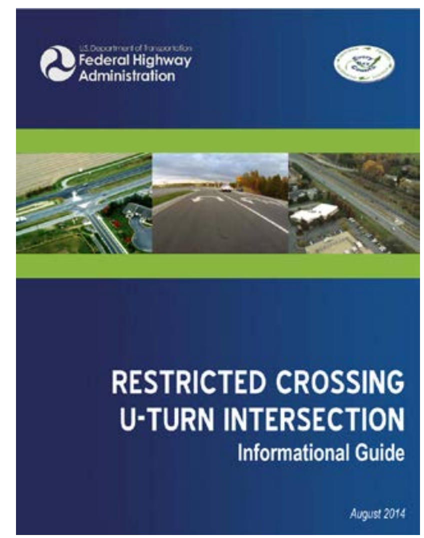
FHWA Diverging Diamond Interchange – Informational Guide











http://safety.fhwa.dot.gov/intersection/alter_design/

Multimodal Benefits of DDIs

- Reduced overall right-of-way footprint, compared to a standard diamond interchange;
- Two-phase traffic signal control with reduced pedestrian wait time;
- Minimized crossing distances;
- Simplification of conflicts to one-directional vehicular traffic; and
- Opportunities for bike lanes and multi-use paths through the interchange.

Challenges for Multimodal Users

- Altered travel paths with travel in the center of the interchange between vehicular lanes;
- Traffic approaching from unexpected directions;
- Unfamiliar signal phases; and
- Uncontrolled crossing of turn lanes.

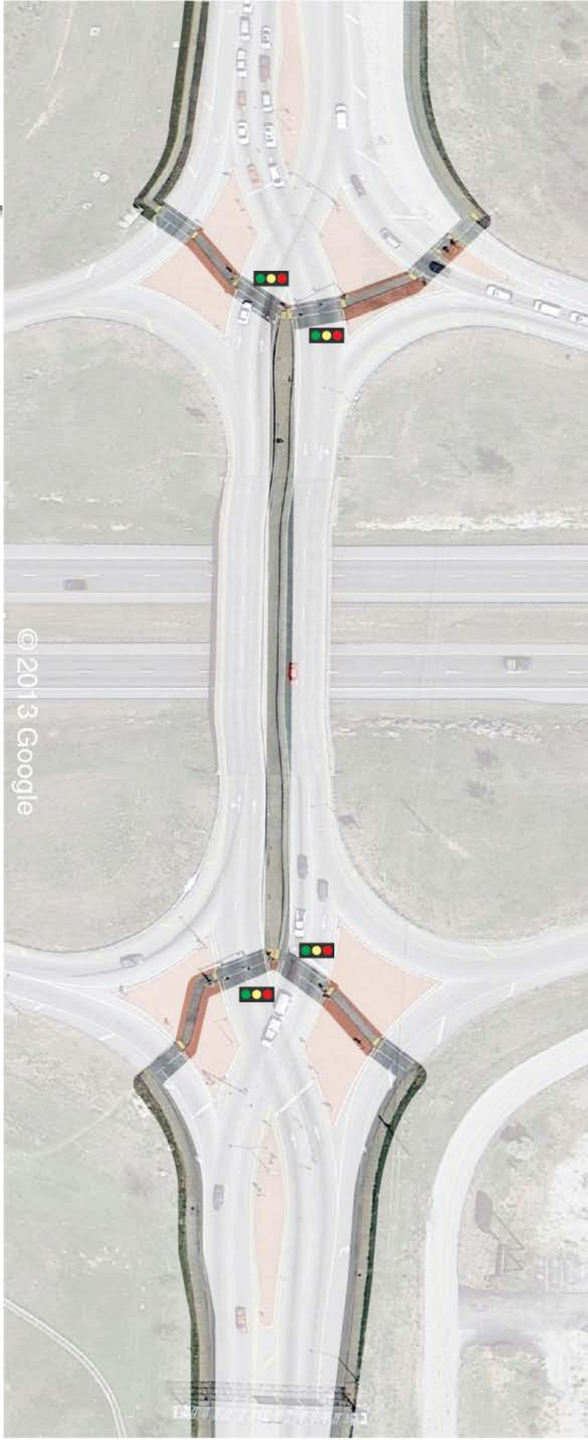
Pedestrian Center Walkway

MO13 DDI in Springfield, MO

Center Walkway

Advantages

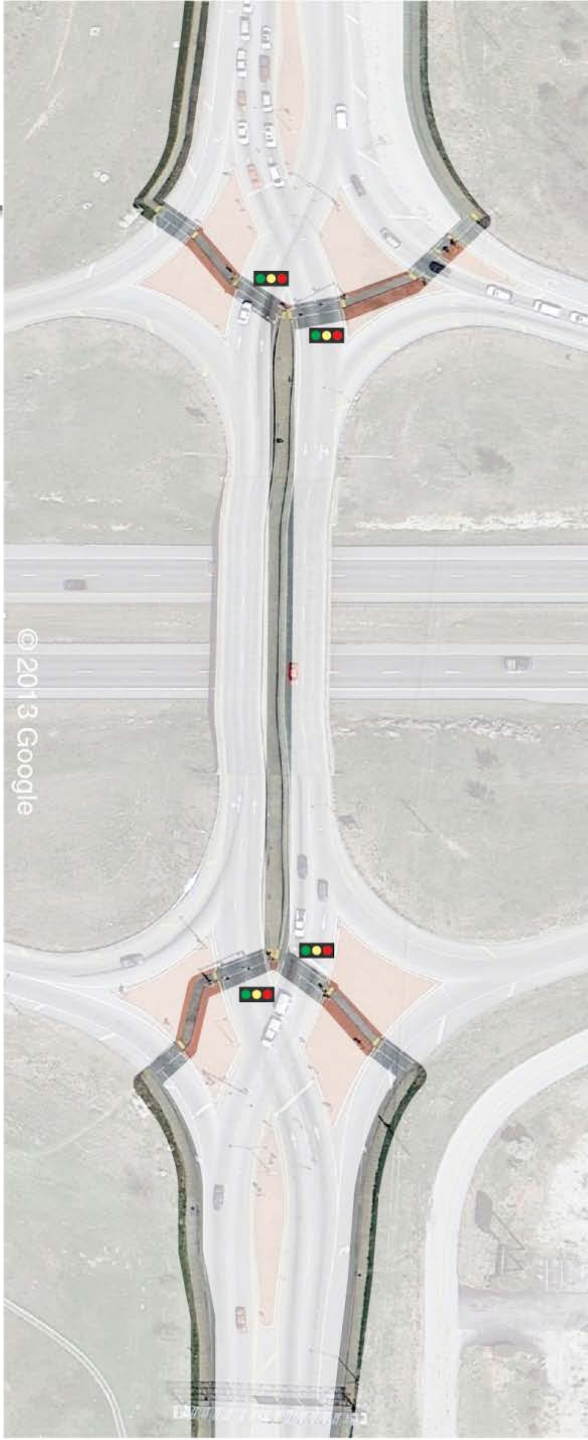
- Crossing of the arterial street provided Crossing one direction of traffic at a time
- Short crossing distances
- **No exposure to free-flowing left turns to freeway**
- Protected signalized crossing to walkway
- Pedestrian clearance time generally provided in crossover signal phasing
- Pedestrian delay to center minimized by short cycles at two-phase signals
- Side walls provide a positive barrier
- Recessed lighting can provide good illumination of walkway



Center Walkway

Challenges

- Crossing of free-flow right-turn movements to/from freeway
- Pedestrians may not know to look to the right when crossing to center
- Wait at center island dictated by length of signal phase for through traffic
- Location of pedestrian signals can conflict with vehicular signals at crossovers
- **Center walkway placement counter to typical hierarchy of street design**
- Potential discomfort from moving vehicles on both sides of walkway
- Sign and signal control clutter



Pedestrian Outside Walkway

Dorsett Road DDI in Maryland Heights, MO

Outside Sidewalk/Path

Advantages

- Crossing one direction of traffic at a time
- Ramp crossing distances are often shorter than through traffic crossing distance
- **Extension of existing pedestrian network (natural placement on outside of travel lanes)**
- Pedestrian typically has view of path ahead (depends on sight lines and obstructions)
- Walkway doesn't conflict with center bridge piers (at underpass)
- Opportunity to use right-of-way outside of bridge piers (at underpass)

Outside Sidewalk/Path

Challenges

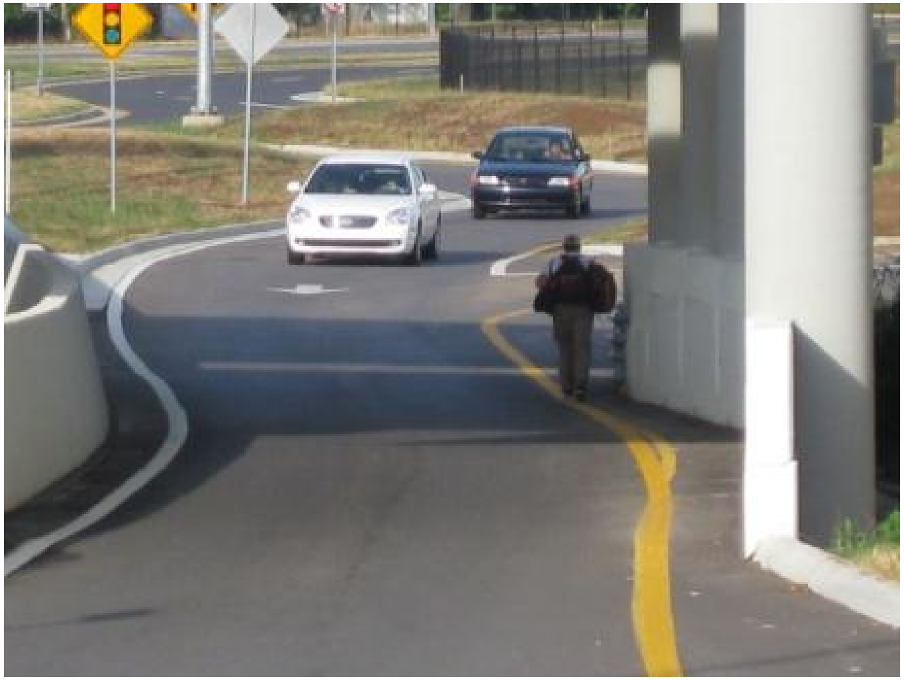
- **Crossing of free-flow right-turn movements, and conflict with free-flow left turns to freeway**
- Crossing of the arterial street sometimes not provided
- Potential sight obstruction of pedestrian crossing left turns behind barrier wall
- Pedestrians may not know which direction to look in, when crossing turn
- Unnatural to look behind to check for vehicles before crossing
- Signalized crossings require more complicated timing
- Need for widened structure for overpass
- Potential for additional right-of-way for underpass

Site Audits: Five key questions to ask

1. Can pedestrian walk safely and comfortably?
2. Do pedestrians understand when and where to cross?
3. Are pedestrian crossings visible for drivers?
4. How fast and how heavy is conflicting vehicular traffic?
5. Are walkways and crossings accessible?

1. CAN PEDESTRIANS WALK SAFELY AND COMFORTABLY?

Without Facilities, Pedestrian are faced with tough choices



Source: ITRE

Pedestrian walking in road due to lack of pedestrian facilities

Source: ITRE

Pedestrian walking through ditch outside of concrete barrier.

Pedestrian Facilities can become part of the design

Source: ITRE

Project landscaping at outside pedestrian facilities

Source: ITRE

Wide center walkway with physical separation that is not too high

Pedestrian walkway with guardrails

Watch for Obstacles, Obstruction, and Uncomfortable Walking Environment

Pole in DDI center walkway

Source: ITRE

Source: ITRE

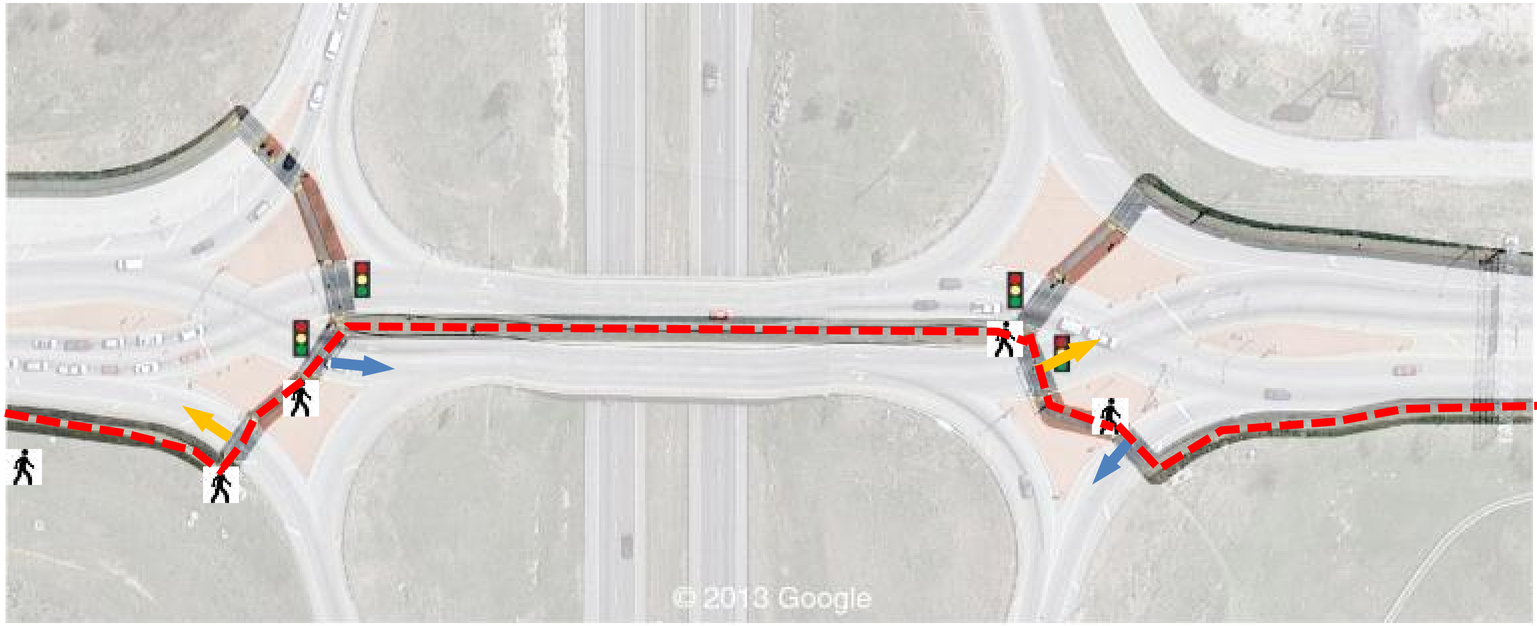
Tight DDI center walkway with high barrier walls

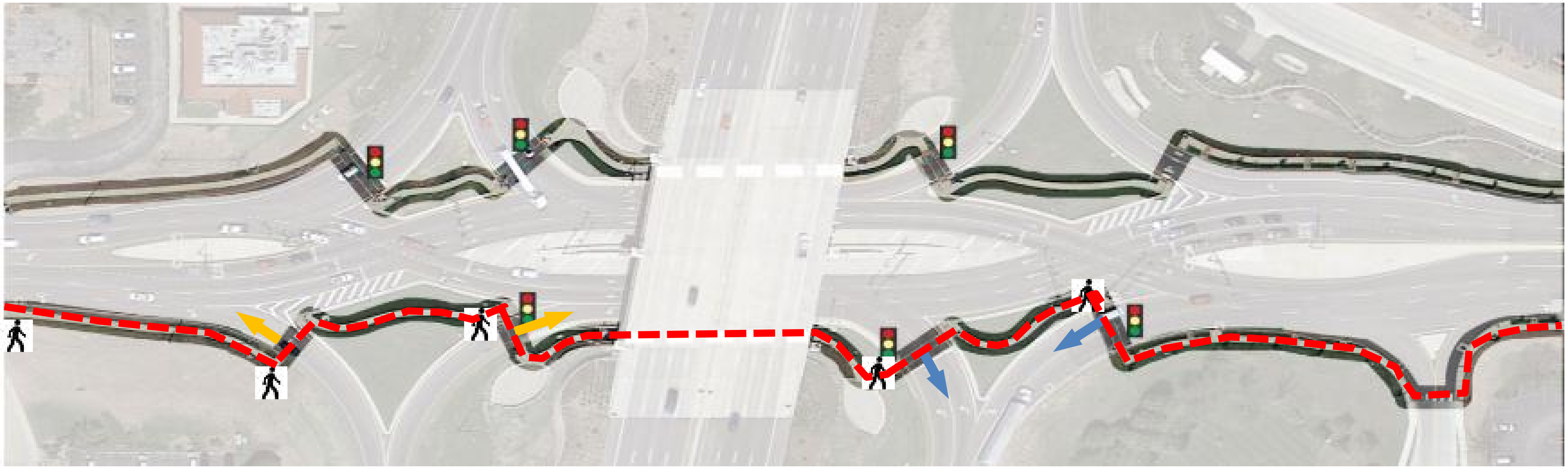
2. DO PEDESTRIANS UNDERSTAND WHEN AND WHERE TO CROSS?

Pedestrian Channelization and Wayfinding

DDI Walkways

Look Left
Look Right





Communicating Direction of Traffic

Source: Google

Pedestrian markings to indicate directionality of traffic (Maryland Heights, MO).

Unusual Geometry brings Unusual Challenges

"Don't Walk" shown together with vehicle "green" at DDI crossover

Source: ITRE

Source: ITRE

Sight-obstructions at DDI crossover

3. ARE PEDESTRIANS VISIBLE TO DRIVERS?

Sight Distance and Visibility Matter

- Open sight lines and good visibility can contribute to increased driver awareness and yielding
- Limited sight lines also impact audible information available at the crosswalk

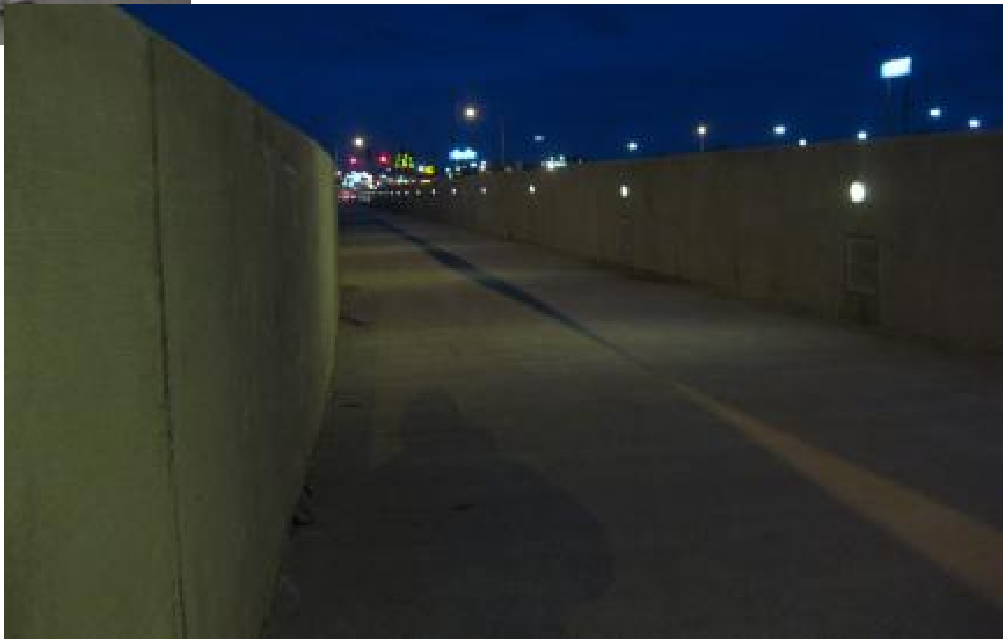
DDI Free-Left Turn Conflict (for Outside Walkway)

Example of pedestrian crossing at free-flow left onto freeway

Lighting is Important

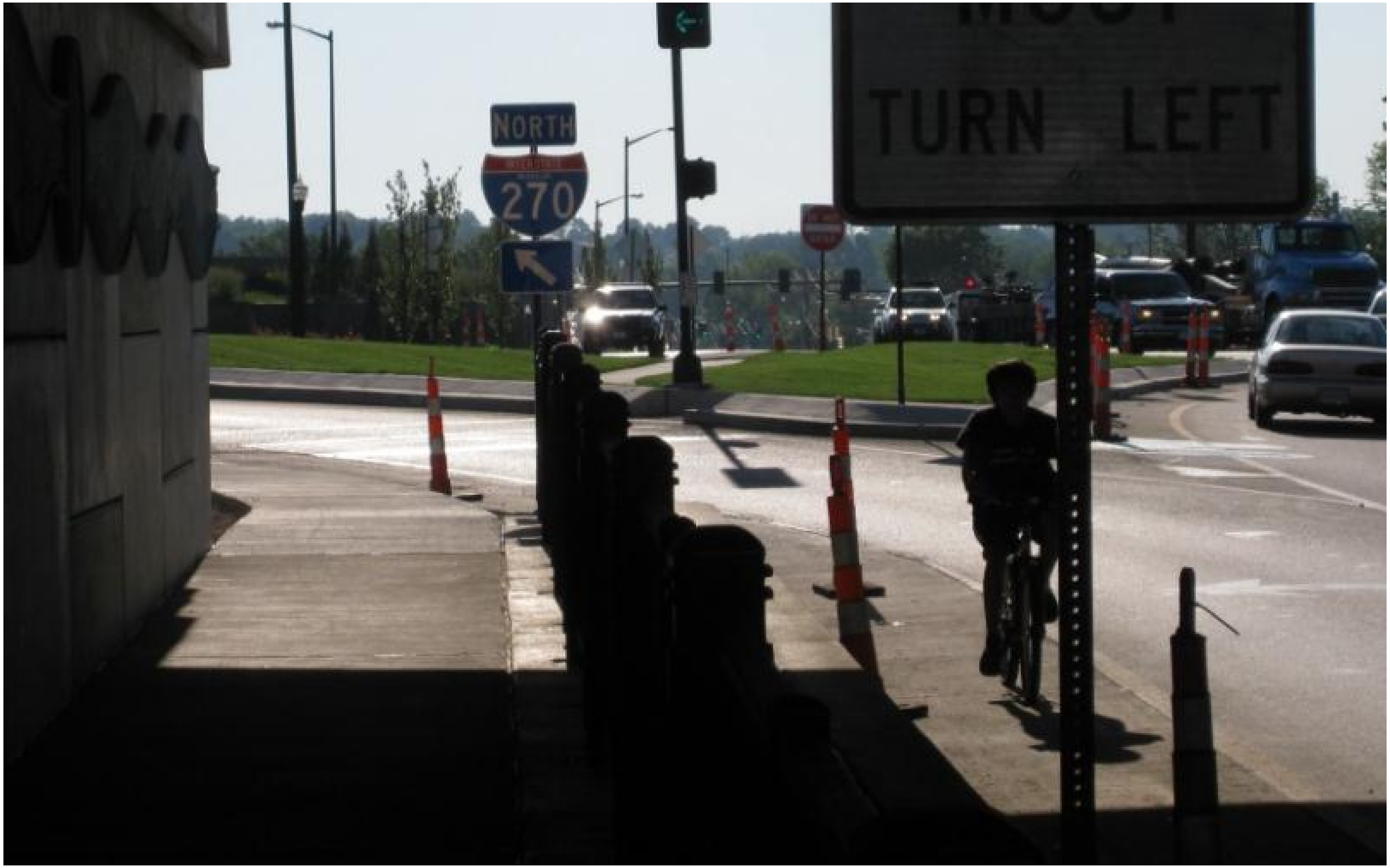
Source: ITRE

Source: ITRE



Lighting on the pedestrian walkway

Lighting in Underpasses



Source: ITRE

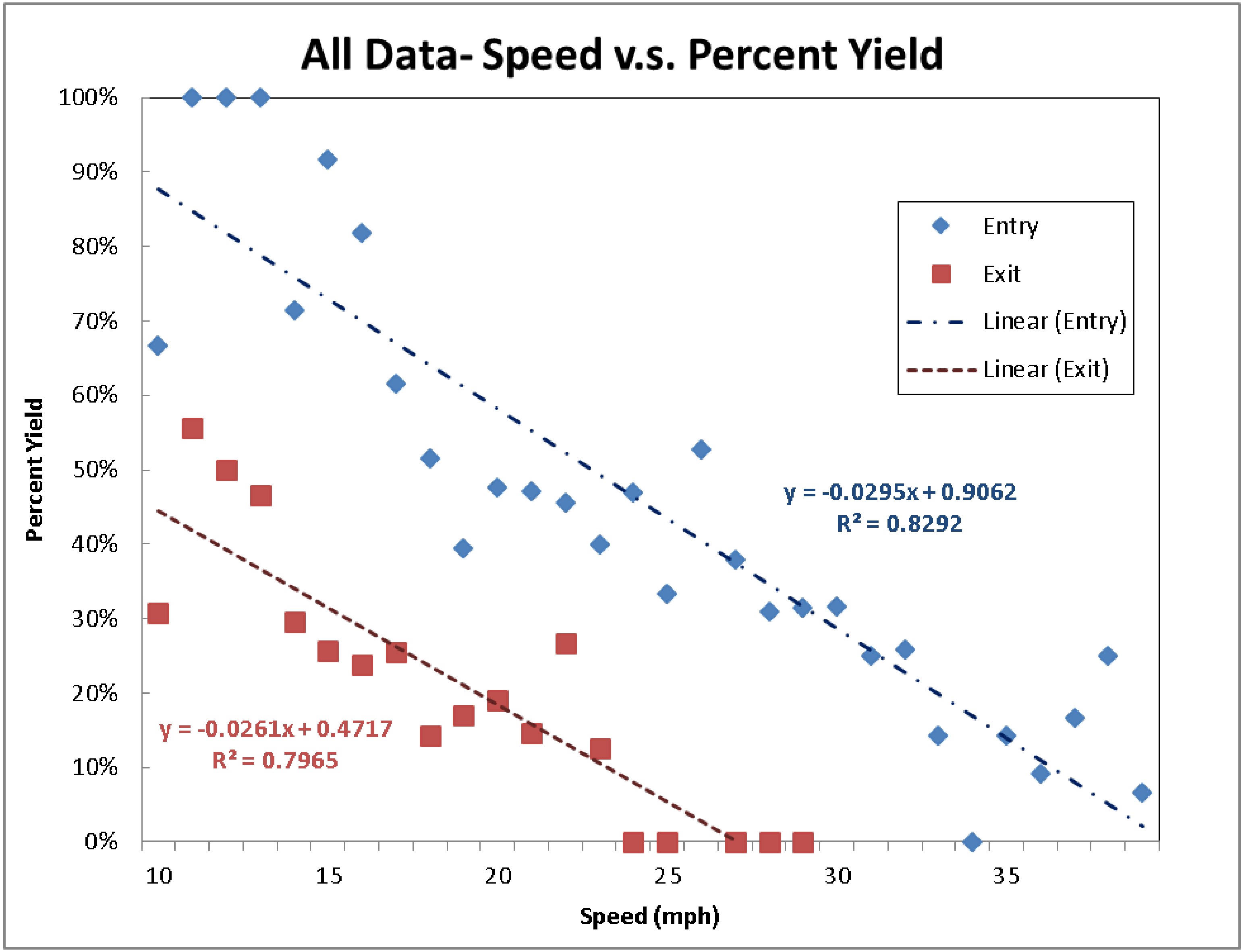
Bicyclist riding in striped shoulder against traffic through DCD crossovers

4. HOW FAST AND HOW HEAVY IS CONFLICTING VEHICULAR TRAFFIC?

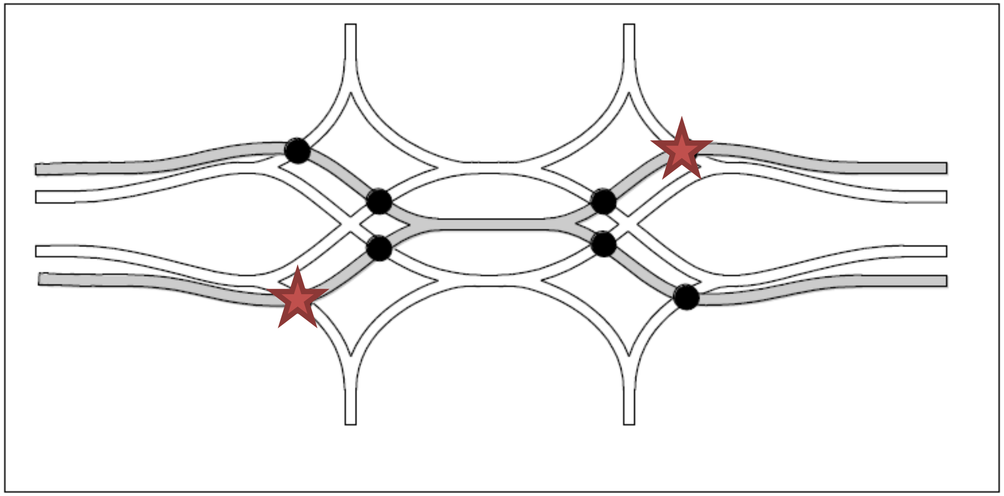
Speed Matters

- Faster Speeds linked to reduced yielding and increased risk
- Prior research also linking higher speeds to greater injury risk and reduced driver attentiveness to pedestrians

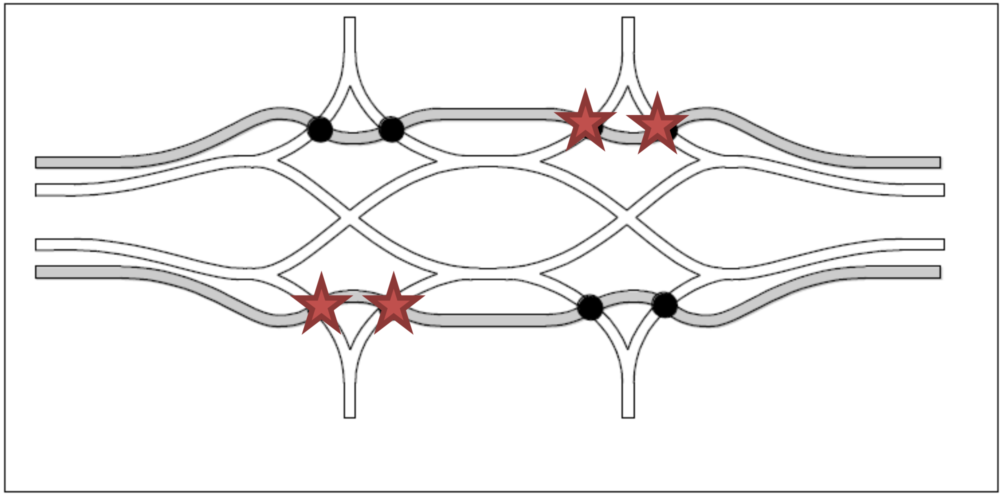
Impact of Speed on Driver Yielding at Two-Lane Roundabouts (6 Sites in 4 states)



Consider Driver Action at DDI

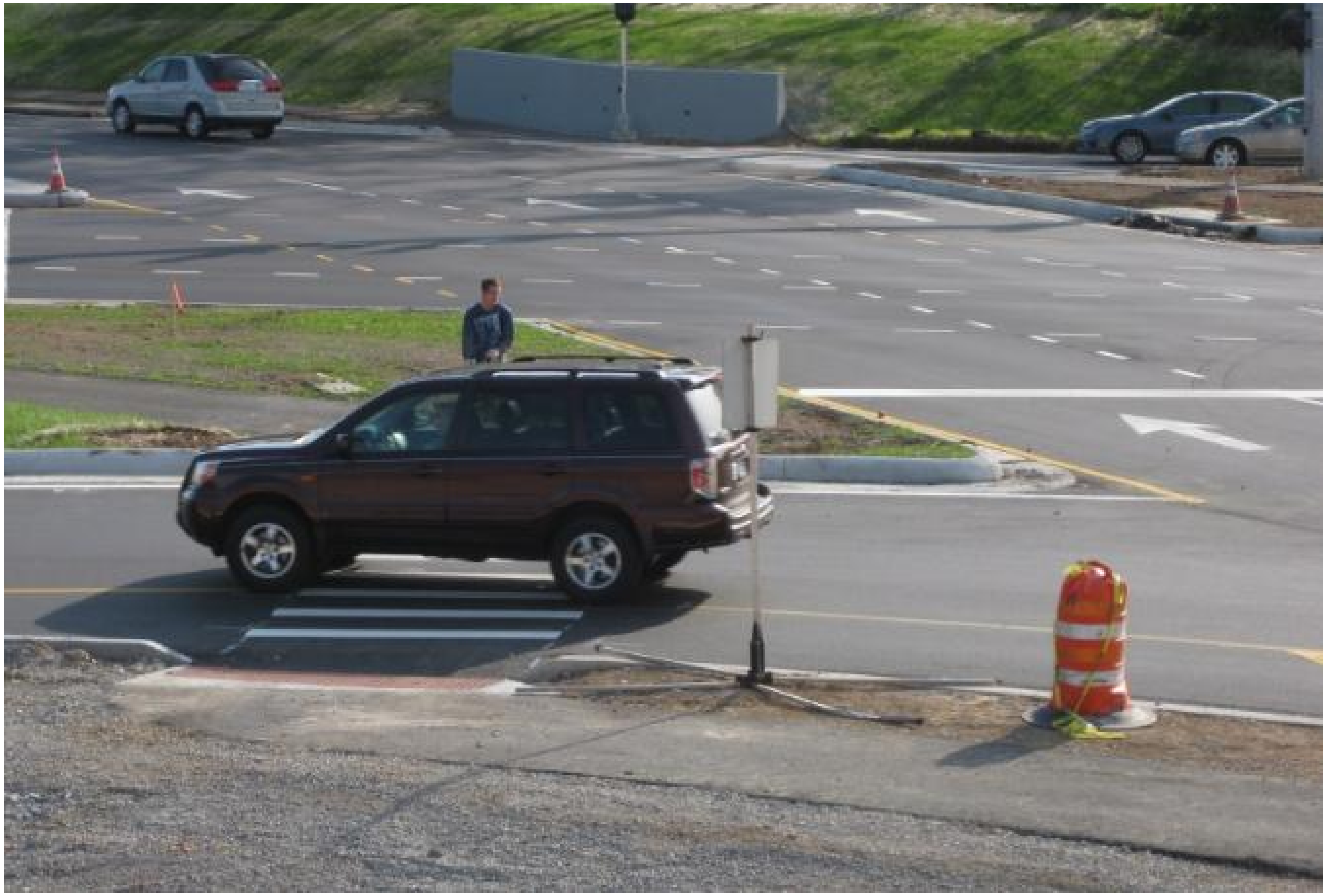


- 8 Conflict Points
  - ★ 2 free/flow or accelerating
  - 6 stopped or decelerating



- 8 Conflict Points
  - ★ 4 free/flow or accelerating
  - 4 stopped or decelerating

Vehicles accelerating to freeway speeds are unlikely to yield (DDI)

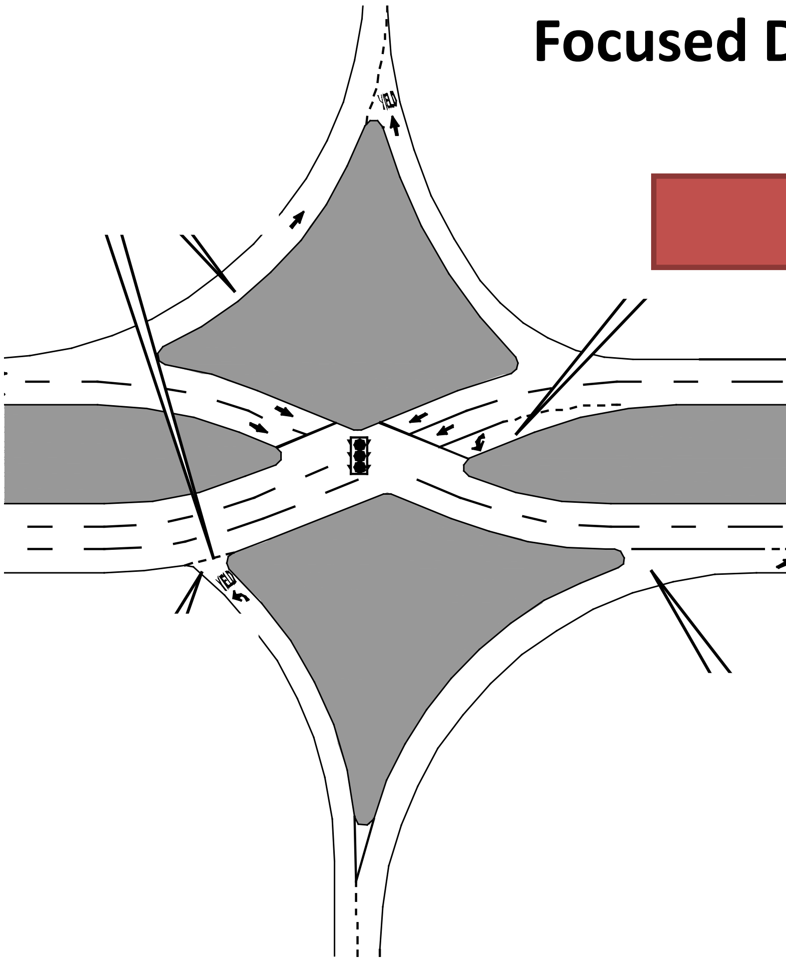


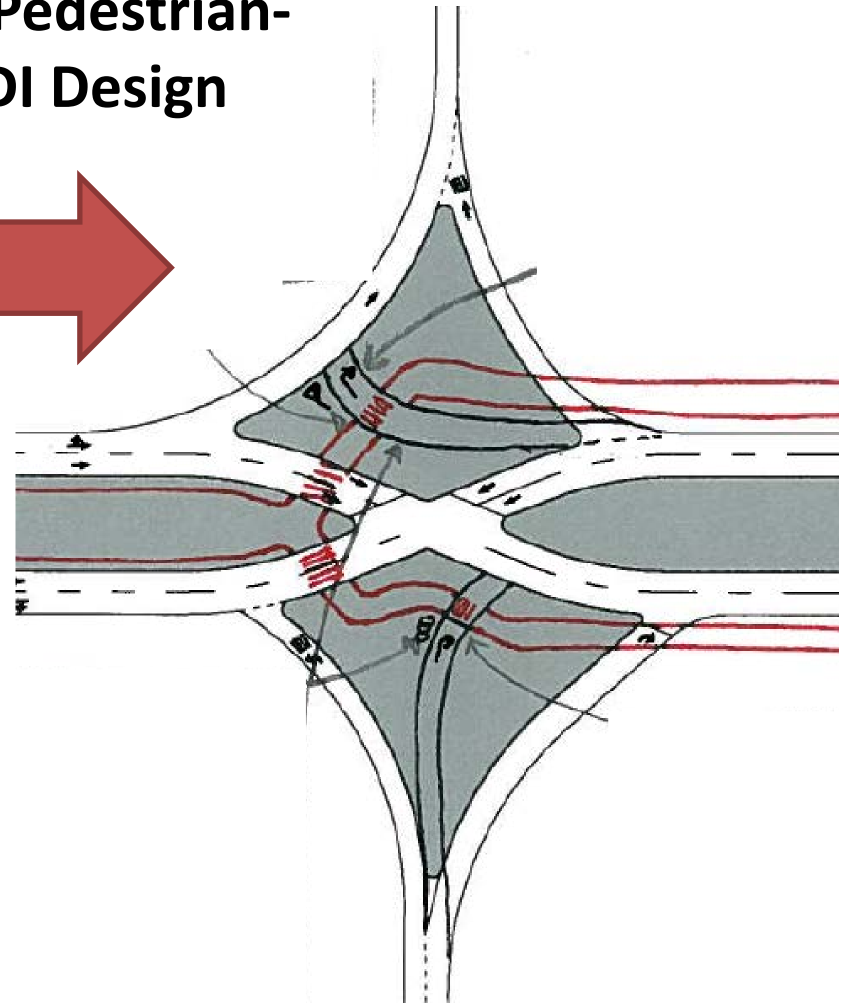
Source: ITRE

Driver failure to yield creates left-turn conflict with pedestrian.

Pedestrian-Focused DDI Design

Towards a Pedestrian-Focused DDI Design





- Larger Radii contribute to greater vehicle speeds and more risky crossing environment

Traffic Volume Matters

- Higher traffic volume can contribute to more yielding (vehicles slow and already delayed)
- But higher traffic are also linked to higher likelihood of multiple-threat events (at multi-lane crossings)
- And, higher traffic volume can also increase the ambient noise level

5. ARE WALKWAYS AND CROSSINGS ACCESSIBLE?

Pedestrians with Disabilities – Basic Principles for Pedestrian Walkways

- Delineate the walkway through landscaping, curbing, or fencing to assist with wayfinding for blind pedestrians.
- Use fencing under the bridge structure where landscaping is more difficult to maintain.
- Provide adequate width and slope for wheelchair users, also considers other non-motorized users.
- Construct an appropriate landing with flat slope and sufficient size at crossing points.

Pedestrians with Disabilities – Basic Principles for Crossing Points

- Provide curb ramps and detectable warning surfaces at the edge of the sidewalk and transition to the street
- Provide accessible pedestrian signals with locator tone at signalized crossings
- Locate push-buttons to be accessible by wheelchairs and adjacent to the crossing at a minimum separation of 10 feet
- Use audible speech messages where spacing is less than 10 feet or where additional narrative for the expected direction of traffic is needed
- Align the crosswalk landing to the intended crossing direction
- Conduct targeted outreach and prepare additional informational material created with these specific users in mind.

Pedestrian Channelization and Wayfinding


Source: Google

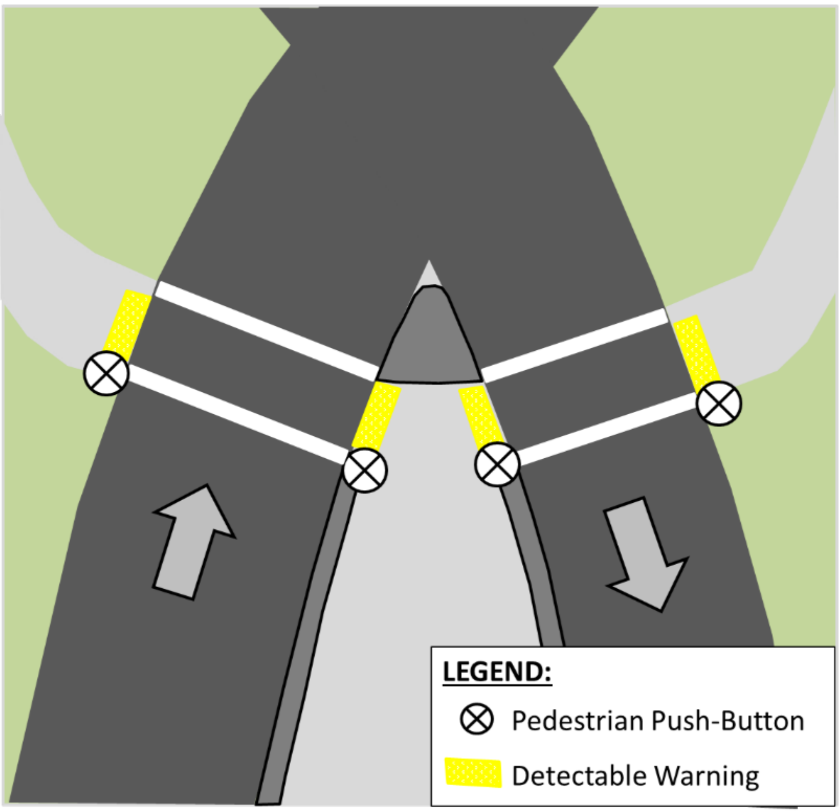

Source: Google

Pedestrian Push-Buttons and APS

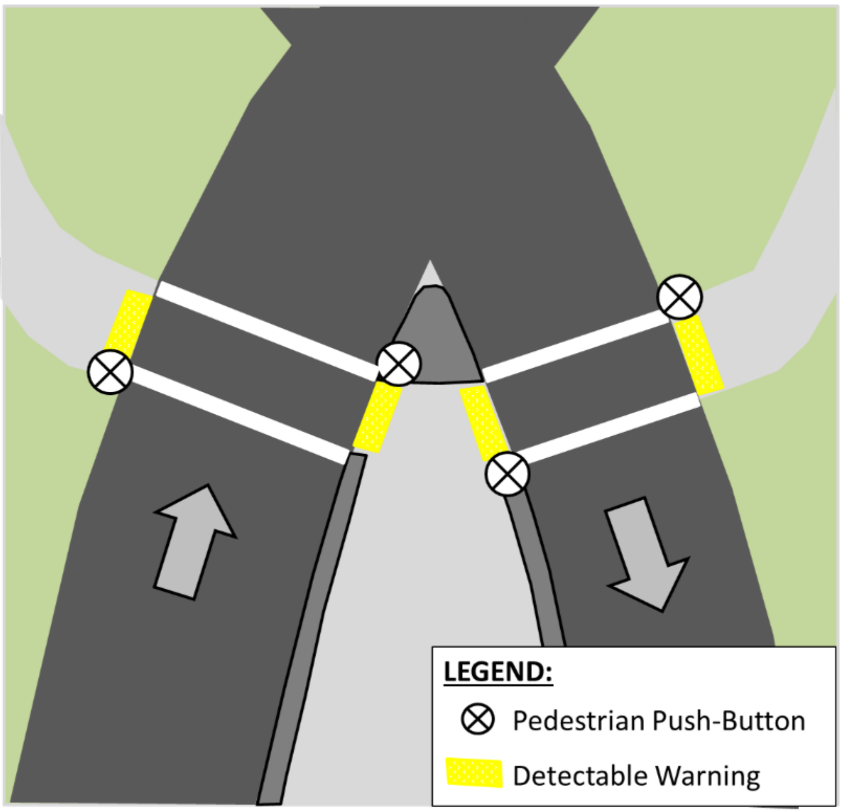
Undesirable use of single pole with two pedestrian push-buttons, no APS, and insufficient separation of the two detectable warning surfaces

Other Options for Push-Buttons

DDI splitter island with pedestrian signals on same side.



DDI splitter island with diagonal pedestrian signals



Consider pedestrians in initial design and throughout design process!

Source: ITRE

Avoid need to retrofit by better initial placement of pole and/or walkway

Source: ITRE

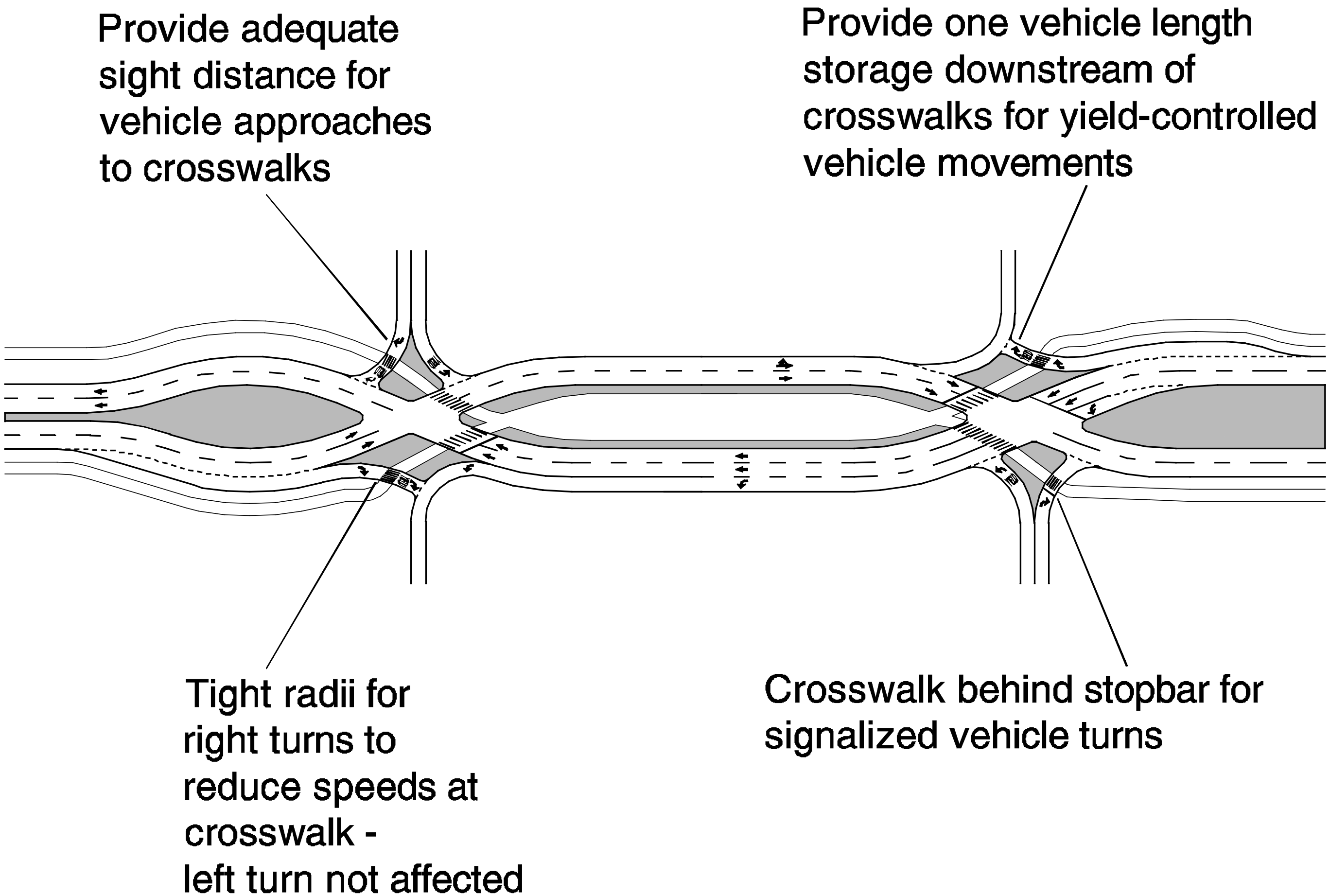
Available right-of-way in island would have allowed for "perpendicular" crosswalk and walkway directing peds towards crossing

CLOSING THOUGHTS

Five key questions to ask

1. Can pedestrian walk safely and comfortably?
2. Do pedestrians understand when and where to cross?
3. Are pedestrian crossings visible for drivers?
4. How fast and how heavy is conflicting vehicular traffic?
5. Are walkways and crossings accessible?

Pedestrian-Focused DDI Design



Questions and Discussion

Pedestrian and Bicyclist Accommodations and Crossings on Superstreets

TRB Innovative Intersections for Pedestrians and Bicyclists

August 19th, 2015

Anne M. Holzem, PE, PTOE

Research Objective:

US-17 in Leland, NC
Courtesy of NCDOT

To modify current superstreet design and operations in North Carolina to better serve pedestrians and bicyclists.

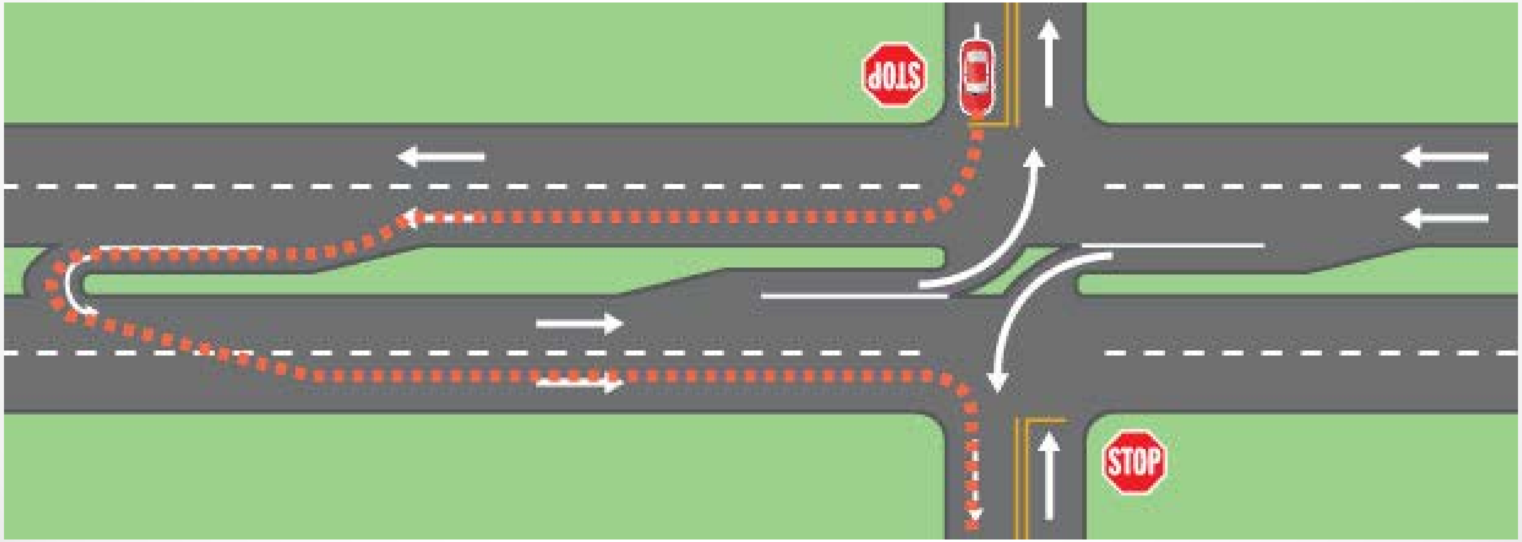
Outline

- Superstreet
- Crossing Alternatives
- Field Data – Simulation Calibration
- Simulation
- Results
- Recommendations
- Additional Current Practice

Superstreet

Superstreet (RCUT / J-Turn)

- 2 one-way streets – great signal progression
- 2 signal phases
  - o 14 conflict points

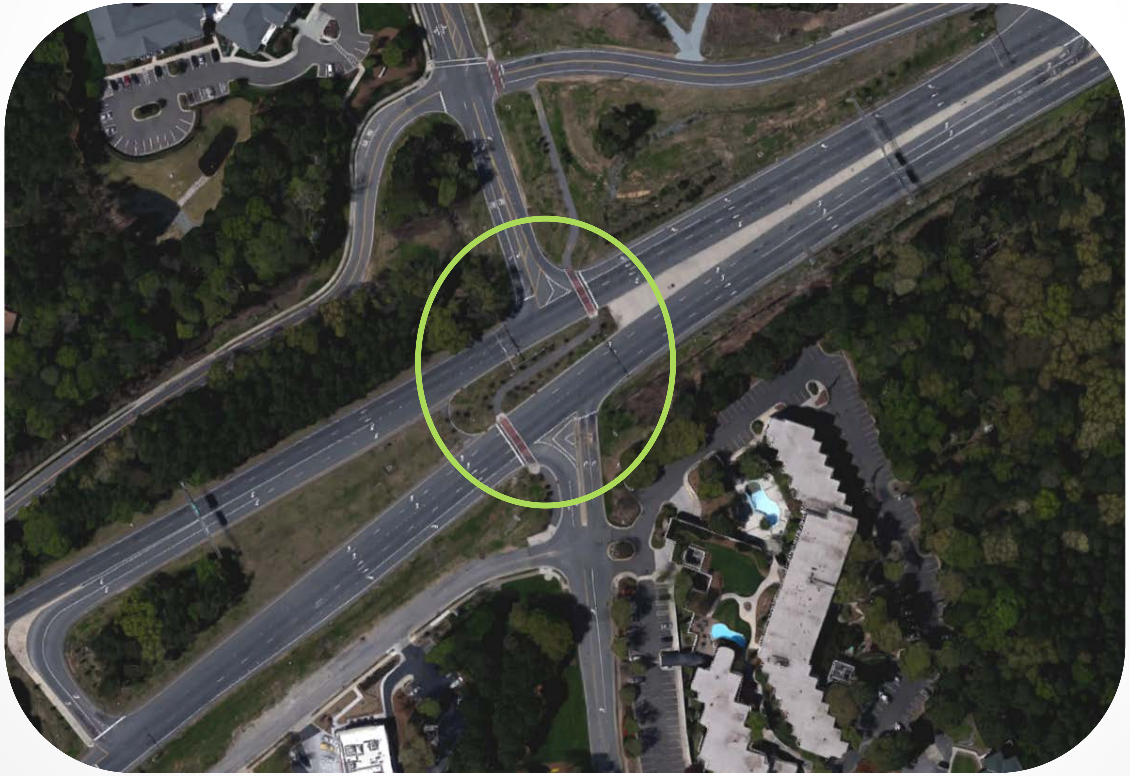


www.aarp.org

Crossing Alternatives

Crossing Alternatives

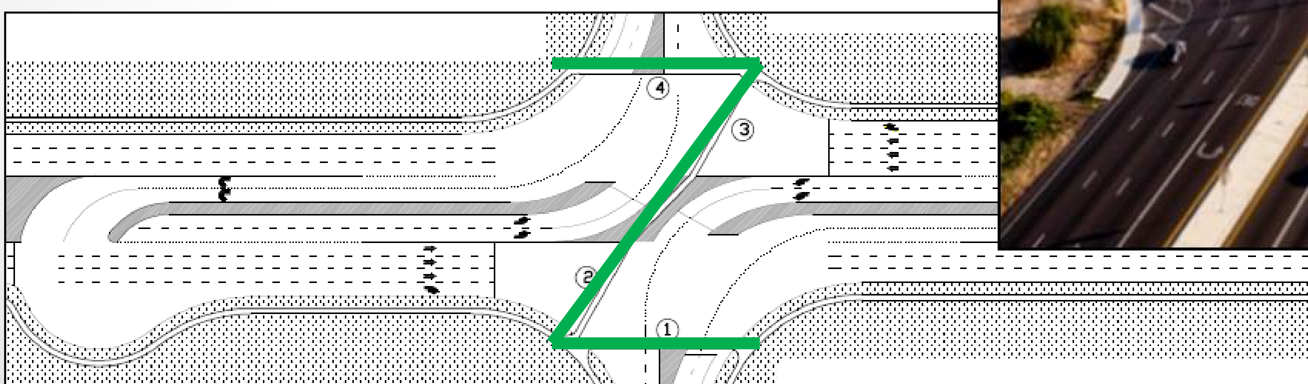
Existing Crossing in NC



Source: Google

Crossing Alternatives

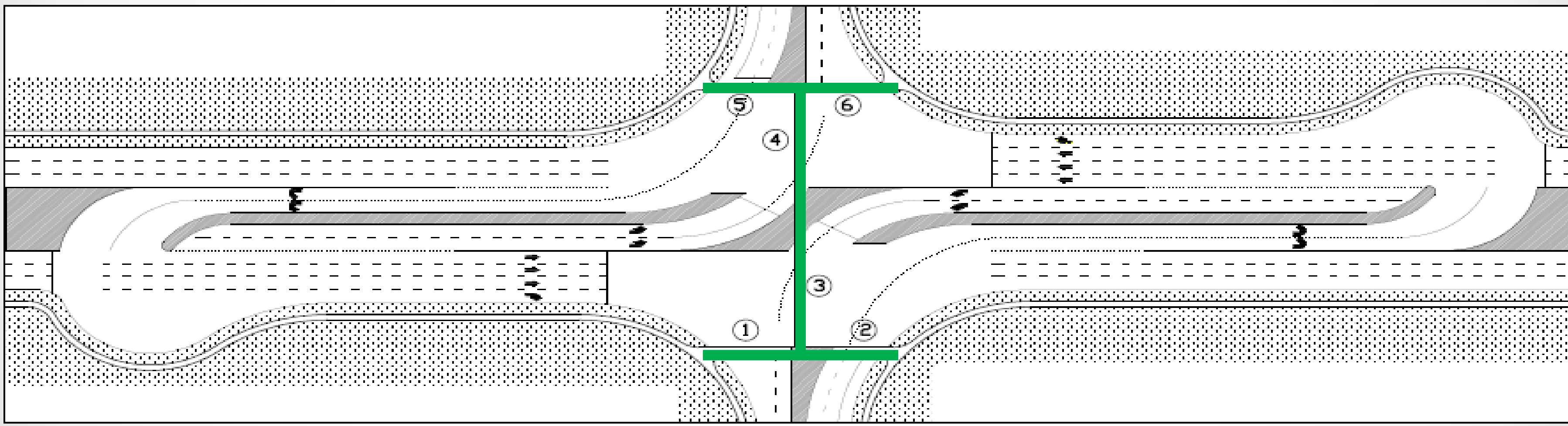
Diagonal Cross (Pedestrian)



San Antonio, TX
Source: Gilmer Gaston, Pape-Dawson Engineers

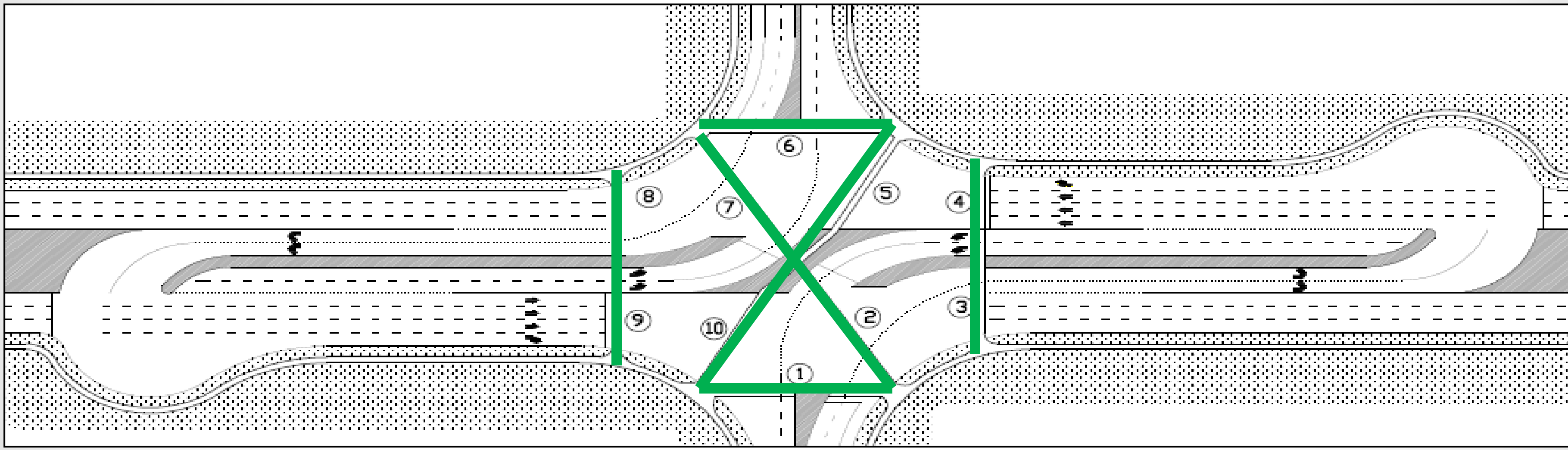
Crossing Alternatives

Median Cross (Pedestrian)



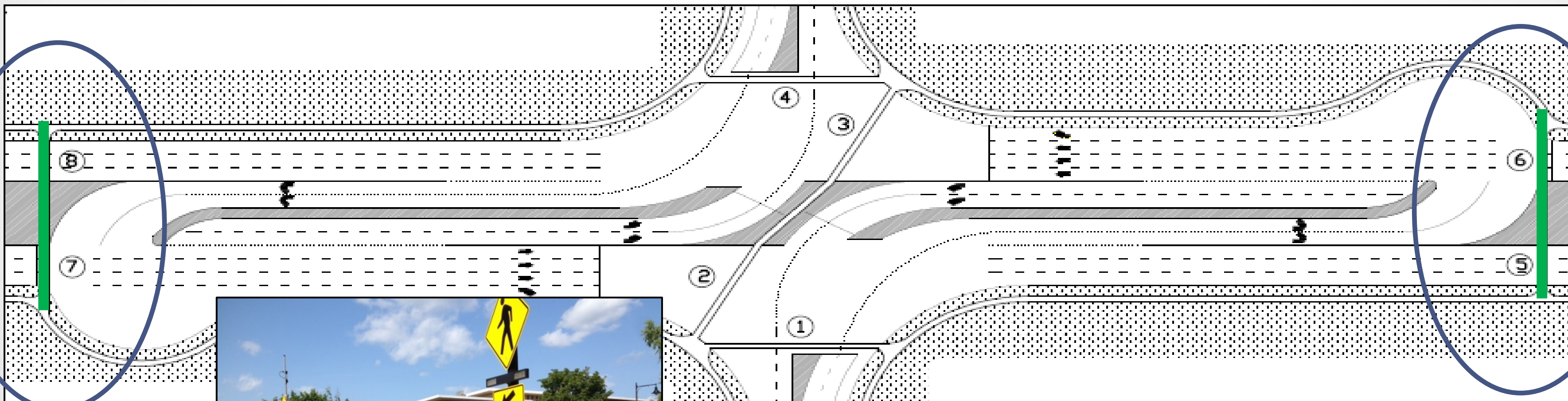
Crossing Alternatives

Two-Stage Barnes Dance Cross (Pedestrian)



Crossing Alternatives

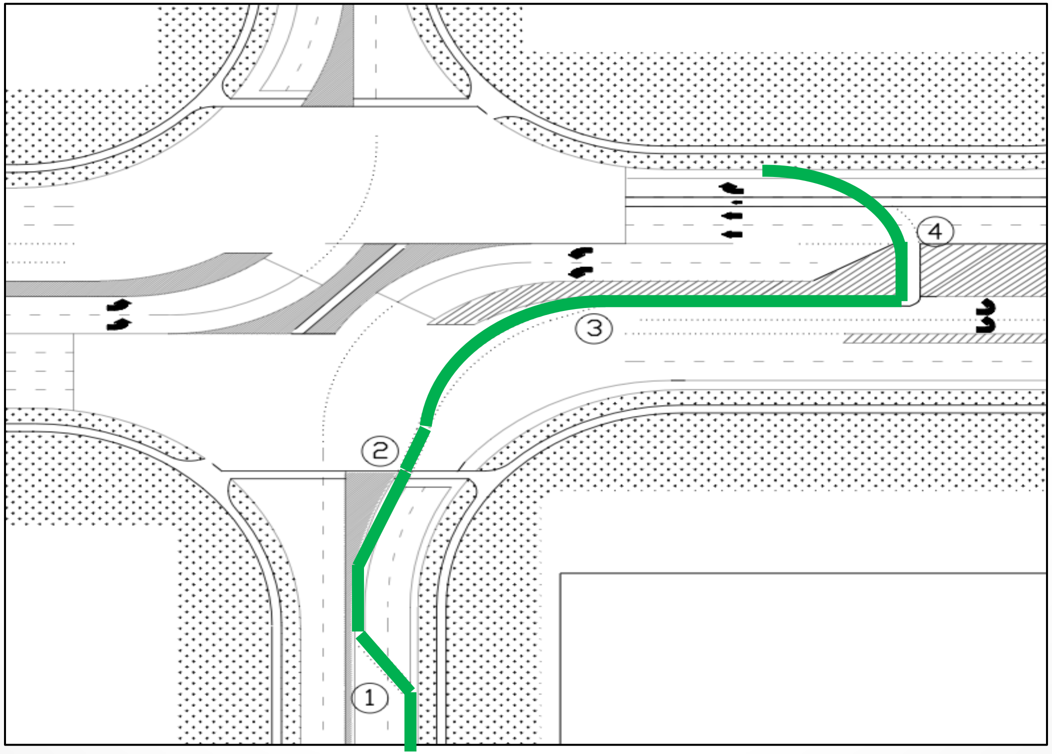
Midblock Cross (Pedestrian)



Source: Patrick Engineering

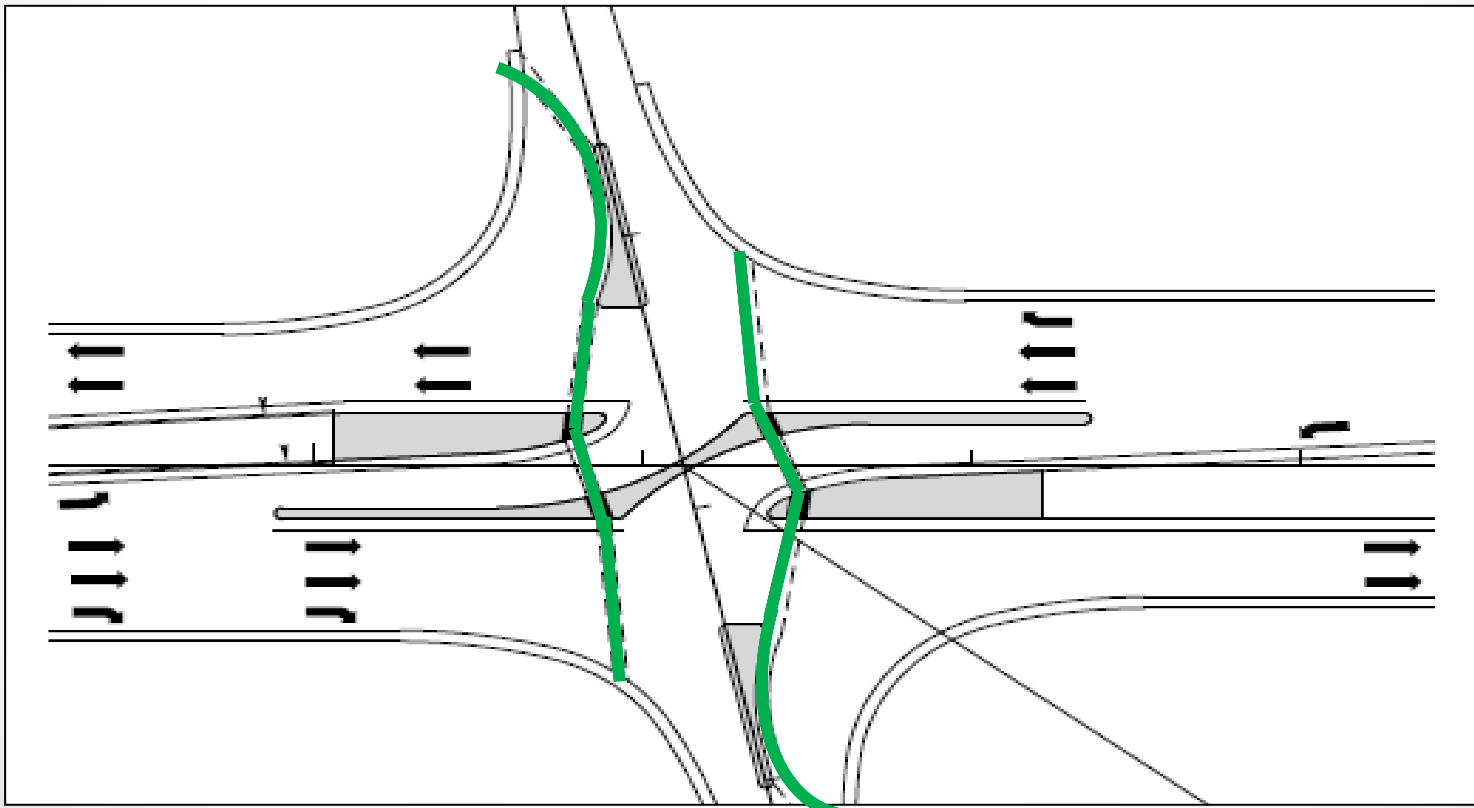
Crossing Alternatives

Bicycle U-turn Option



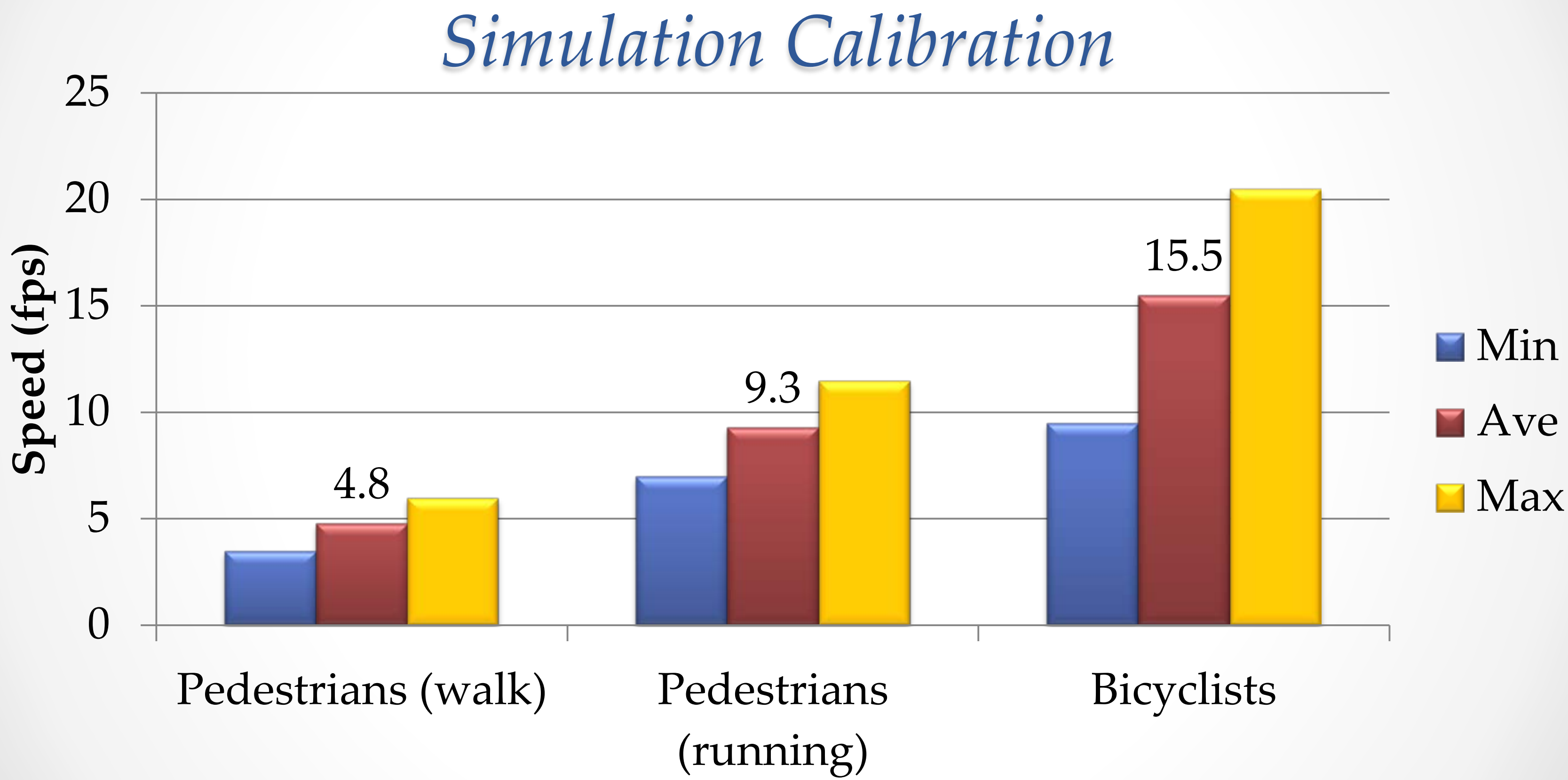
Crossing Alternatives

Bicycle Direct Cross



Field Data – Simulation Calibration

Analysis Method



1,400 pedestrians

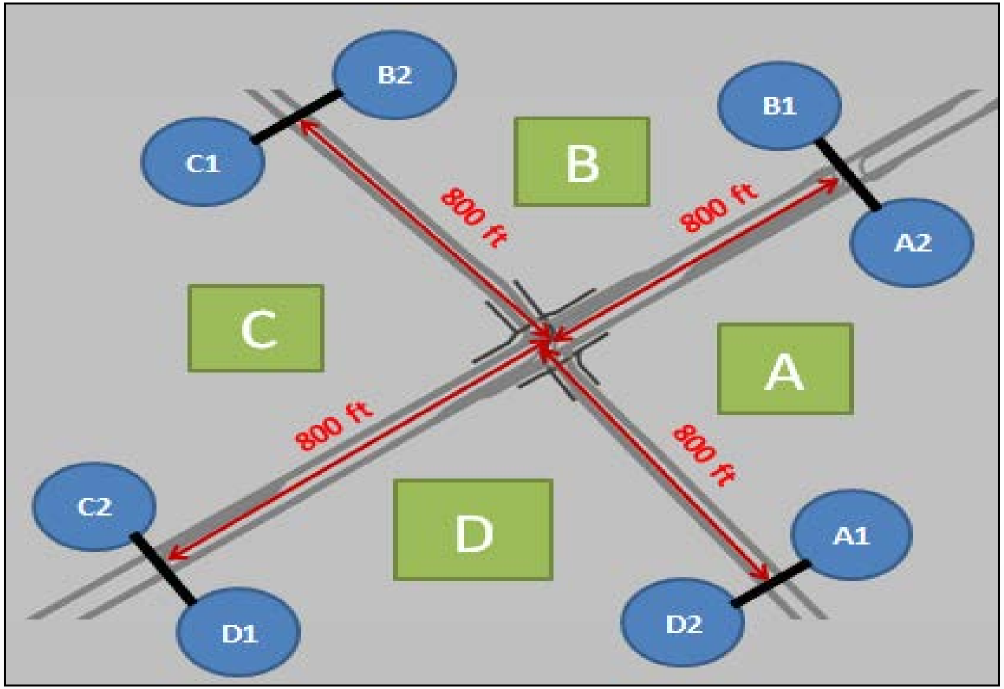
550 bicyclists

Simulation

Simulation

Simulation

Routes



<u>48</u> possible routes

Simulation

Variables

- Midblock locations
  - 600'
  - 800'
- Signal Timing (arrival of platoons)
  - Simultaneous
  - Offset
- Cycle Lengths
  - 90 second
  - 180 second
- Splits
  - 75/25
  - 60/40

<u>**16**</u> different scenarios per crossing geometry

Simulation

Outputs (MOEs)

- Average # of Stops per route
- Average Stopped Delay per route (sec)
- Average Travel Time per route (sec)

Results

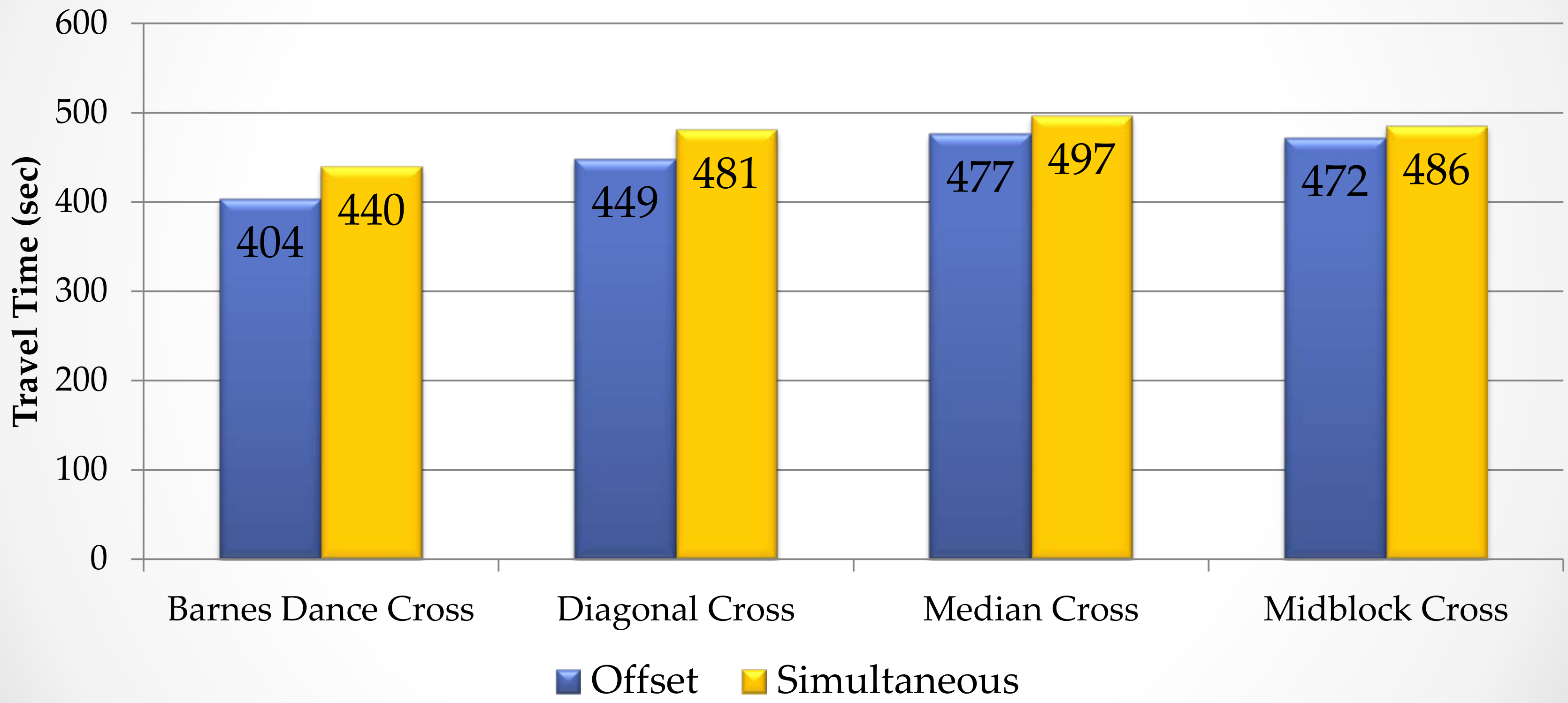
Results

Pedestrian Crossings

- Factors that contributed to lower travel times for **<u>all 4</u>** pedestrian crossings:
  - Offset signal design (vs. simultaneous)
  - 90 second cycle length (vs. 180 second)
  - 60/40 signal split (vs. 75/25)

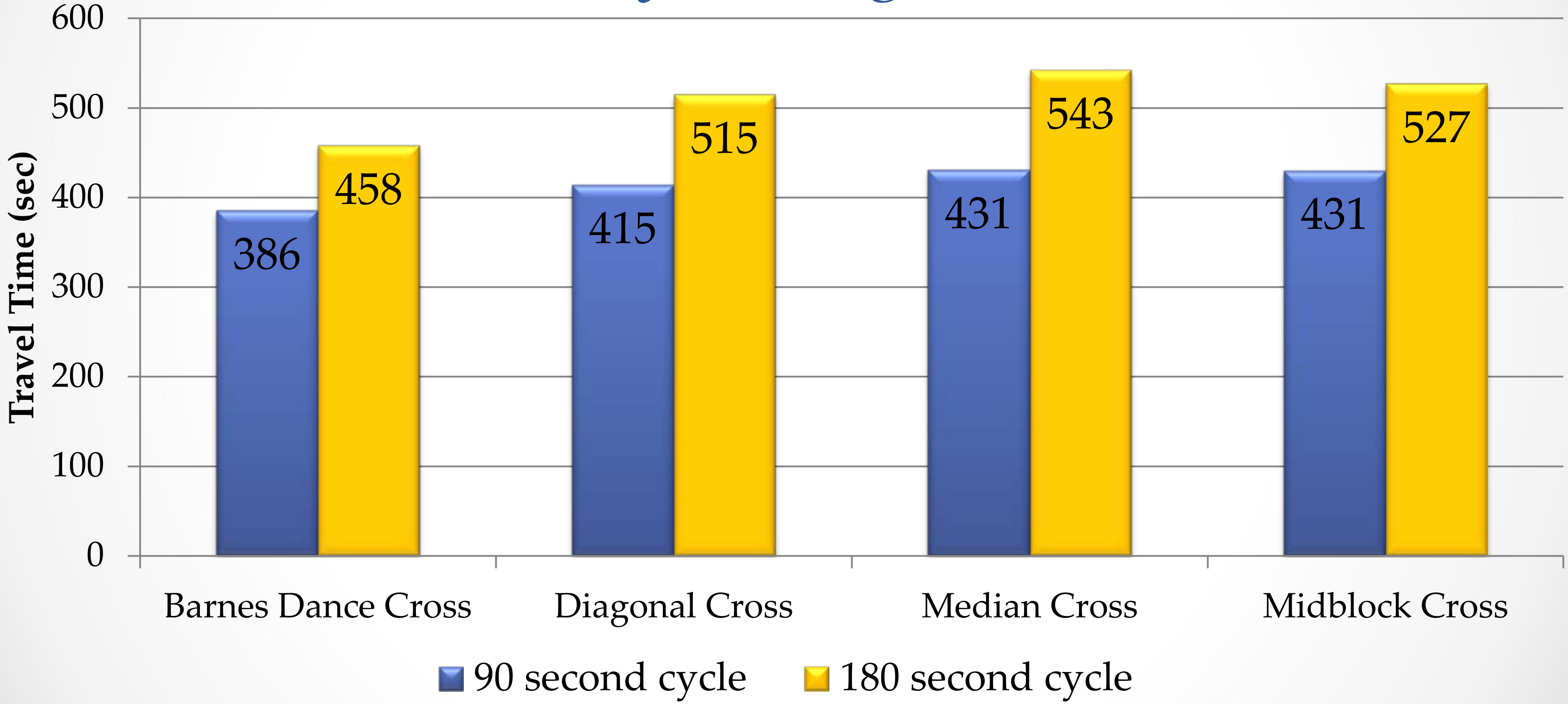
Results – Pedestrian Crossings

Signal Design



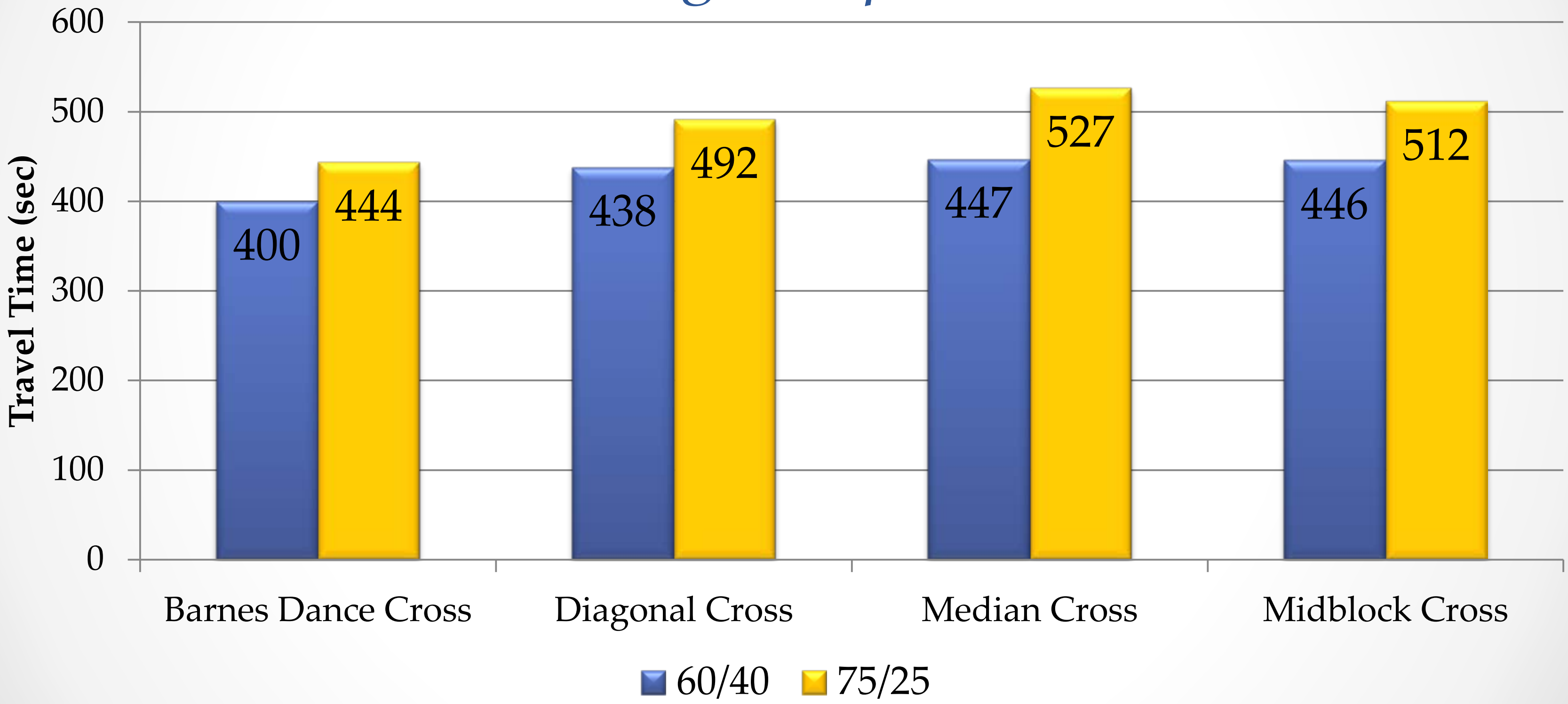
Results – Pedestrian Crossings

Cycle Length



Results – Pedestrian Crossings

Signal Splits

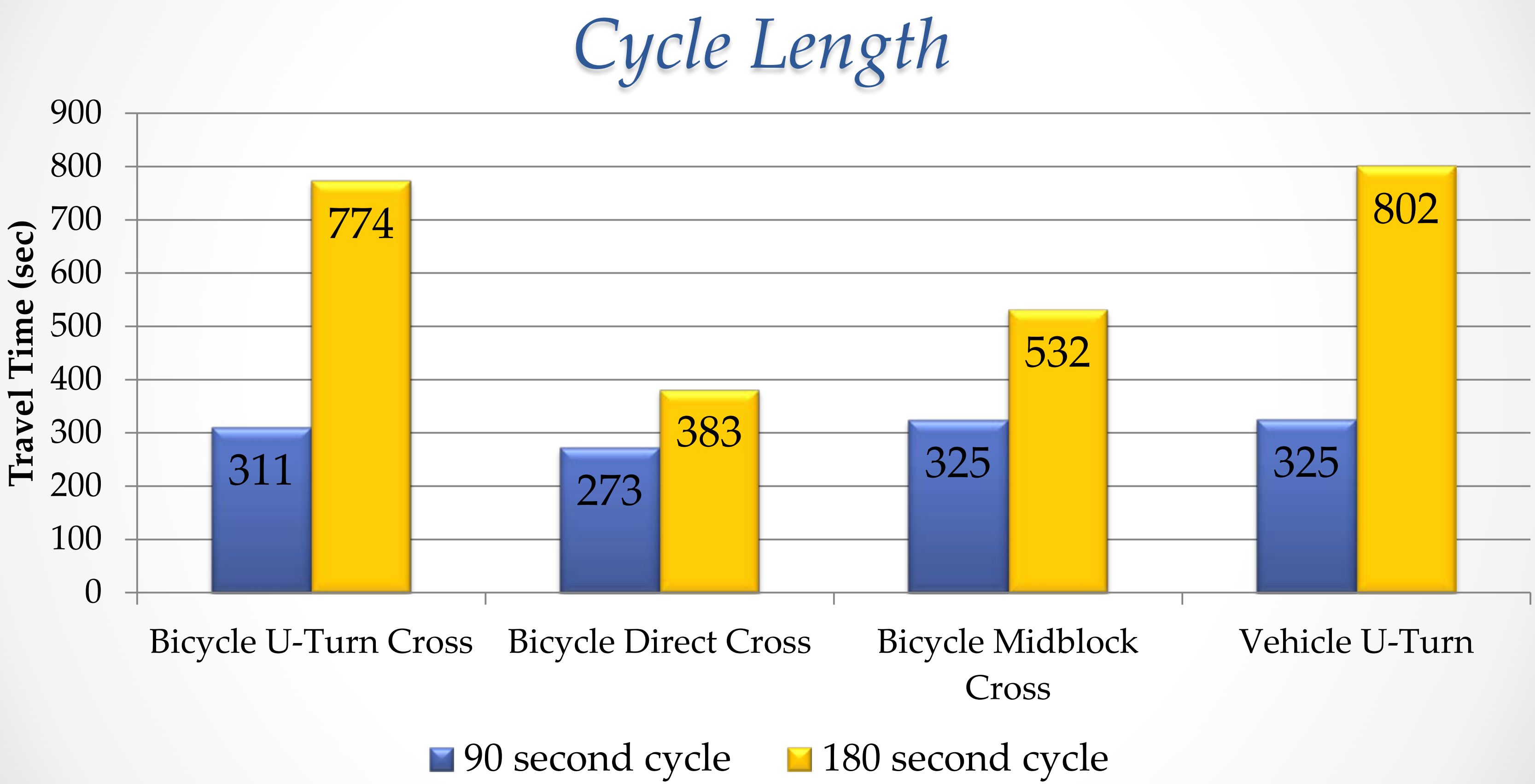


Results

Bicycle Crossings

- Factors that contributed to lower travel times for **all 3** crossings:
  - 90 second cycle length (vs. 180 second)

Results – Bicycle Crossings



Recommendations

Recommendations

- Pedestrian Crossing:
  - Diagonal Cross with Midblock Cross
- Bicyclist Crossing:
  - Bicycle Direct Cross
  - (Though Bicycle U-turn Cross had potential)

Recommendations

- Short cycle lengths (90 seconds) – *peds/bikes*
- Offset signal design - *pedestrians*
- Signal splits near 50/50 (60/40) - *pedestrians*

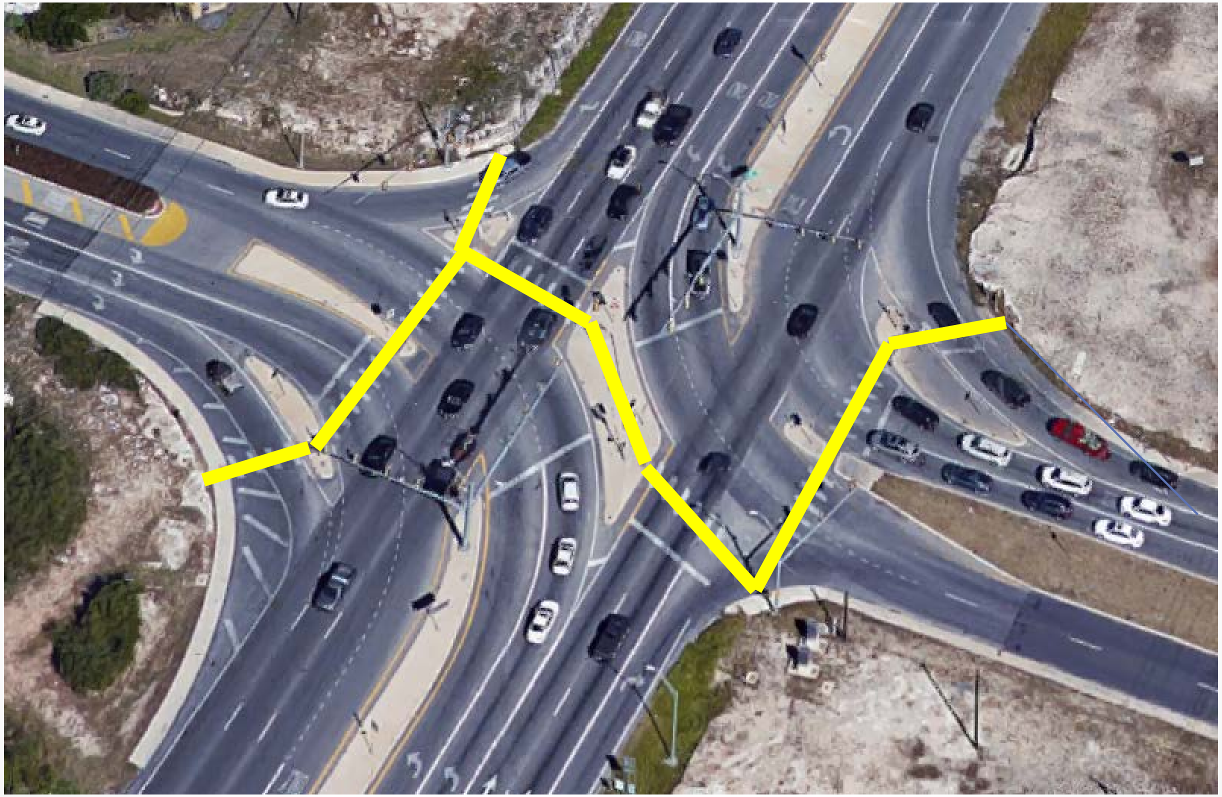
Additional Current Practice

Additional Current Practice

Source: Google

281 & Evans Rd, San Antonio, TX

Additional Current Practice



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281 & Evans Rd, San Antonio, TX

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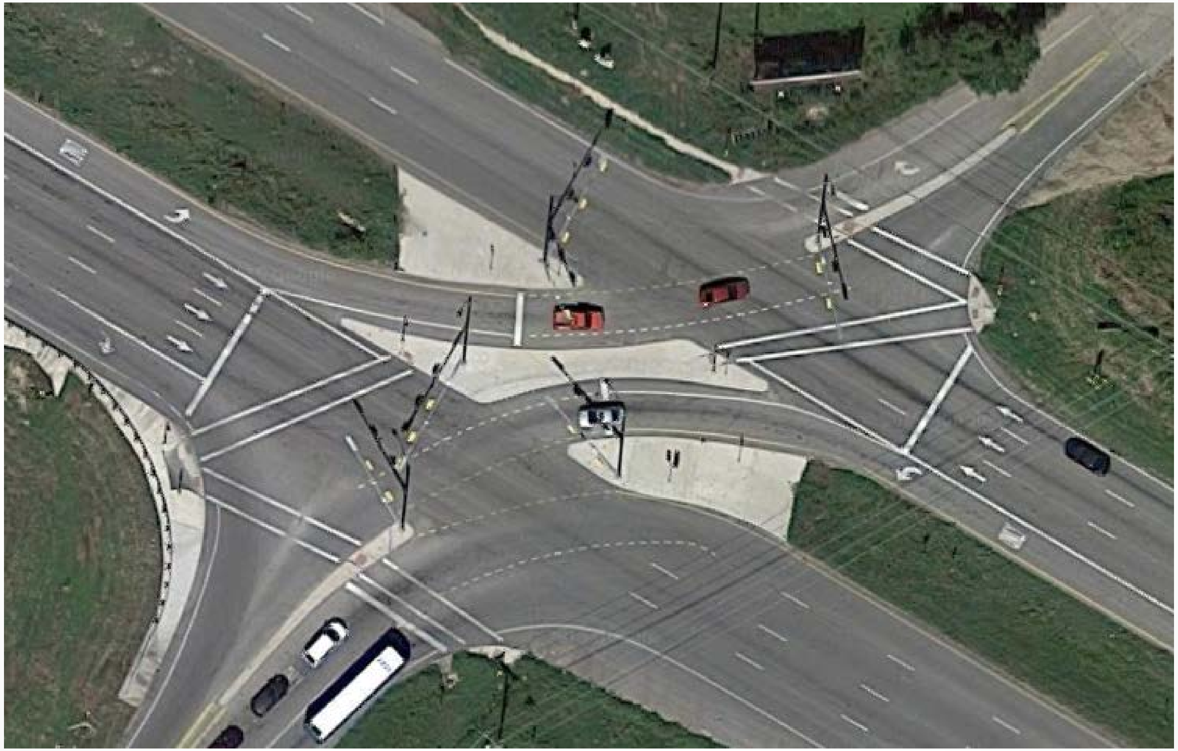
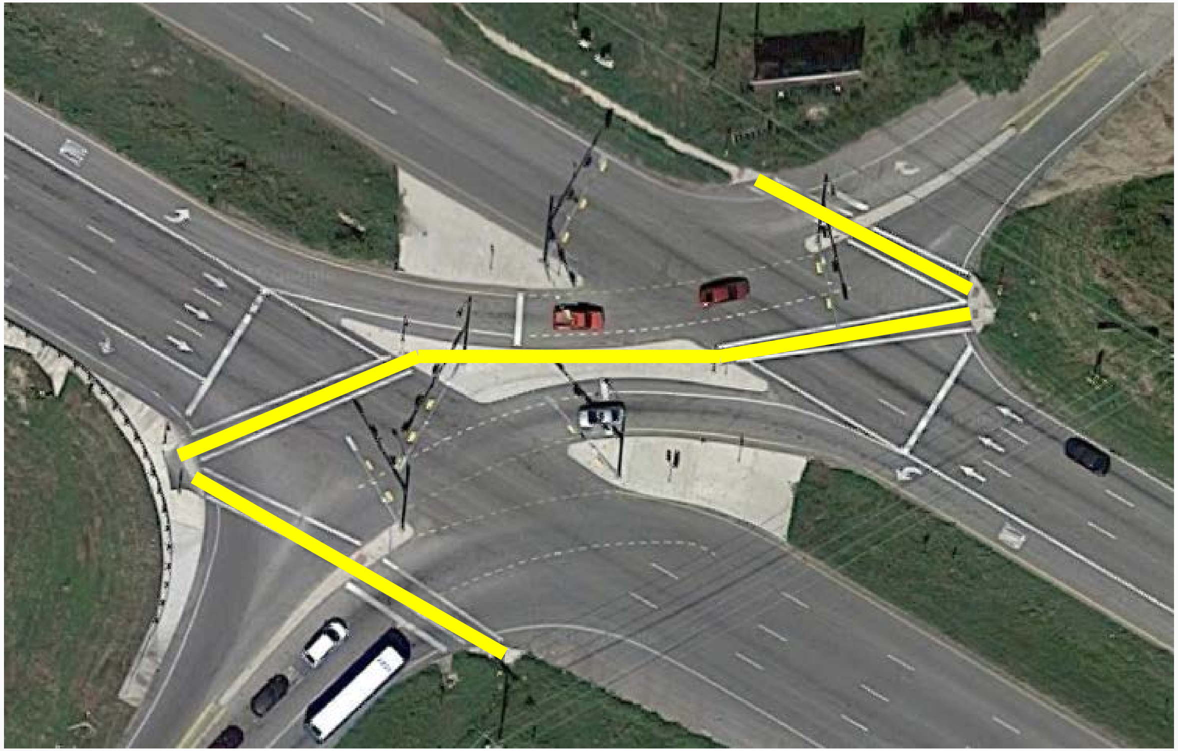


Source: Google

71 & Falwell Ln, Austin, TX

Additional Current Practice



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Additional Current Practice

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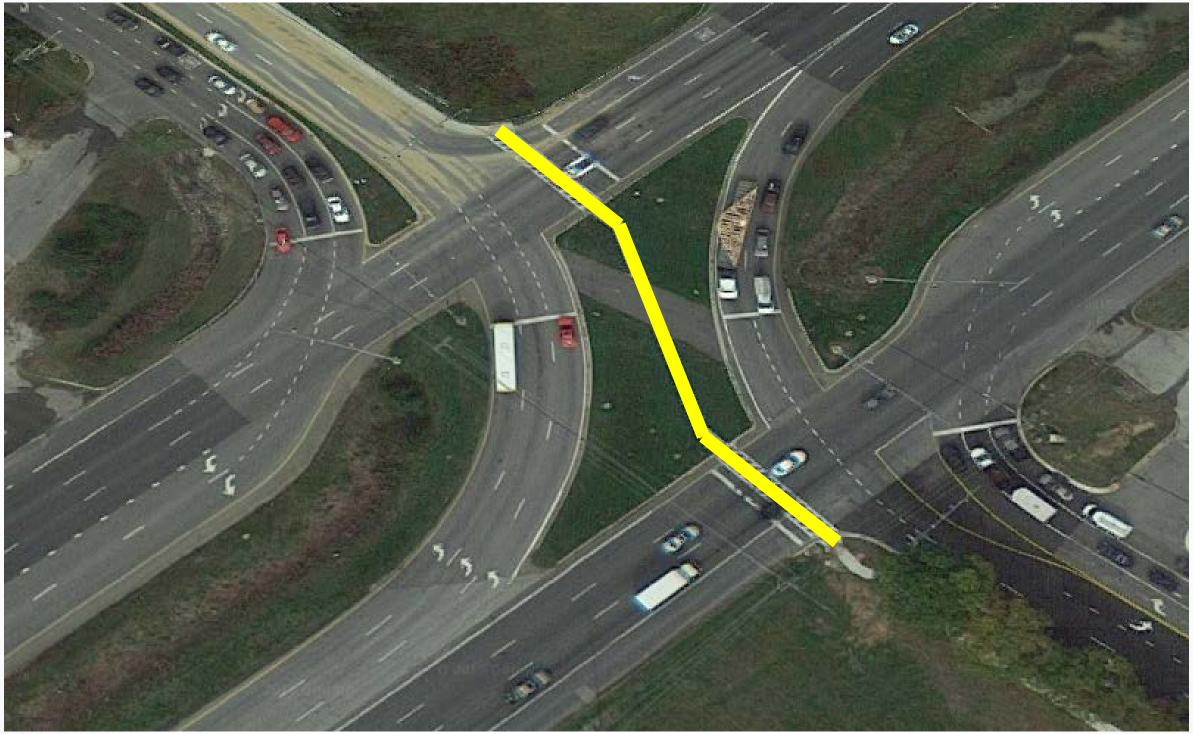
Crain Hwy & Waugh Chapel Rd, Gambrills, MD

Additional Current Practice



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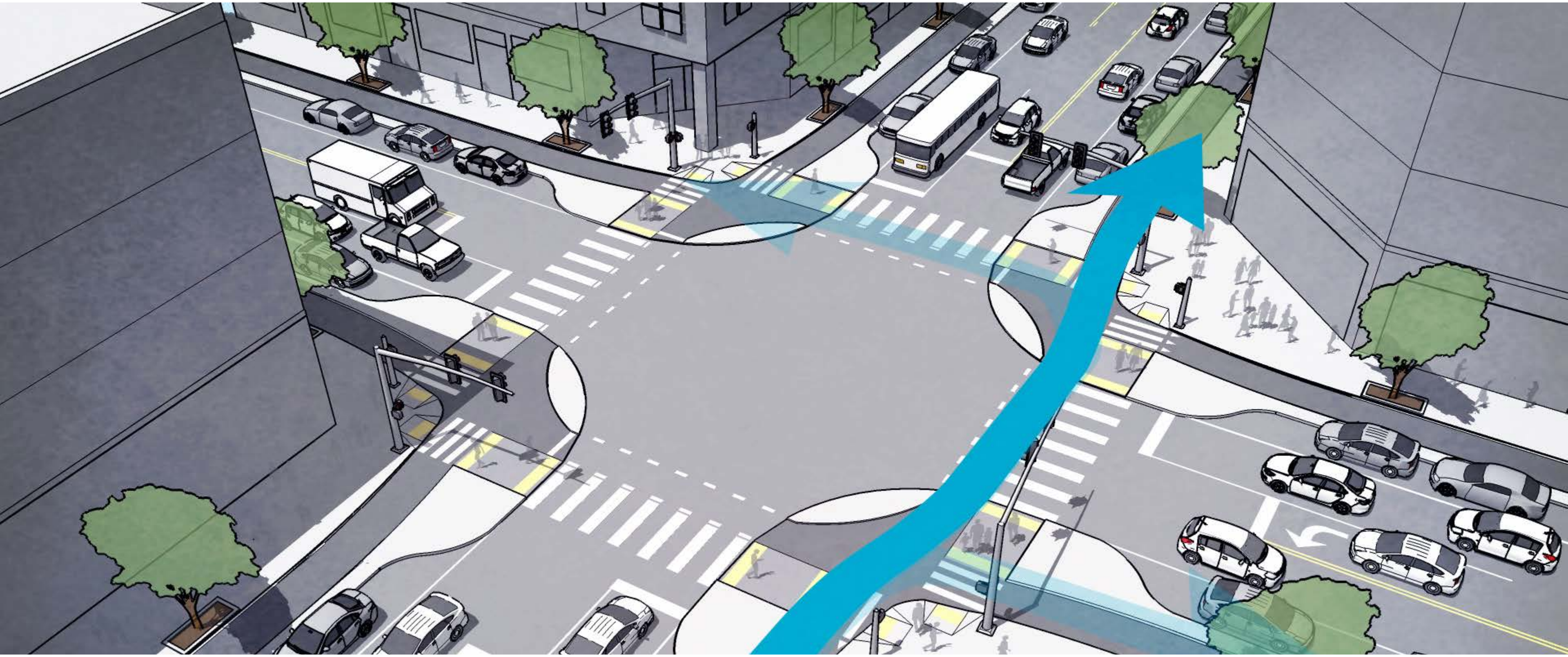
Protected Intersections for Protected Bike Lanes



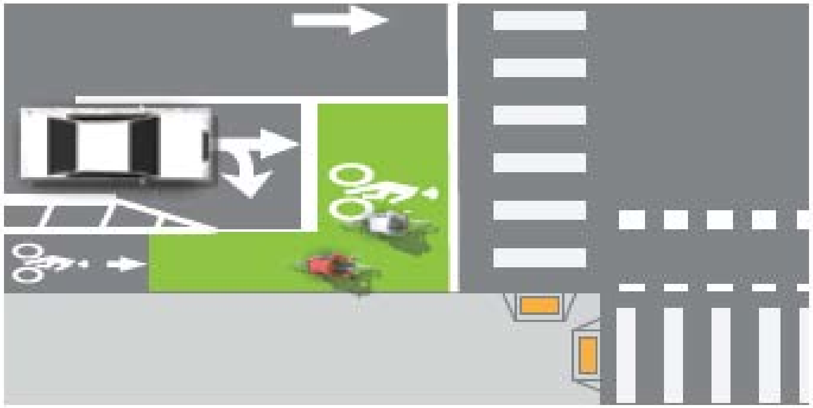
Nick Falbo
August 19, 2014
Innovative Intersections for Pedestrians and Bicycles

Topics

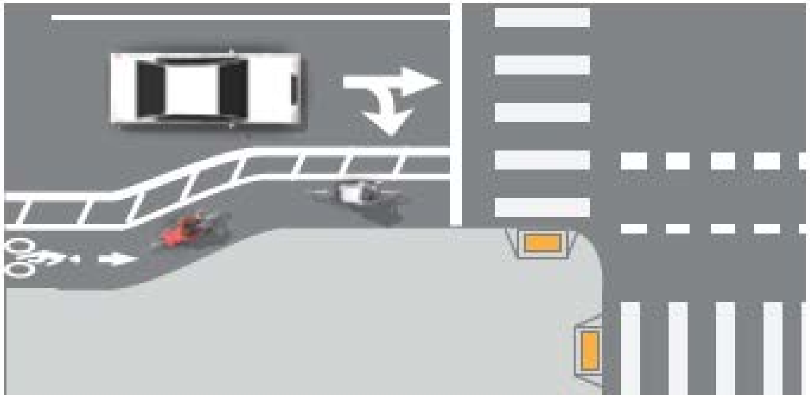
- Current Practice
- Protected Intersection Design Concept
- History
- Design Elements Today
- Current Developments

Current Practice

Adjacent to Through/Right Turn Lane

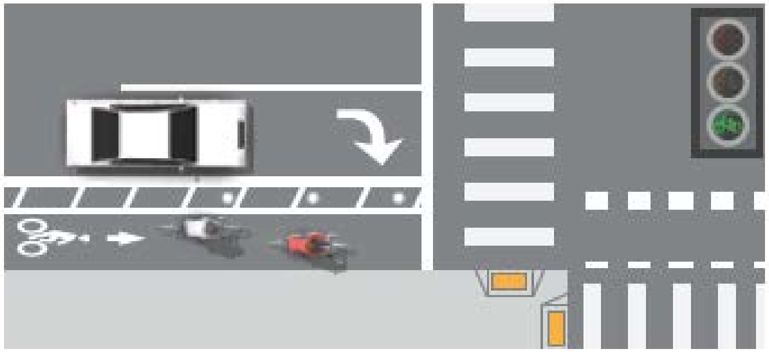


Bike Box

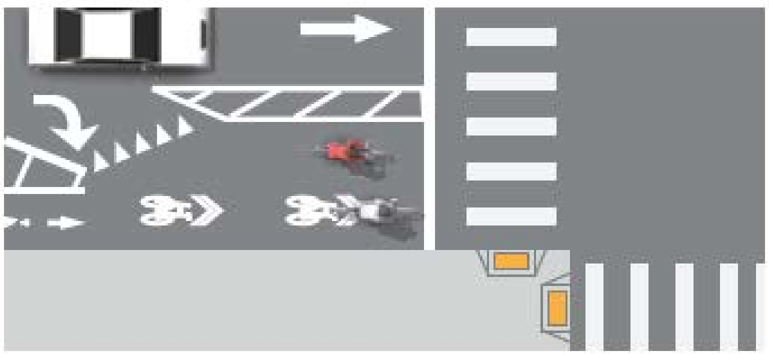


"Bend-in"

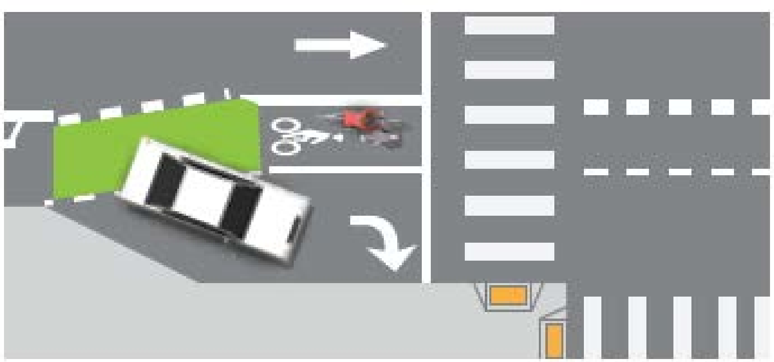
Adjacent to Right Turn Only Lane



Bicycle Signal



Mixing Zone



Drop to regular bike lane

Current Practice

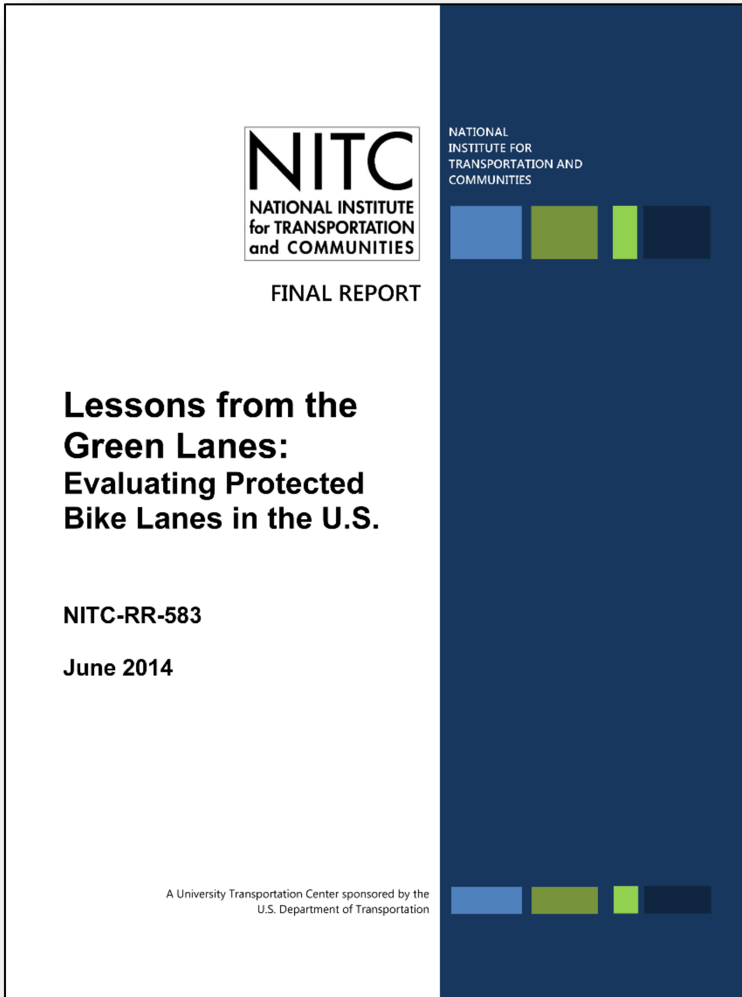
Intersection Design Strategies:

- Increasing Awareness
- Increasing Conspicuity
- Isolating Conflicts
- Clearly Assigning Priority

Current Practice

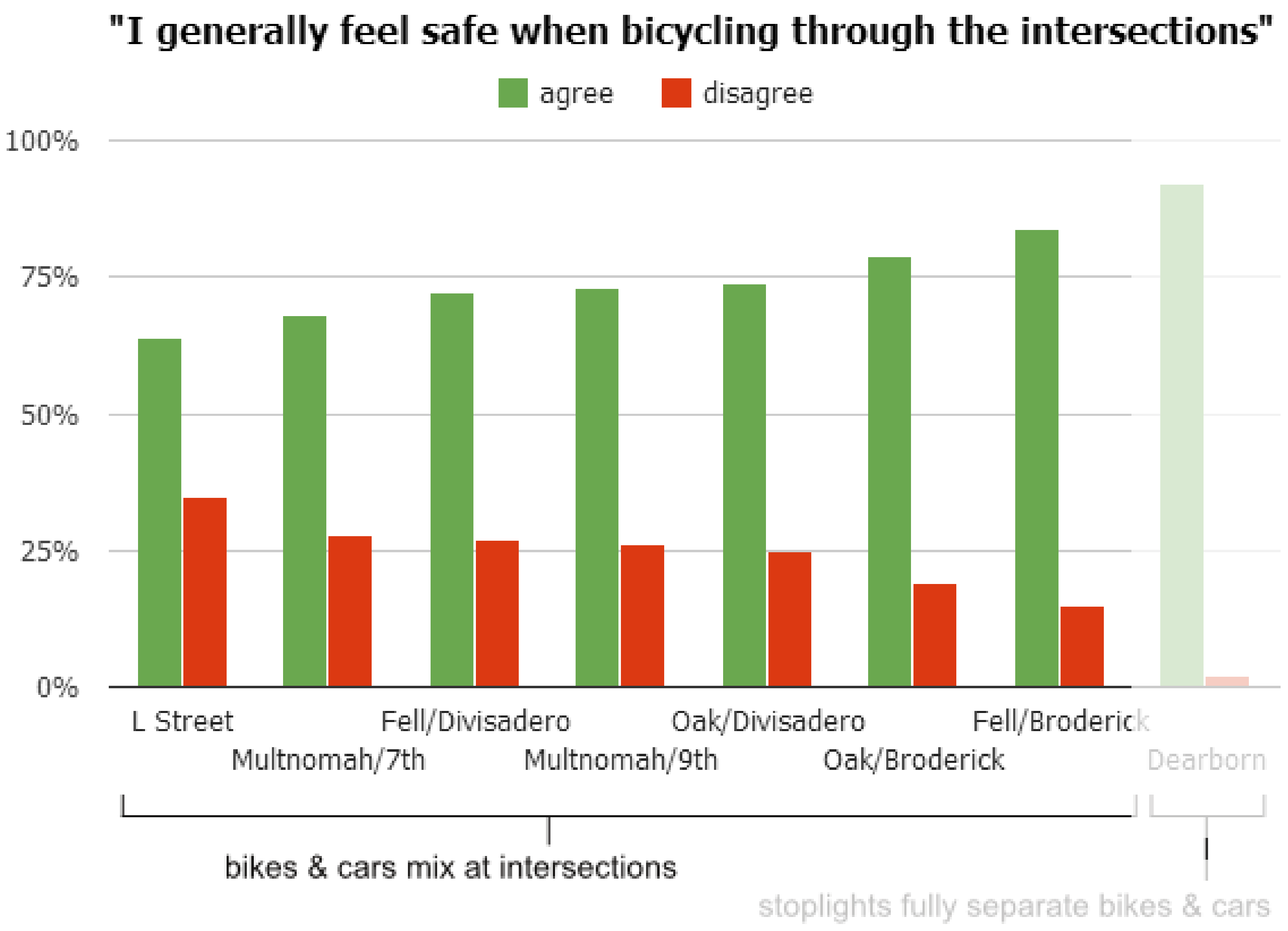
Intersection Design Strategies:

- Increasing Awareness
- Increasing Conspicuity
- Isolating Conflicts
- Clearly Assigning Priority
- **Maintaining Bikeway Comfort**

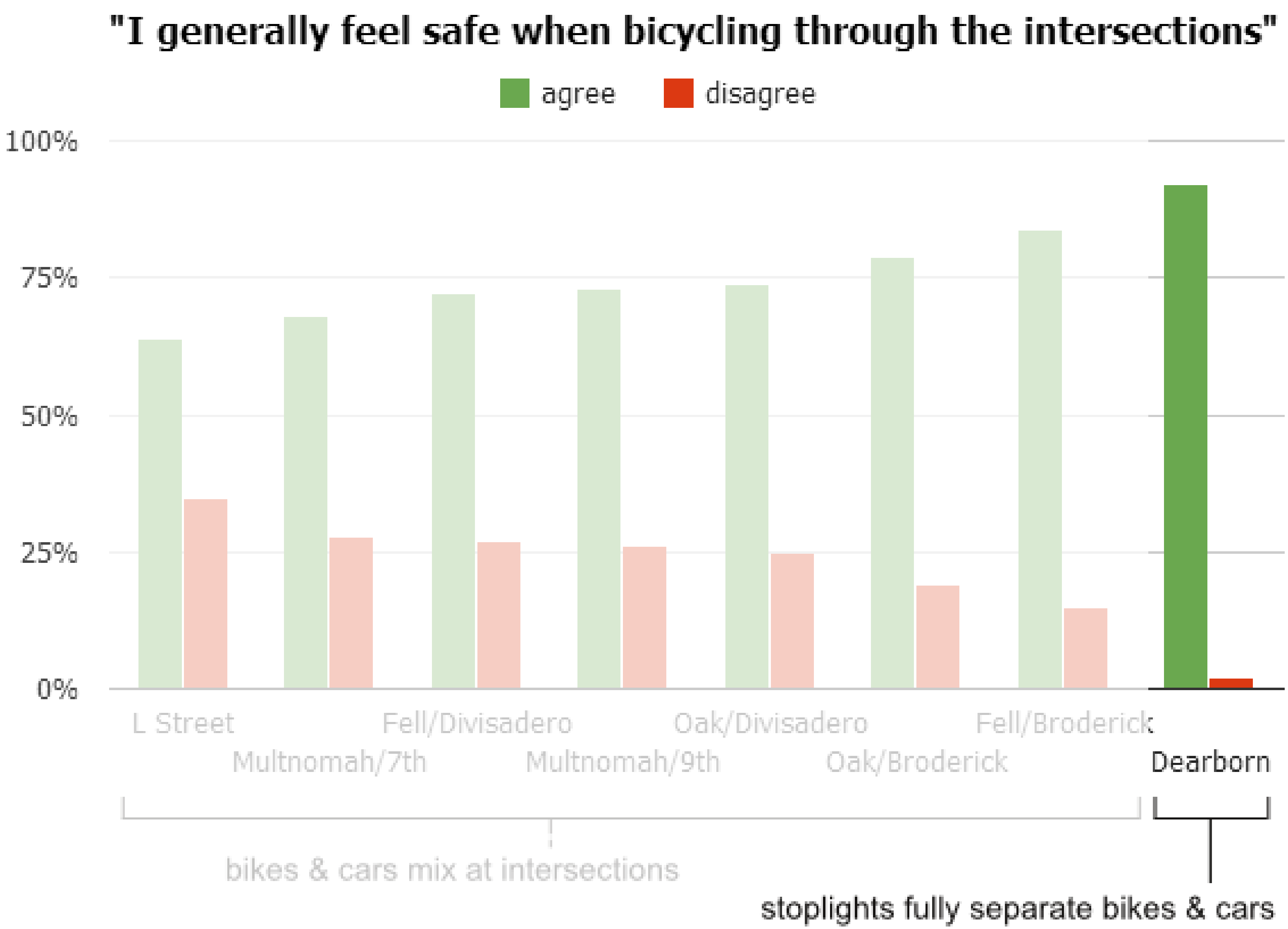


"I generally feel safe when bicycling through the intersection."

Agree or Disagree?



"I generally feel safe when bicycling through the intersections"
agree
disagree
100%
75%
50%
25%
0%
L Street
Multnomah/7th
Fell/Divisadero
Multnomah/9th
Oak/Divisadero
Oak/Broderick
Fell/Broderick
Dearborn
bikes & cars mix at intersections
stoplights fully separate bikes & cars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Fell/Broderick
Dearborn
bikes & cars mix at intersections
stoplights fully separate bikes & cars


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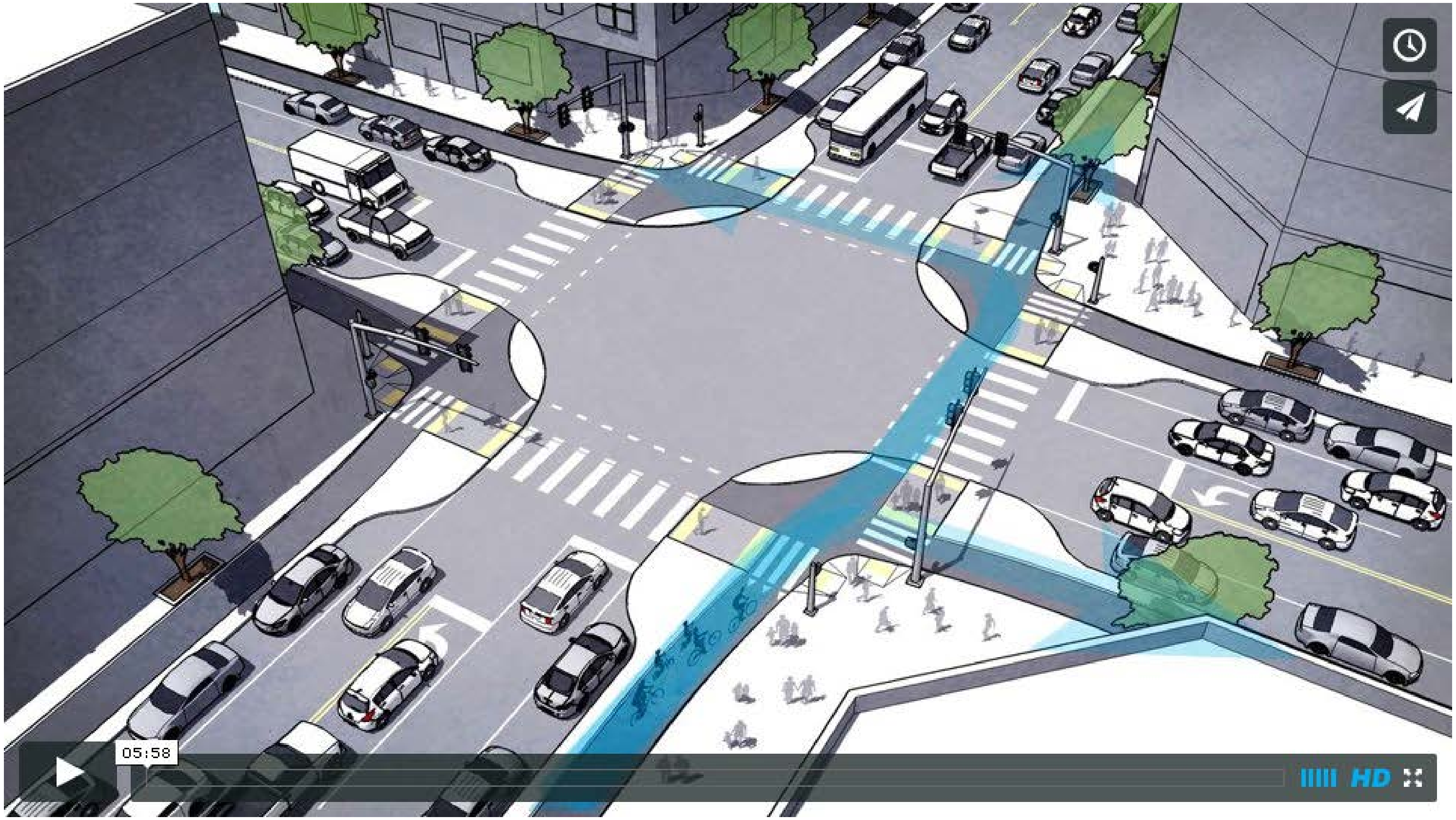
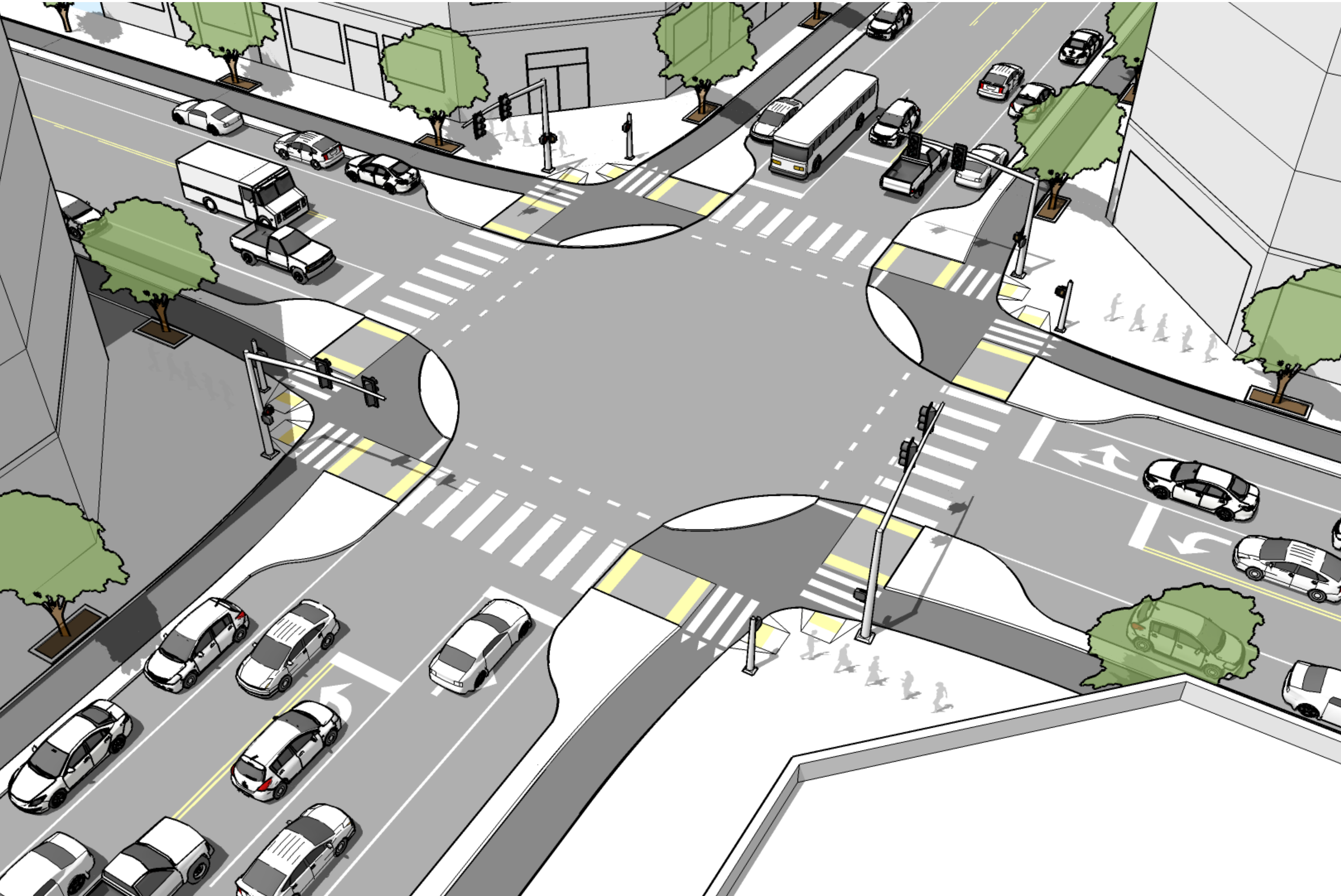
4.0m

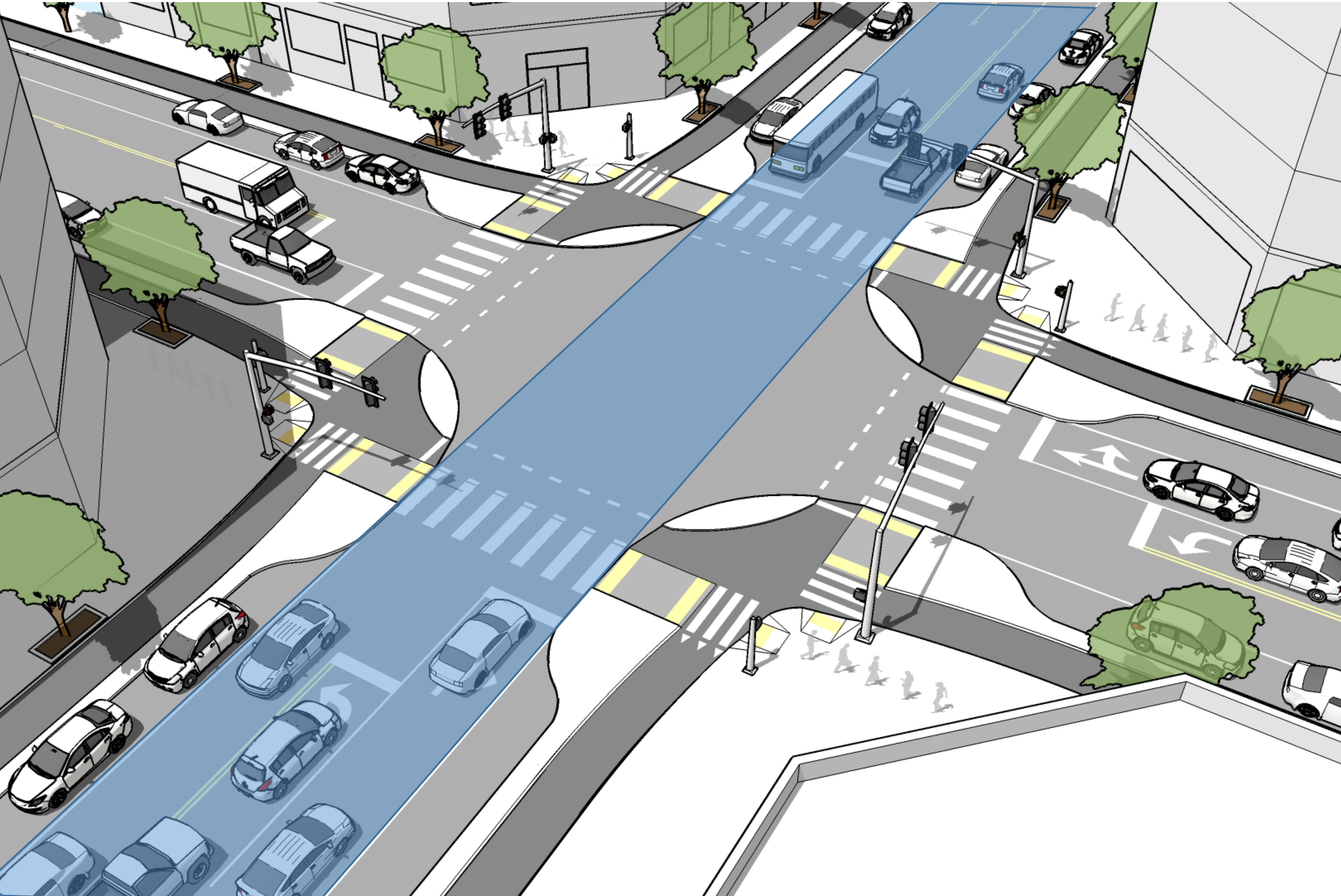
The Protected Intersection Design Concept

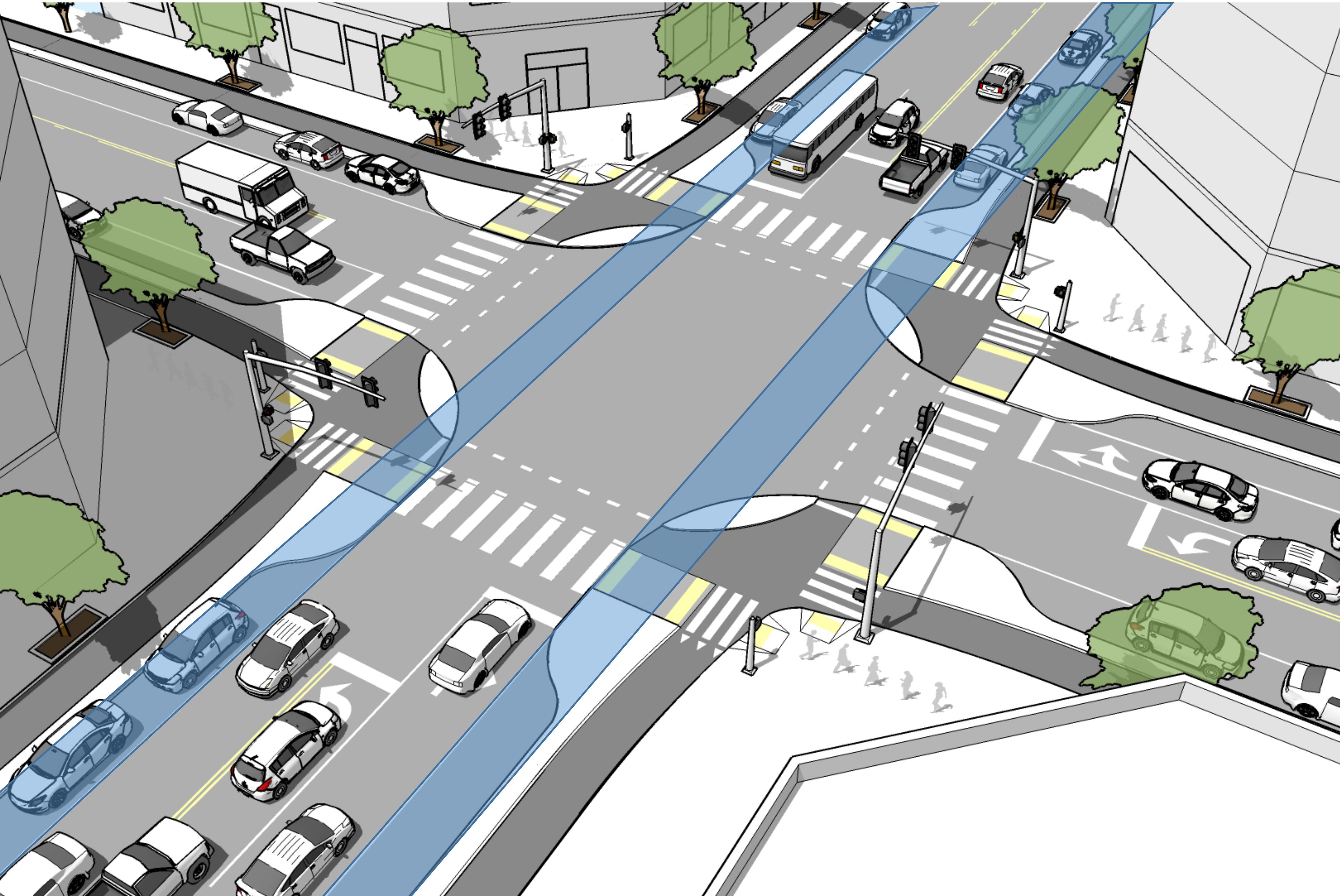
The Concept

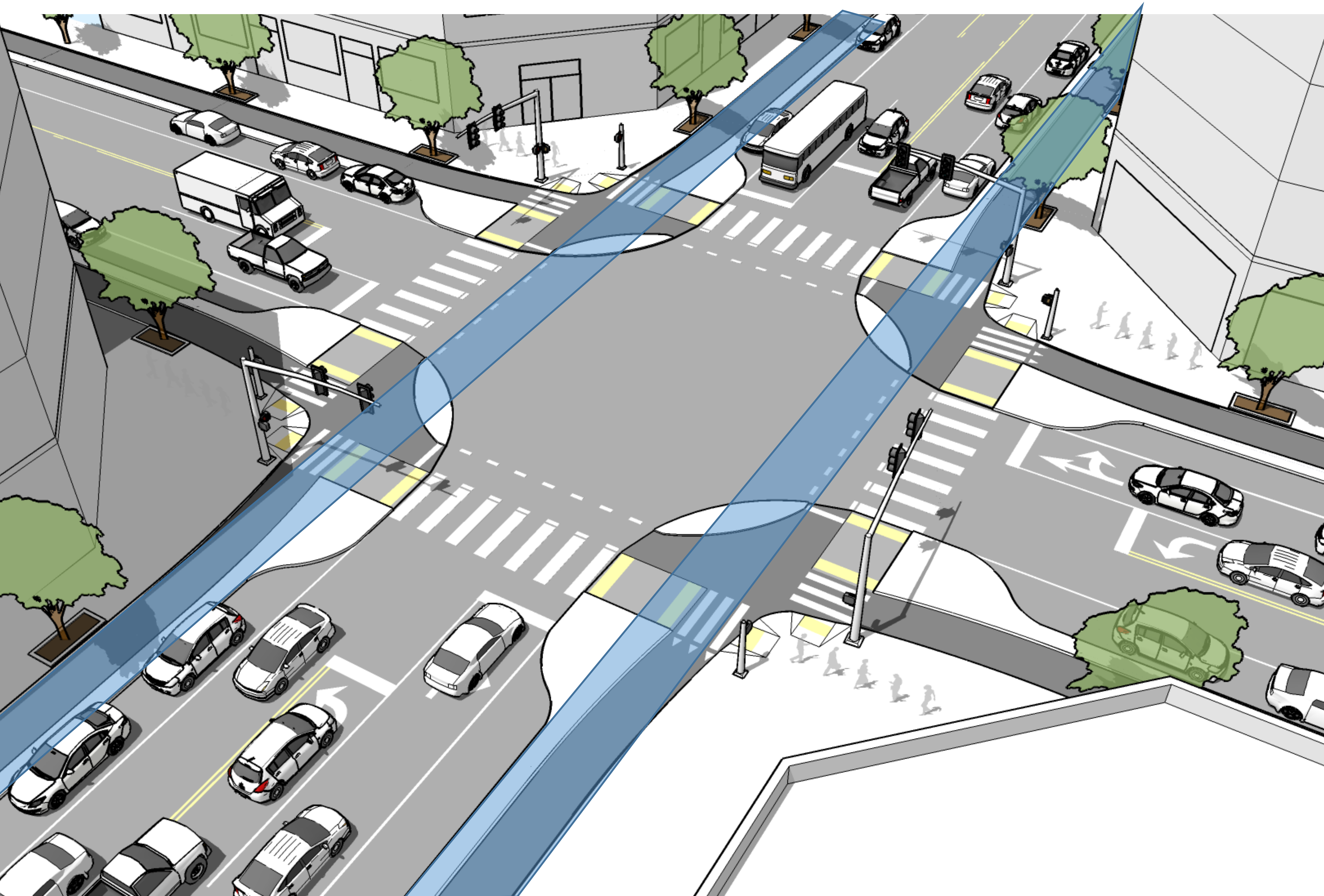


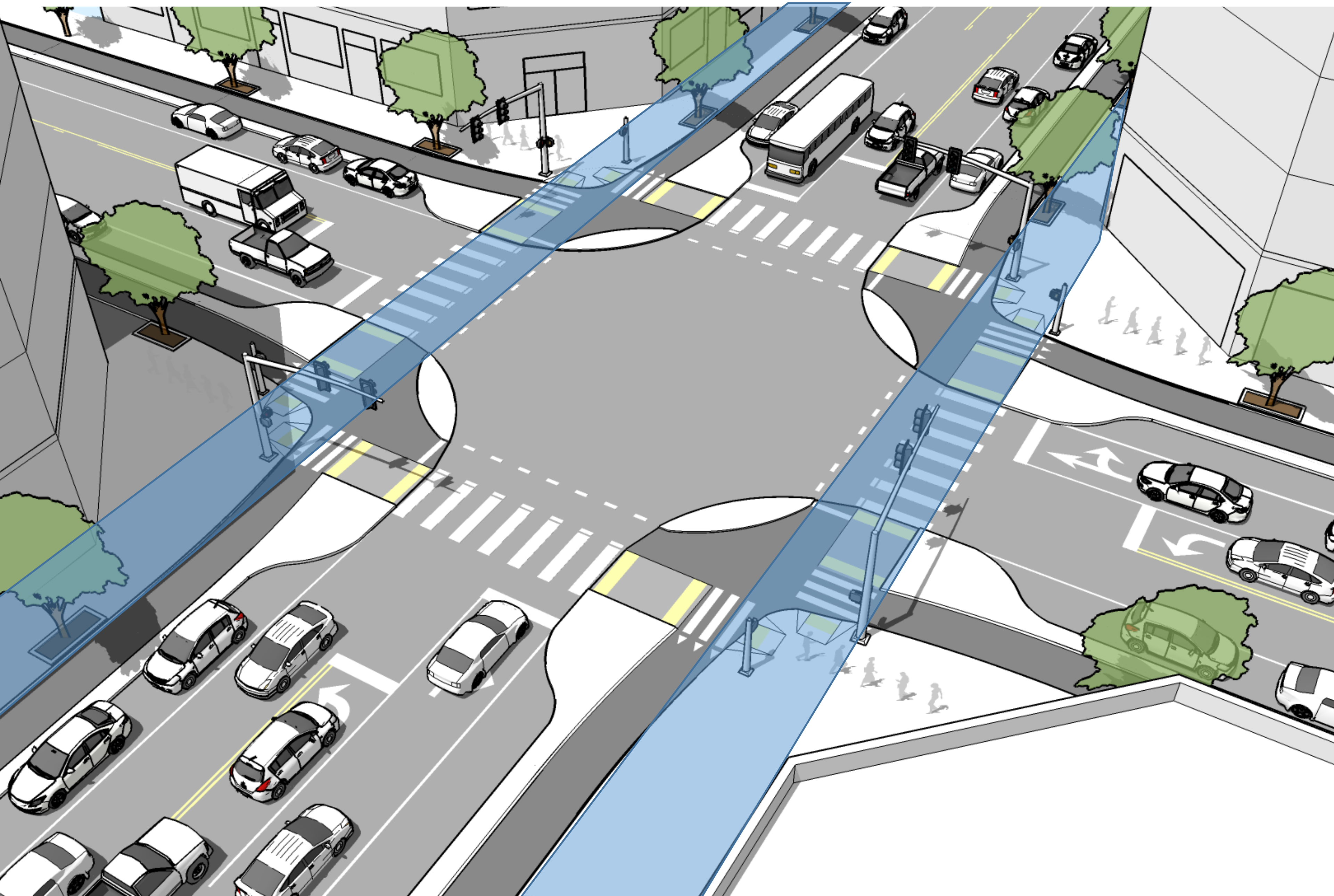
ProtectedIntersection.com

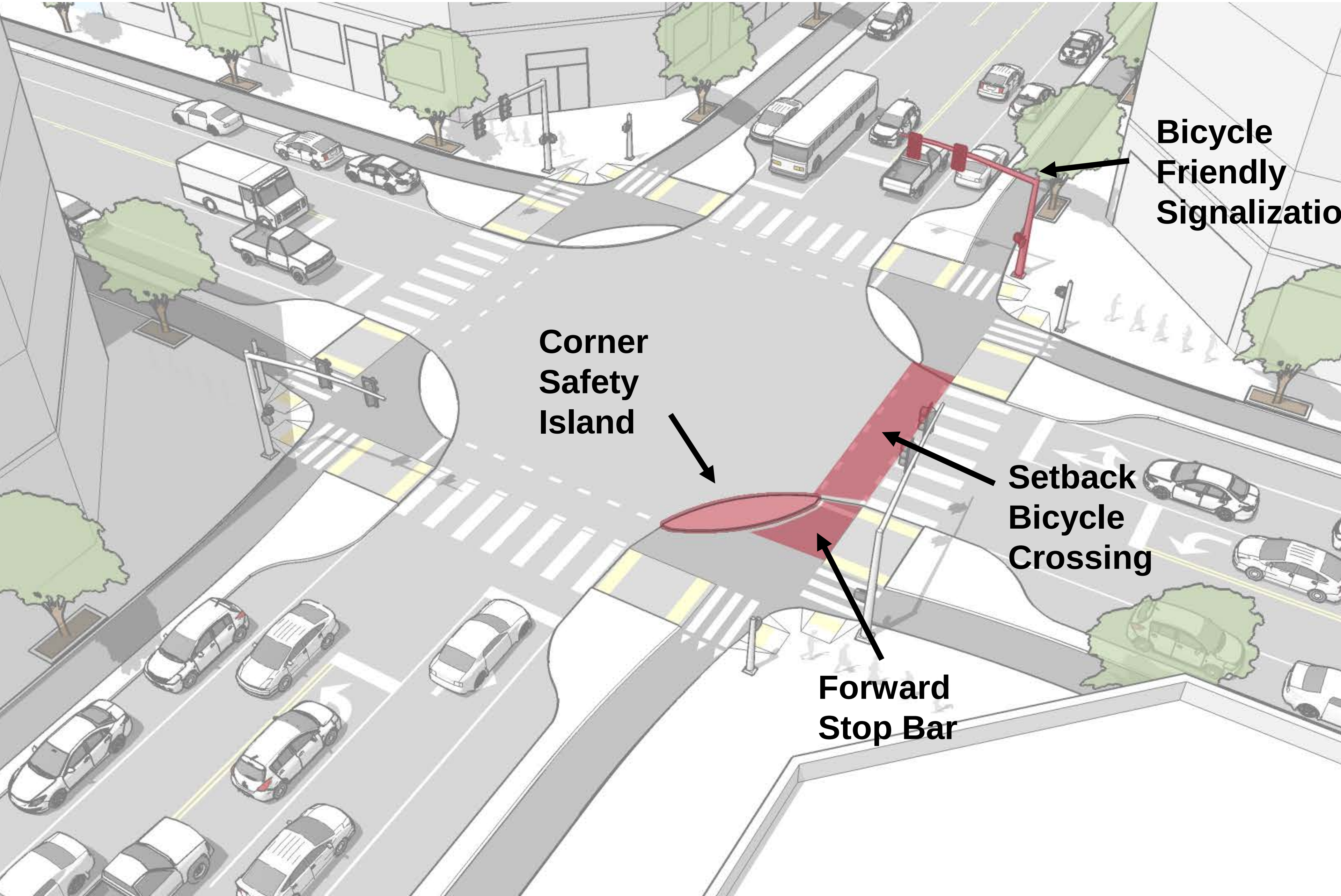


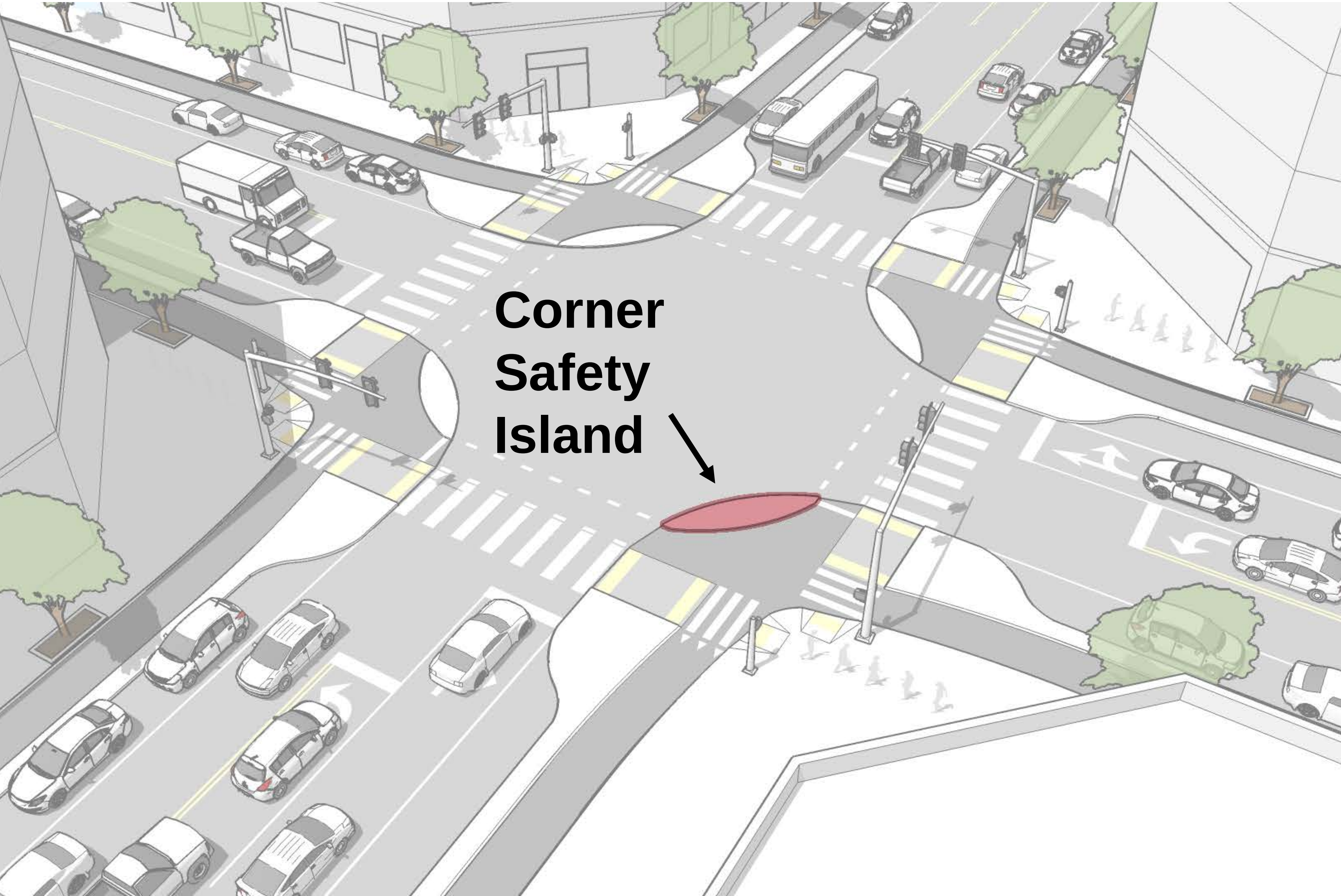


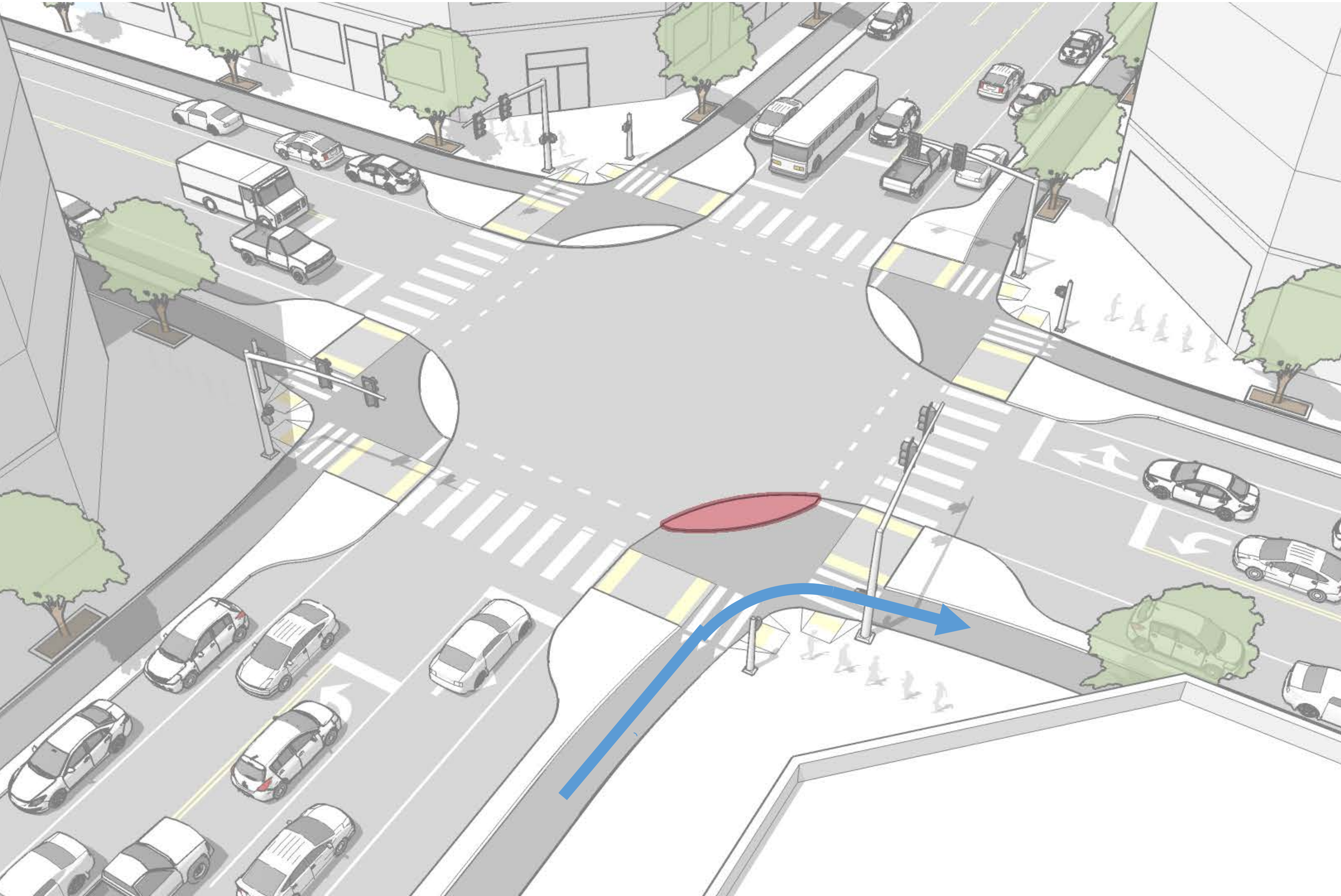


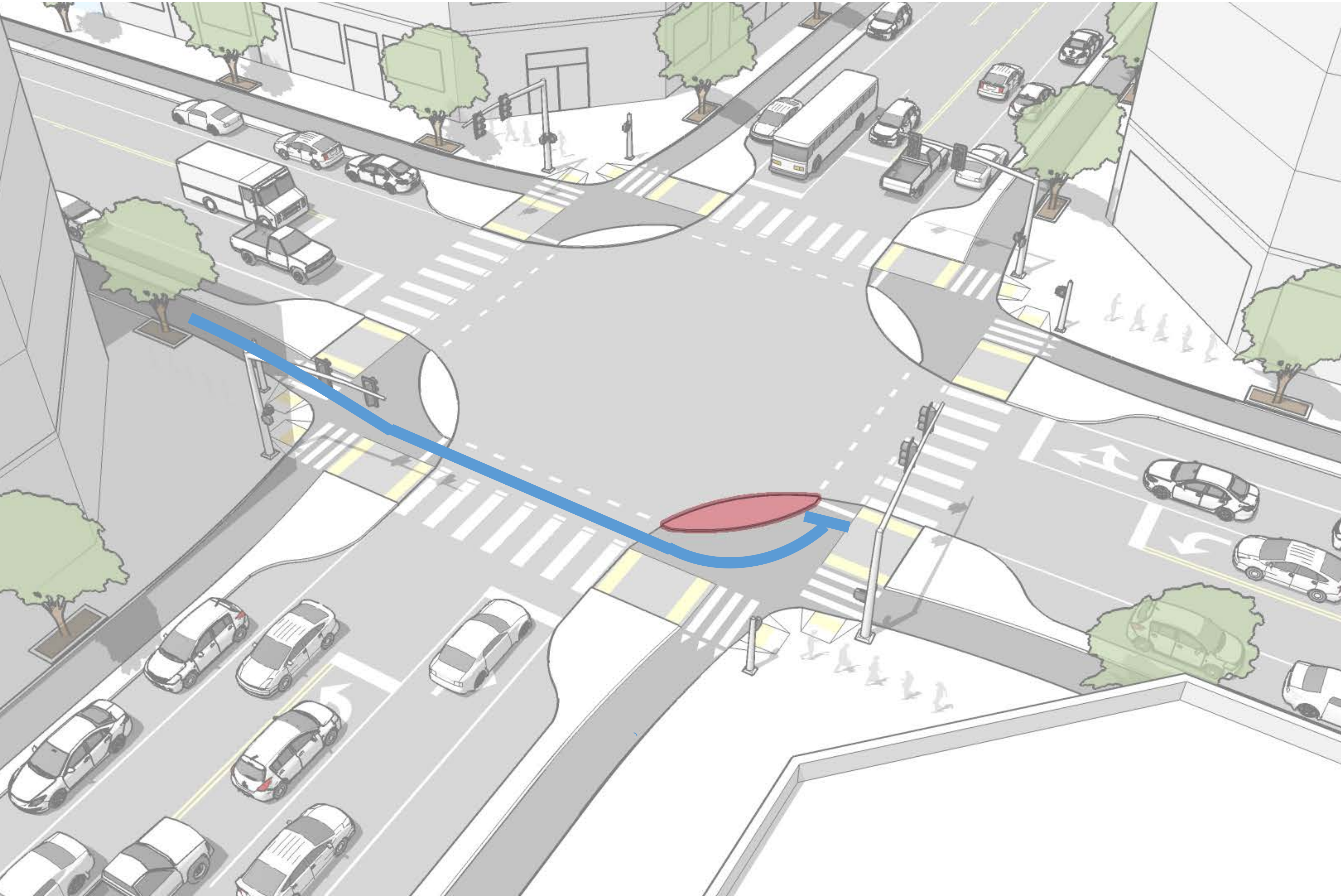


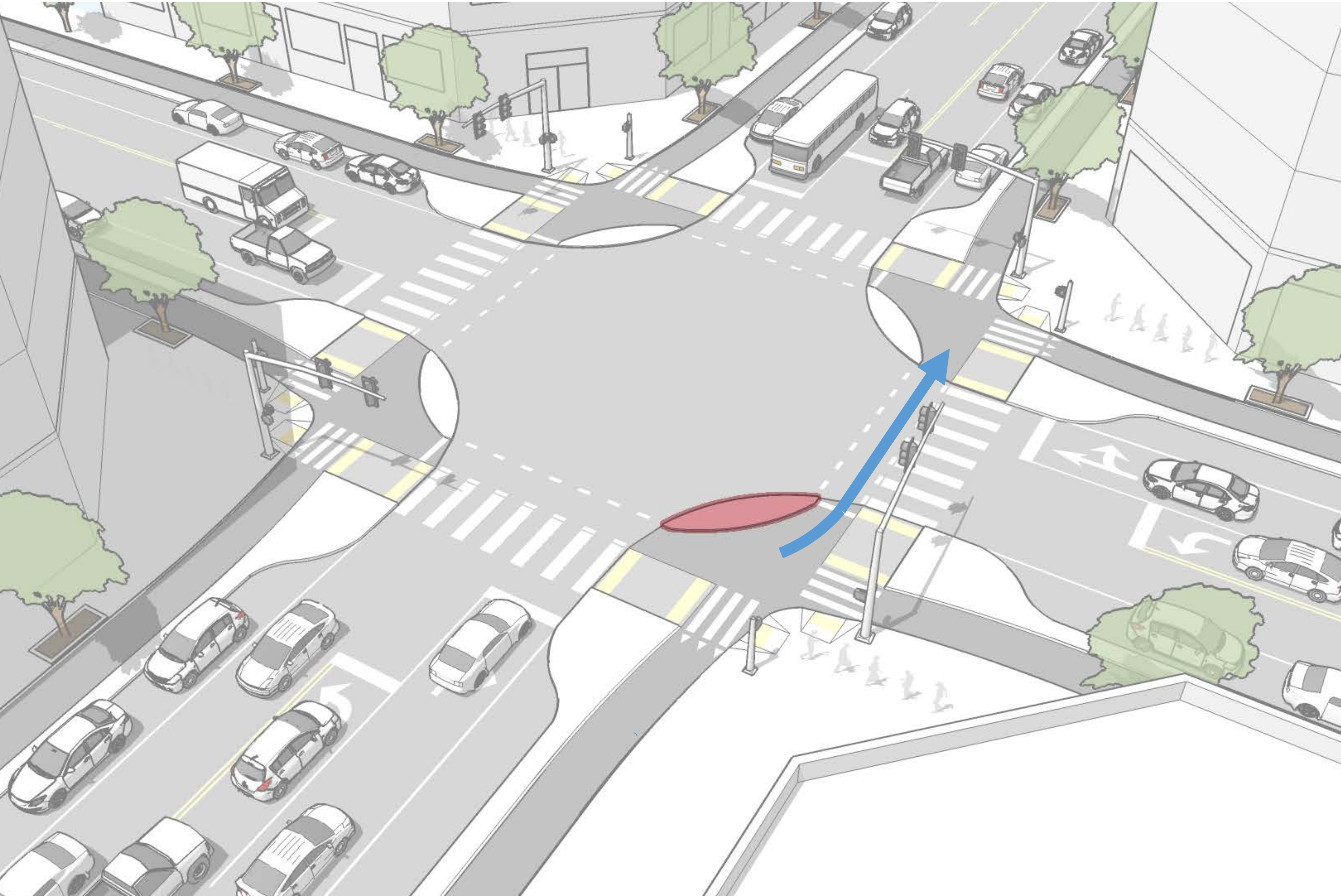


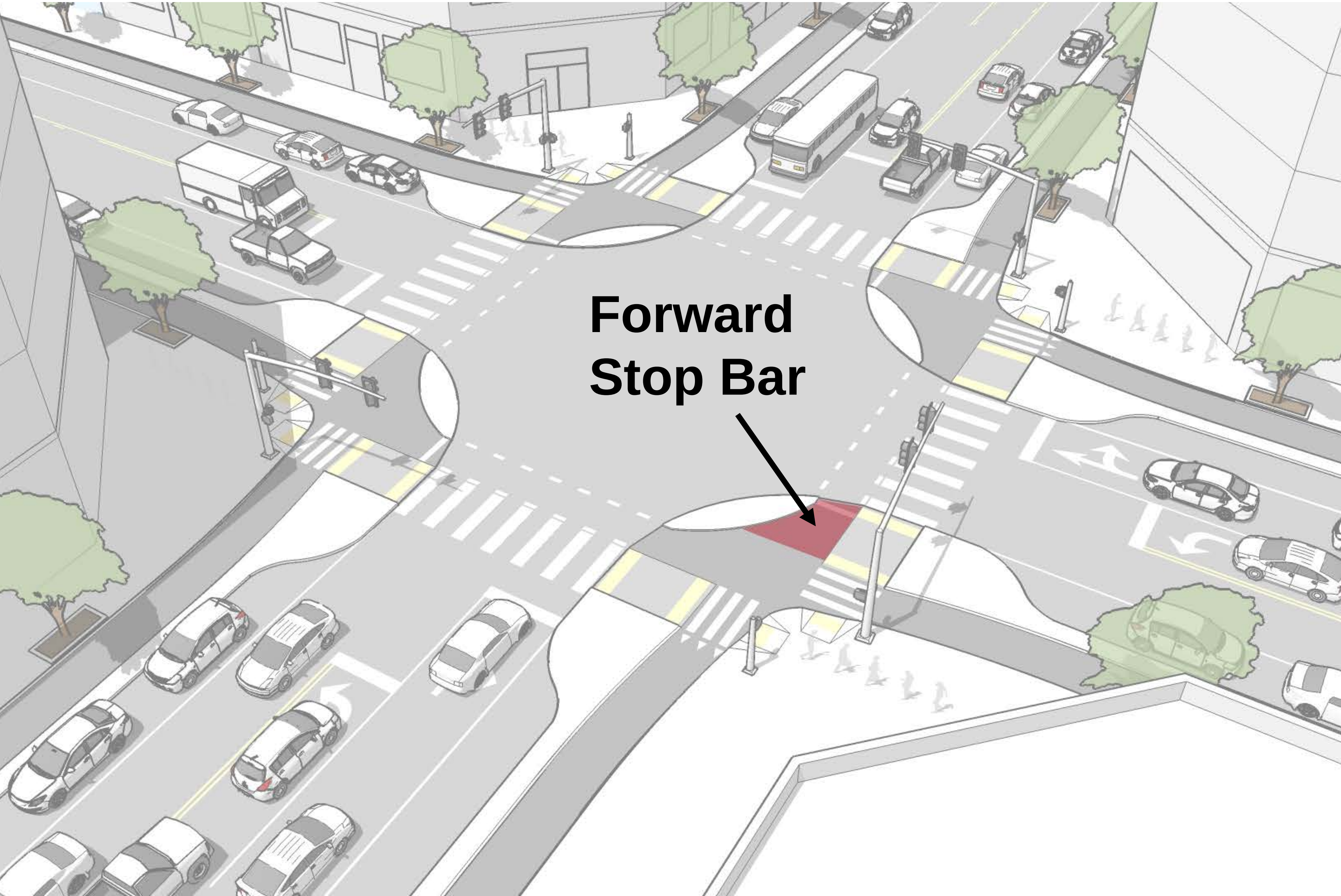

Bicycle Friendly Signalizatio
Corner Safety Island
Setback Bicycle Crossing
Forward Stop Bar


Corner
Safety
Island

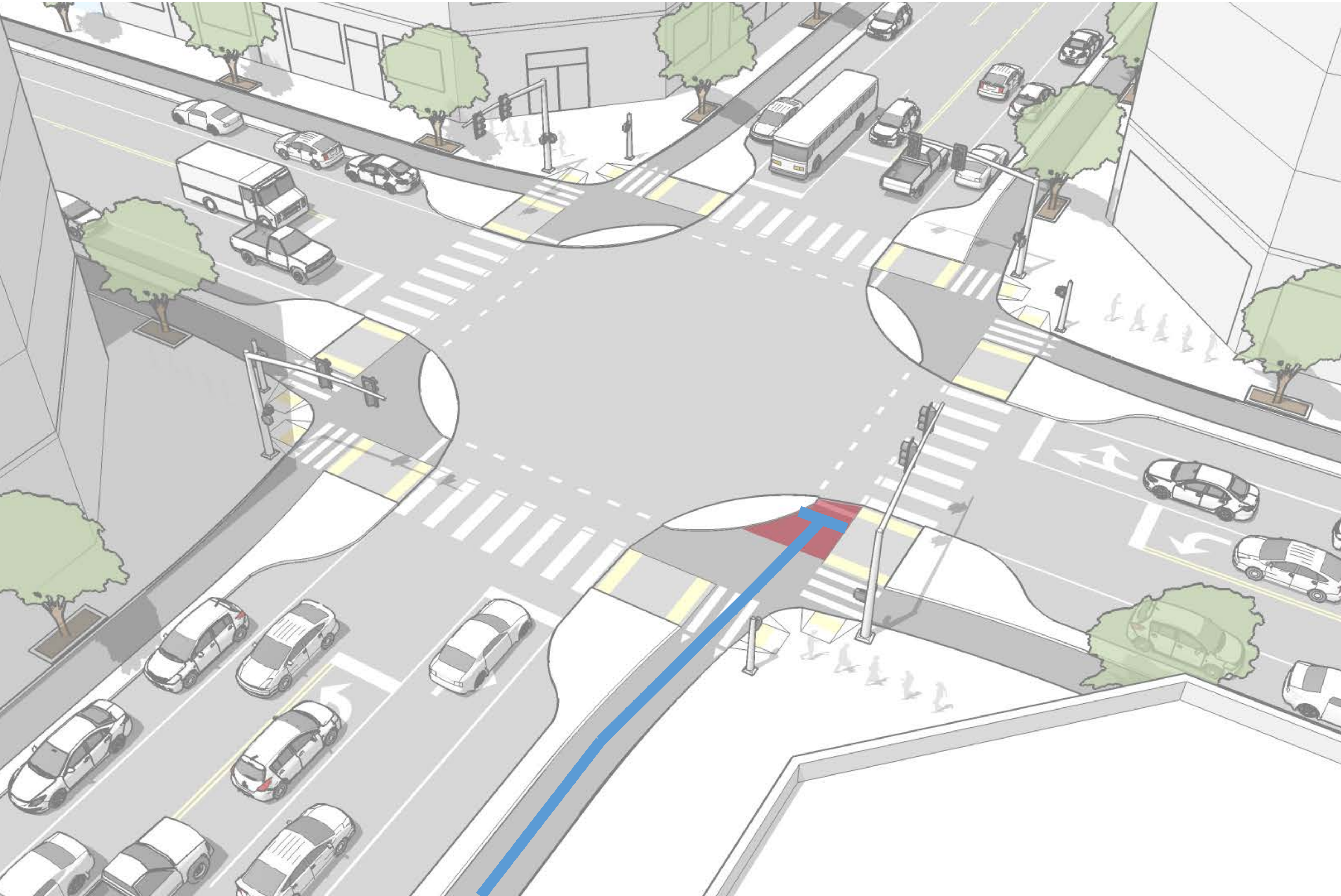


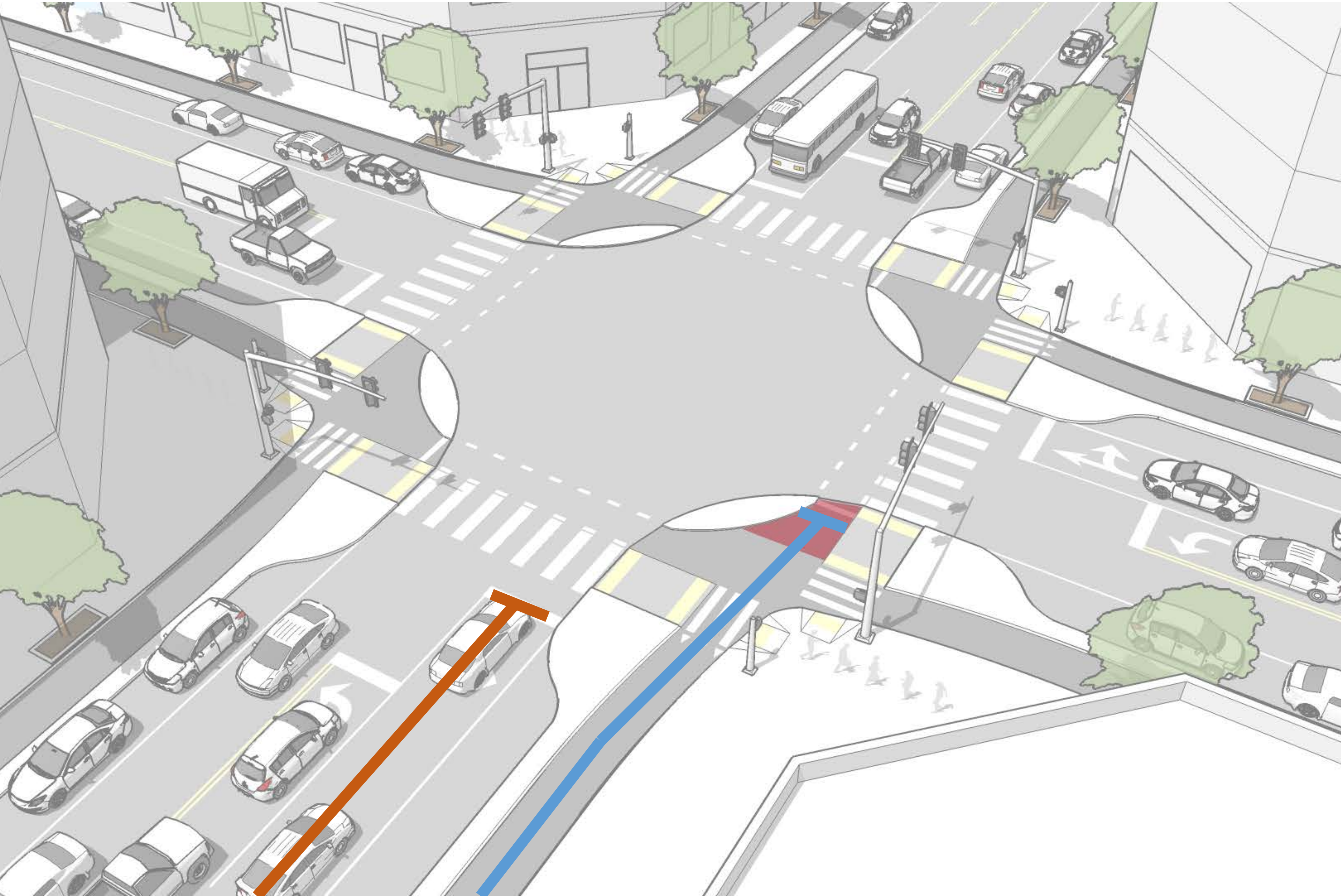


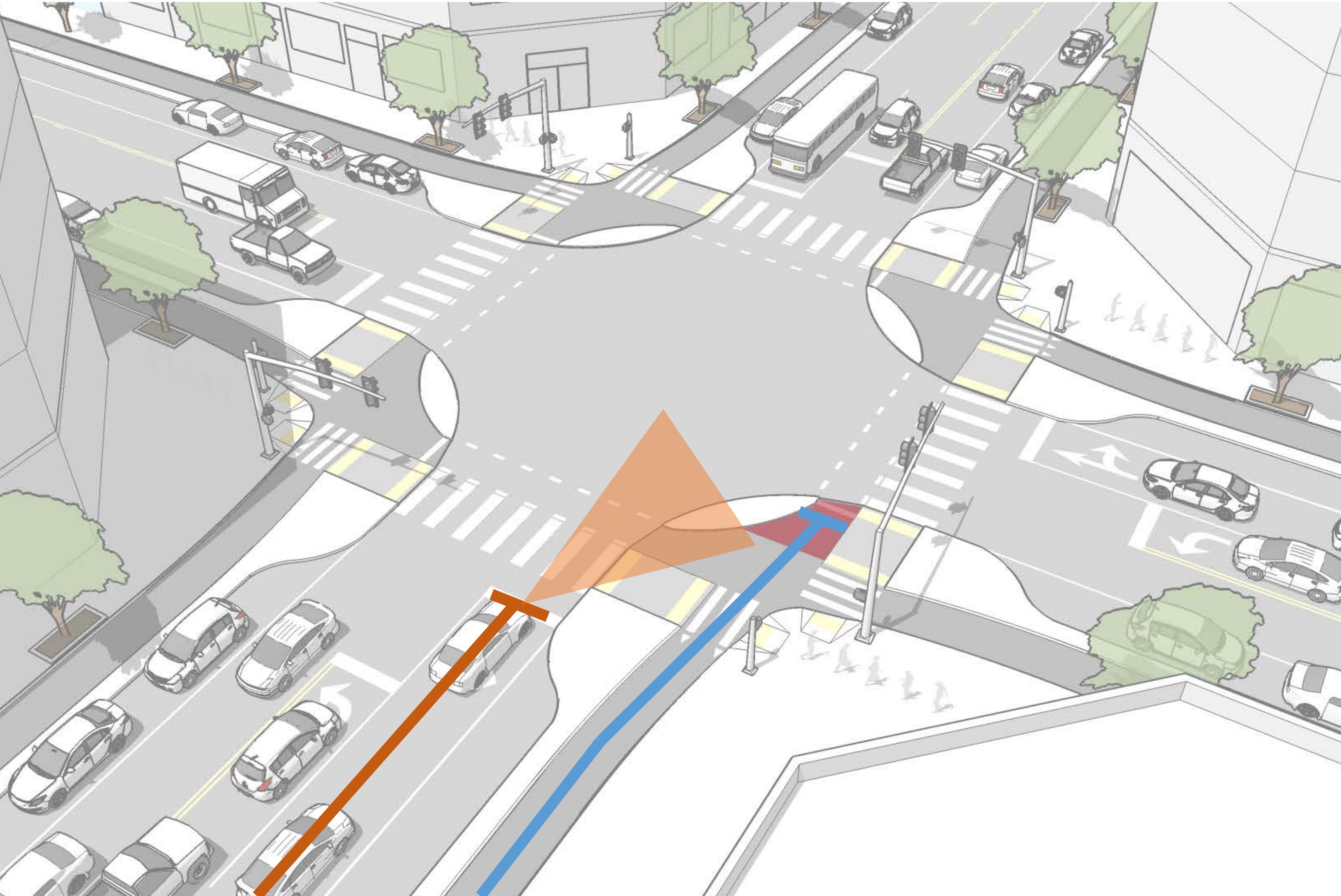


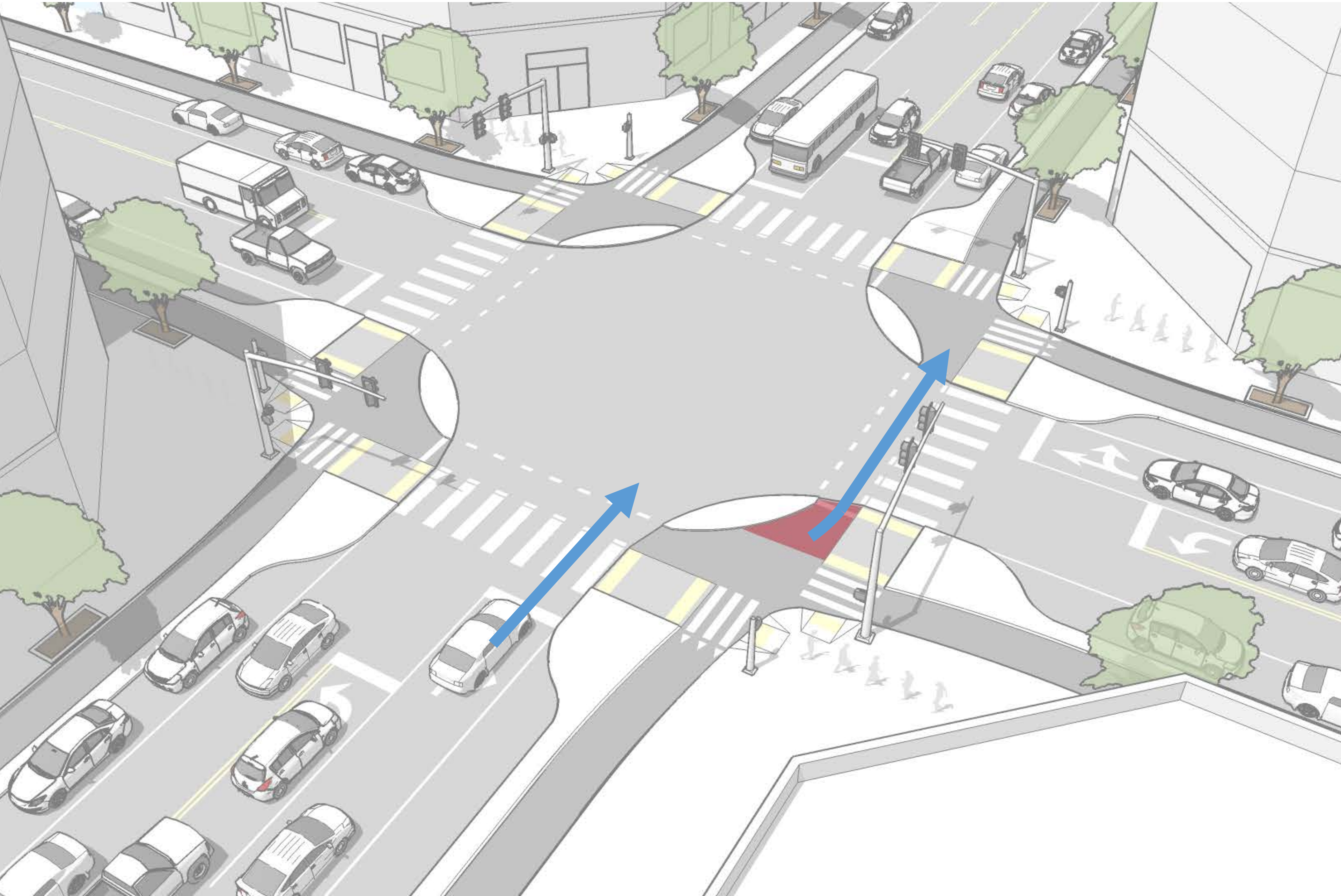


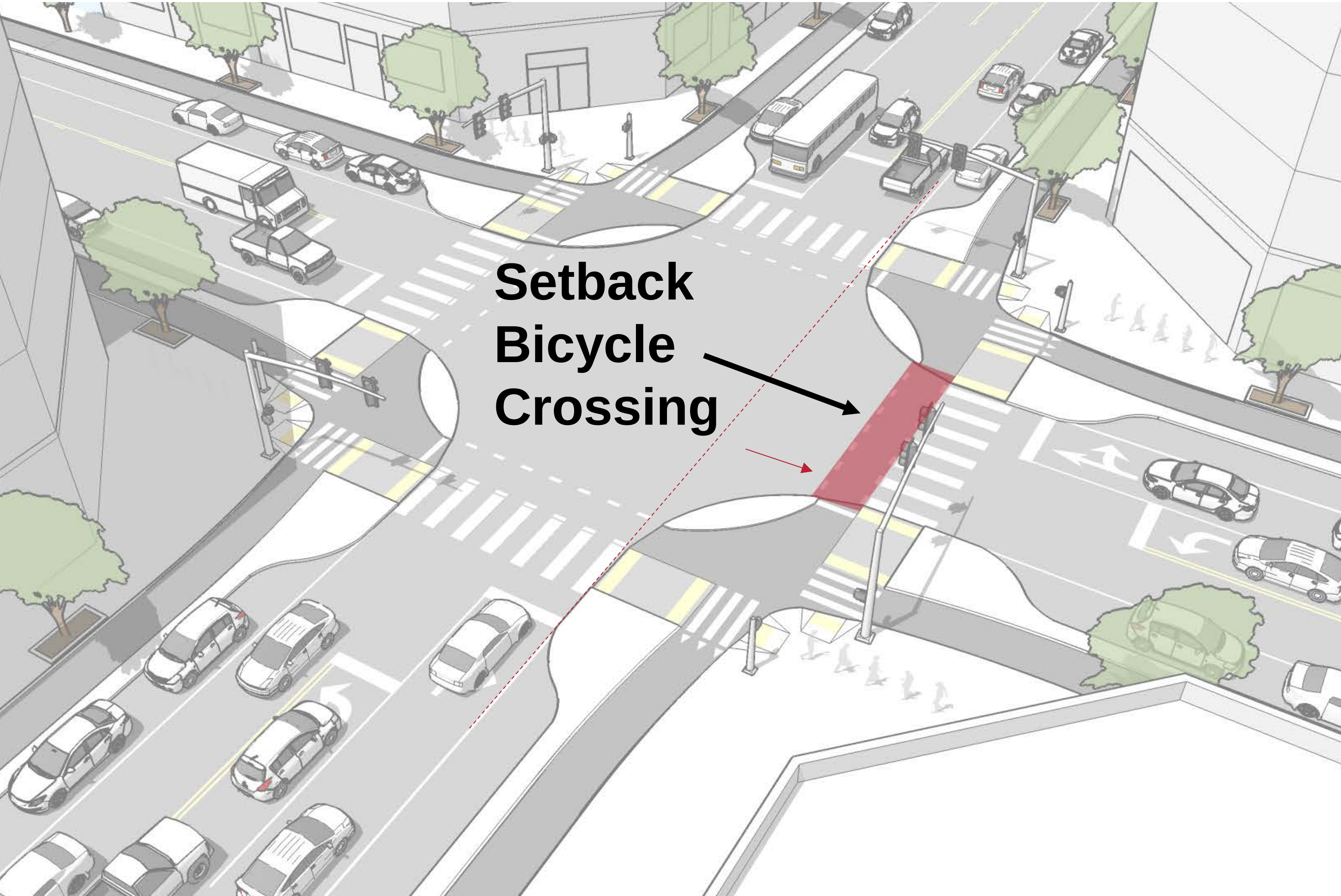
Forward
Stop Bar

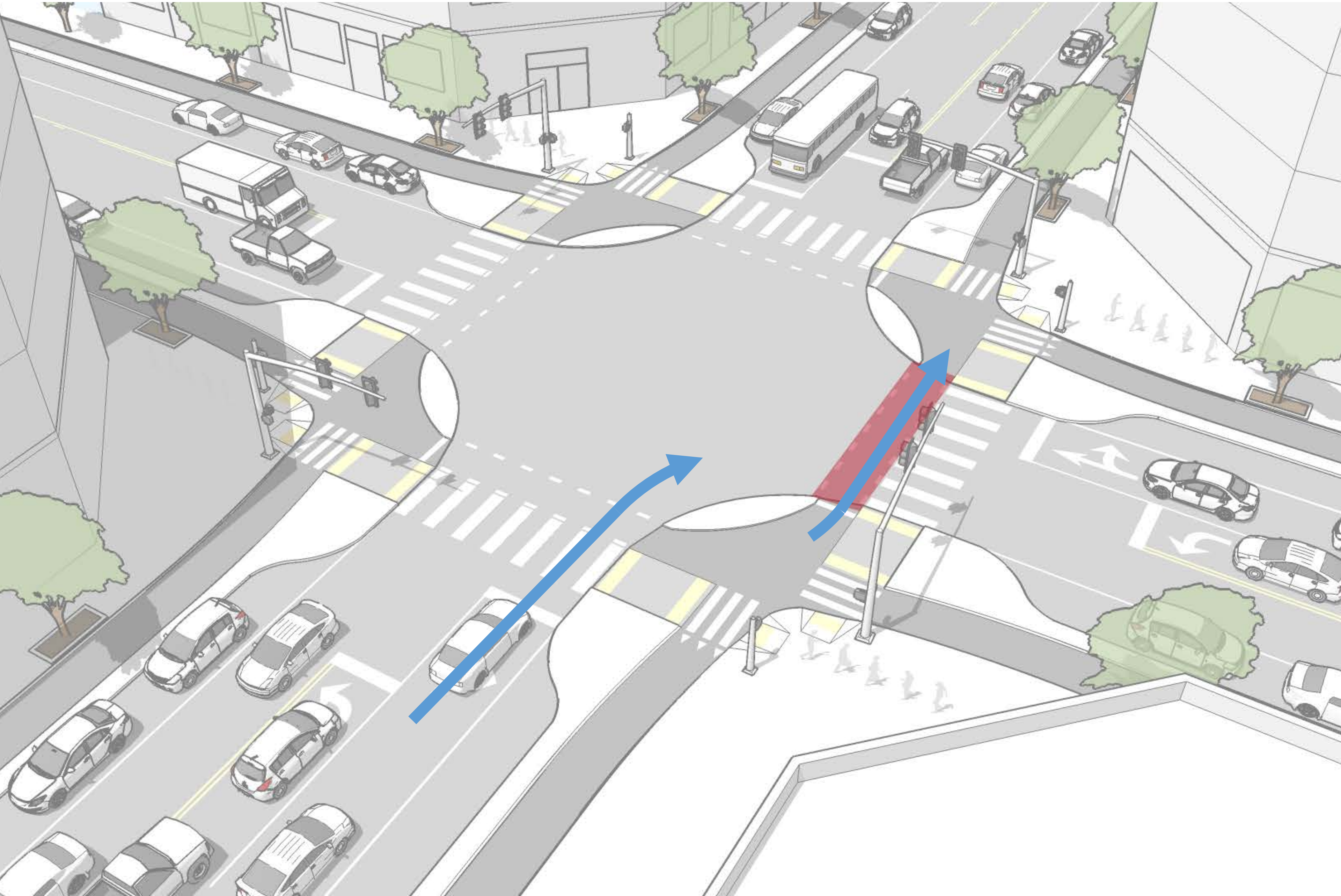


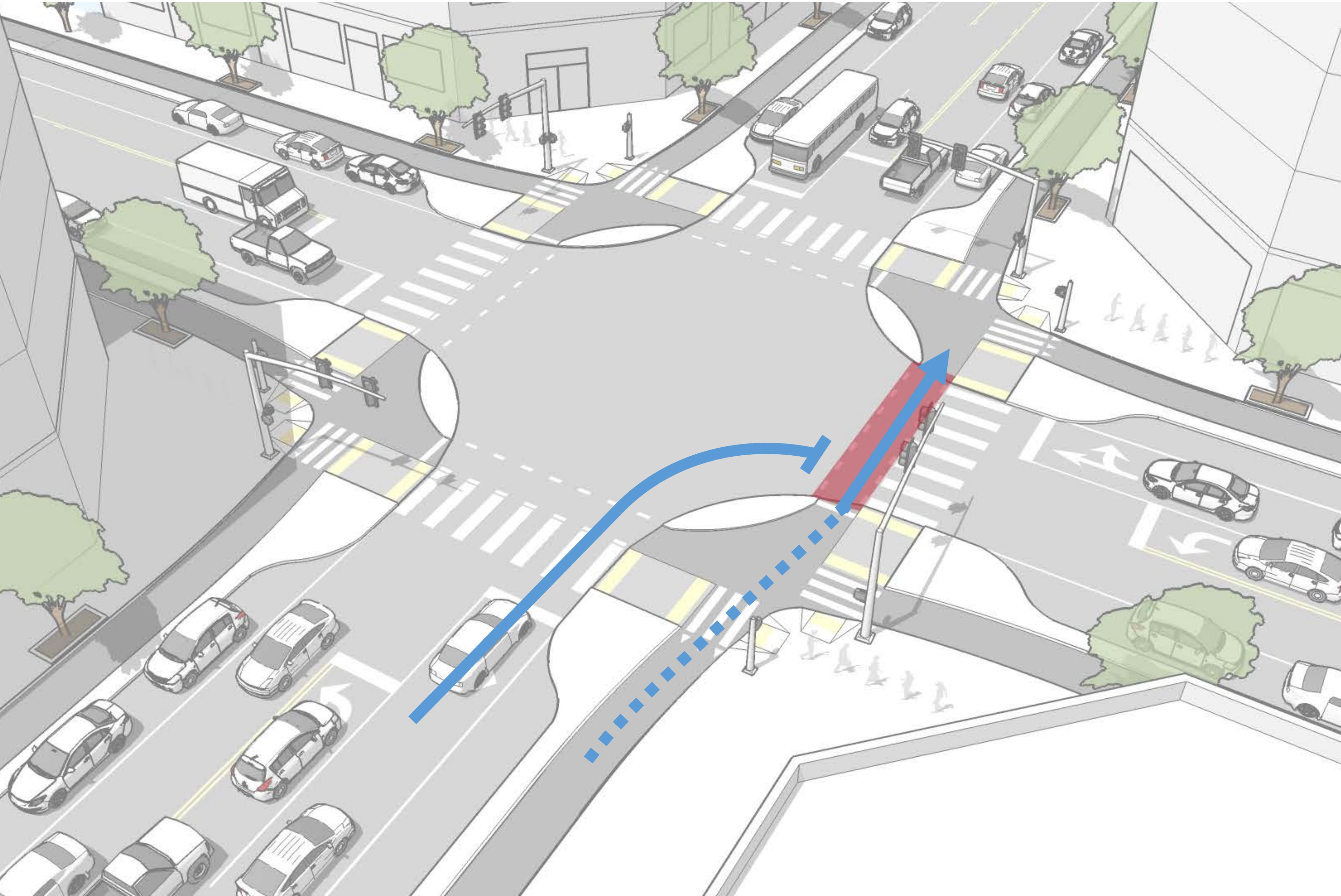


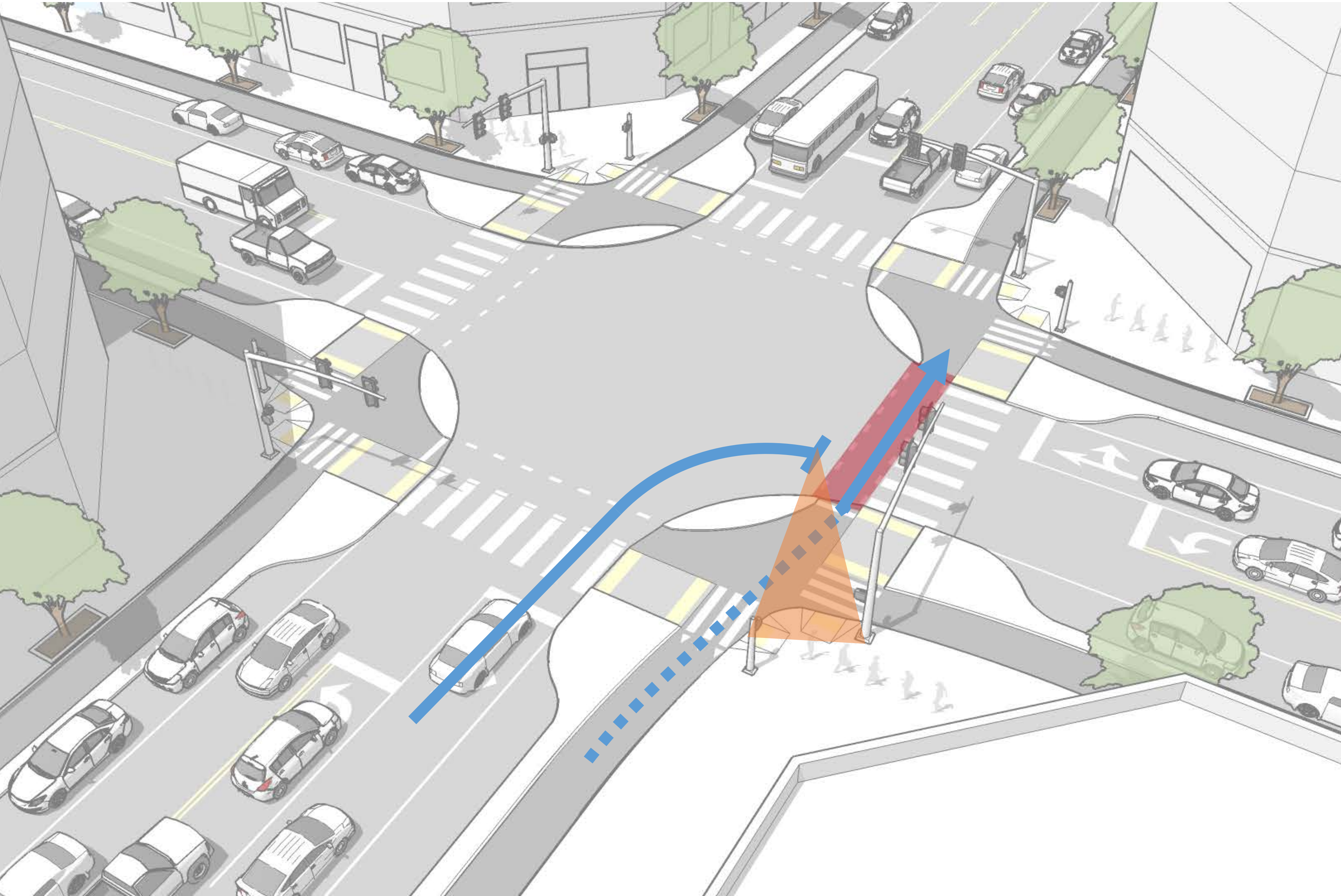


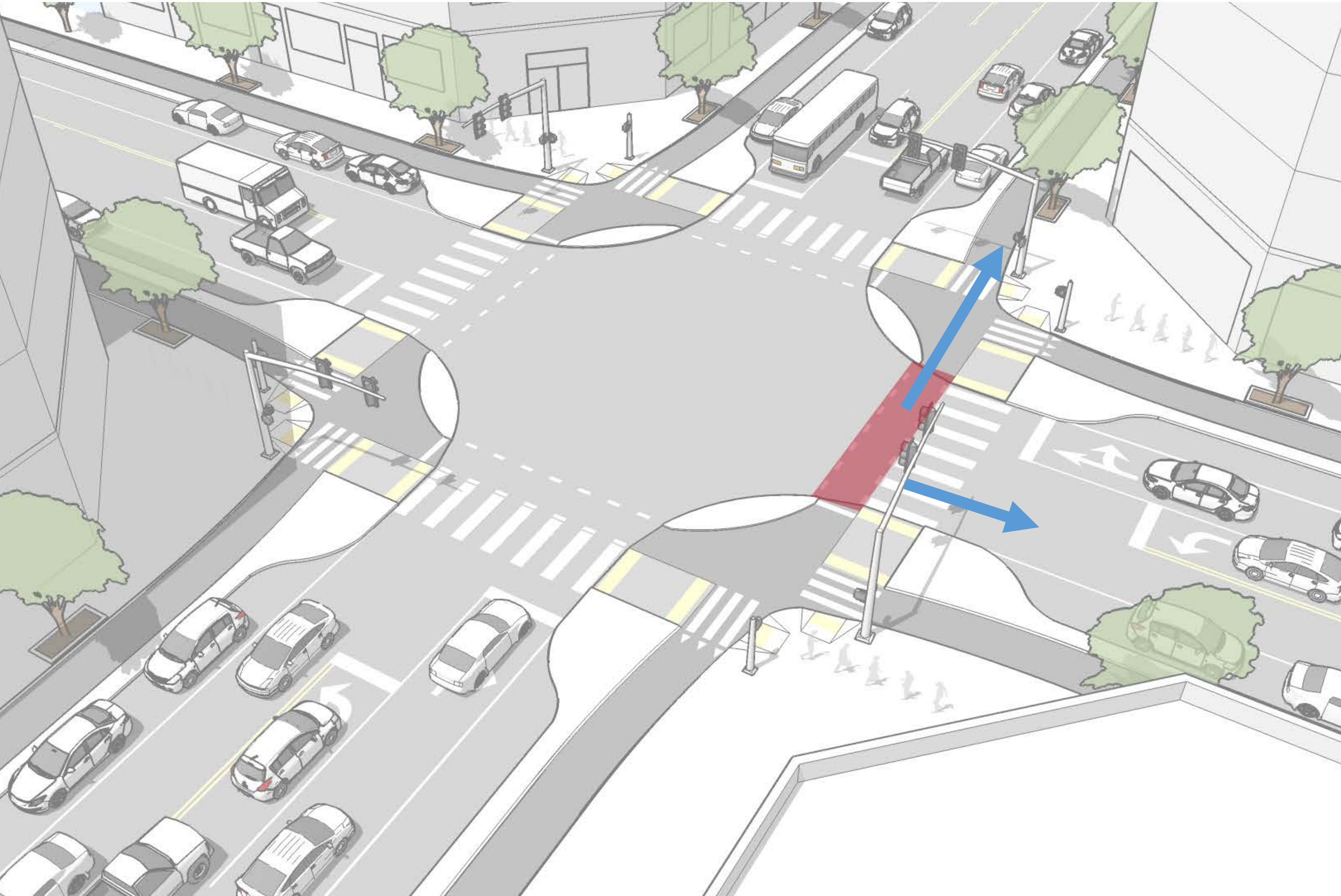


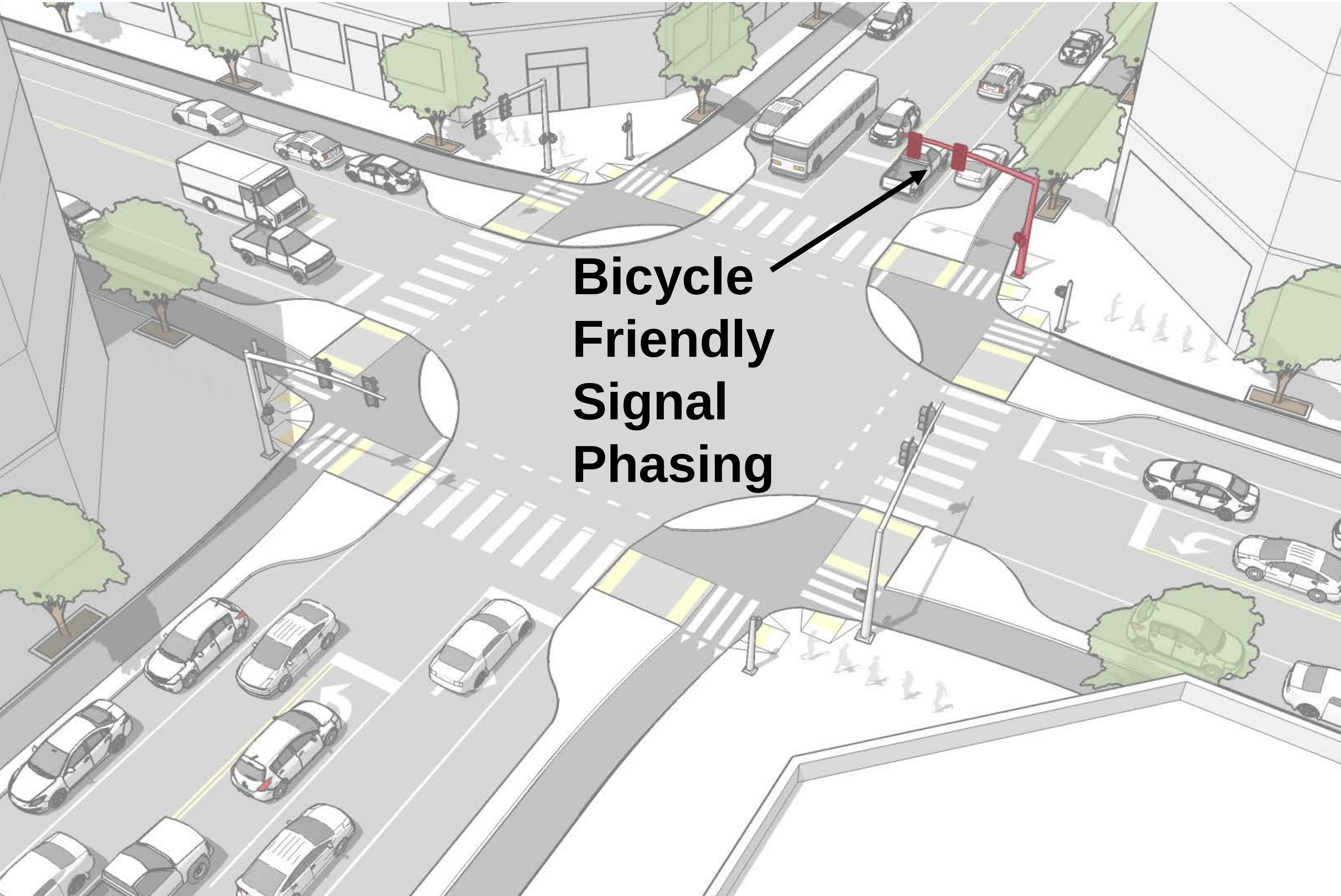

Setback
Bicycle
Crossing

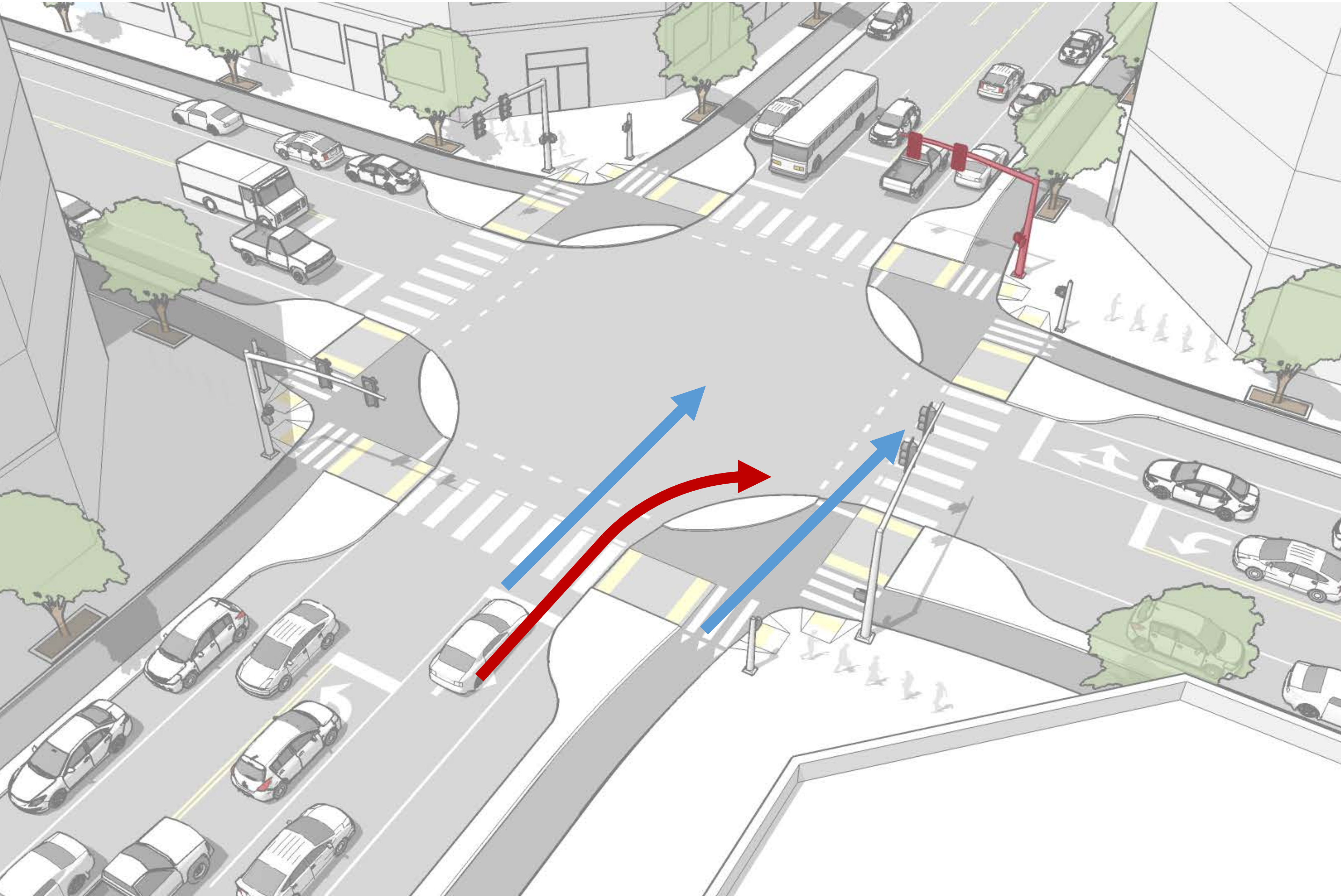


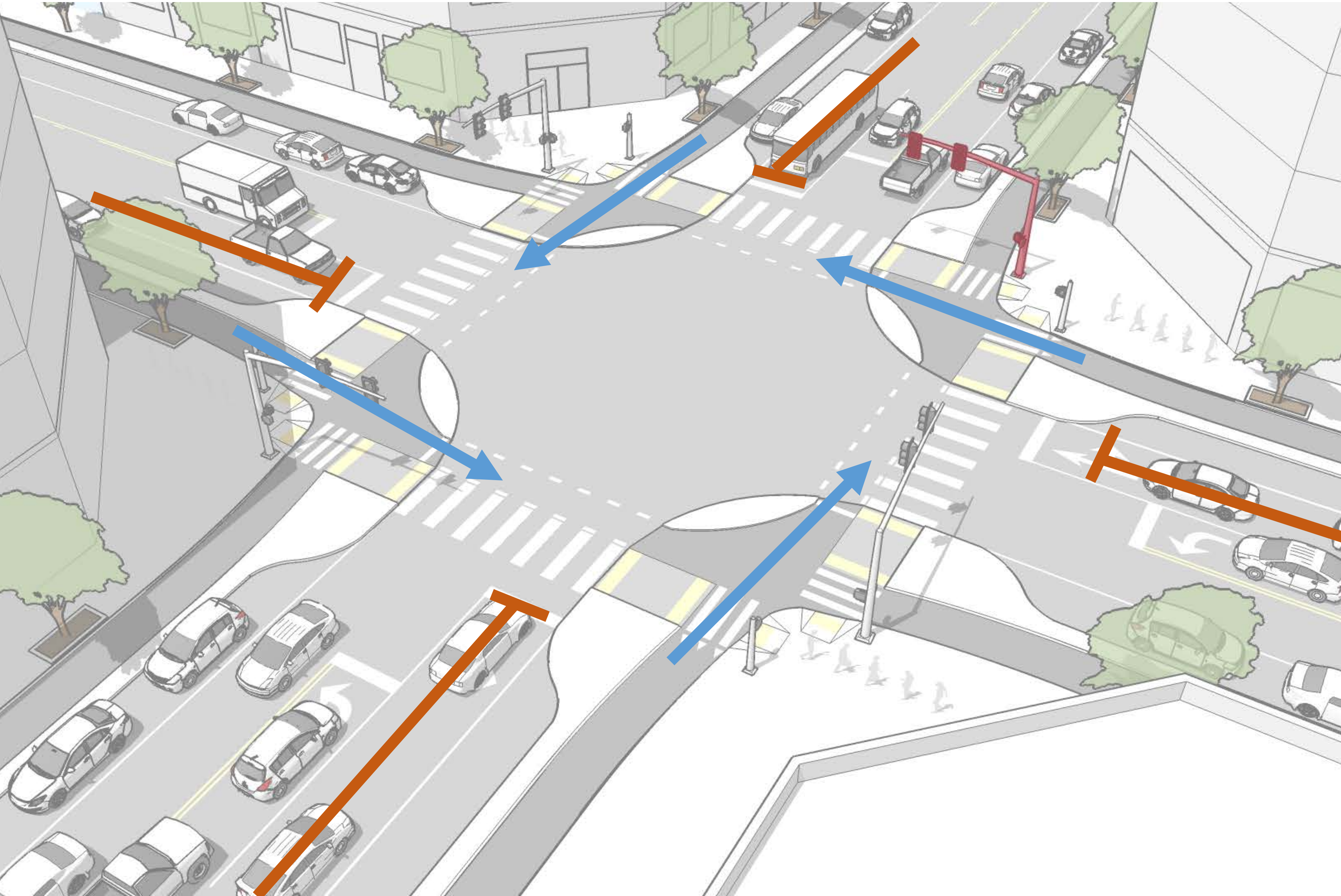


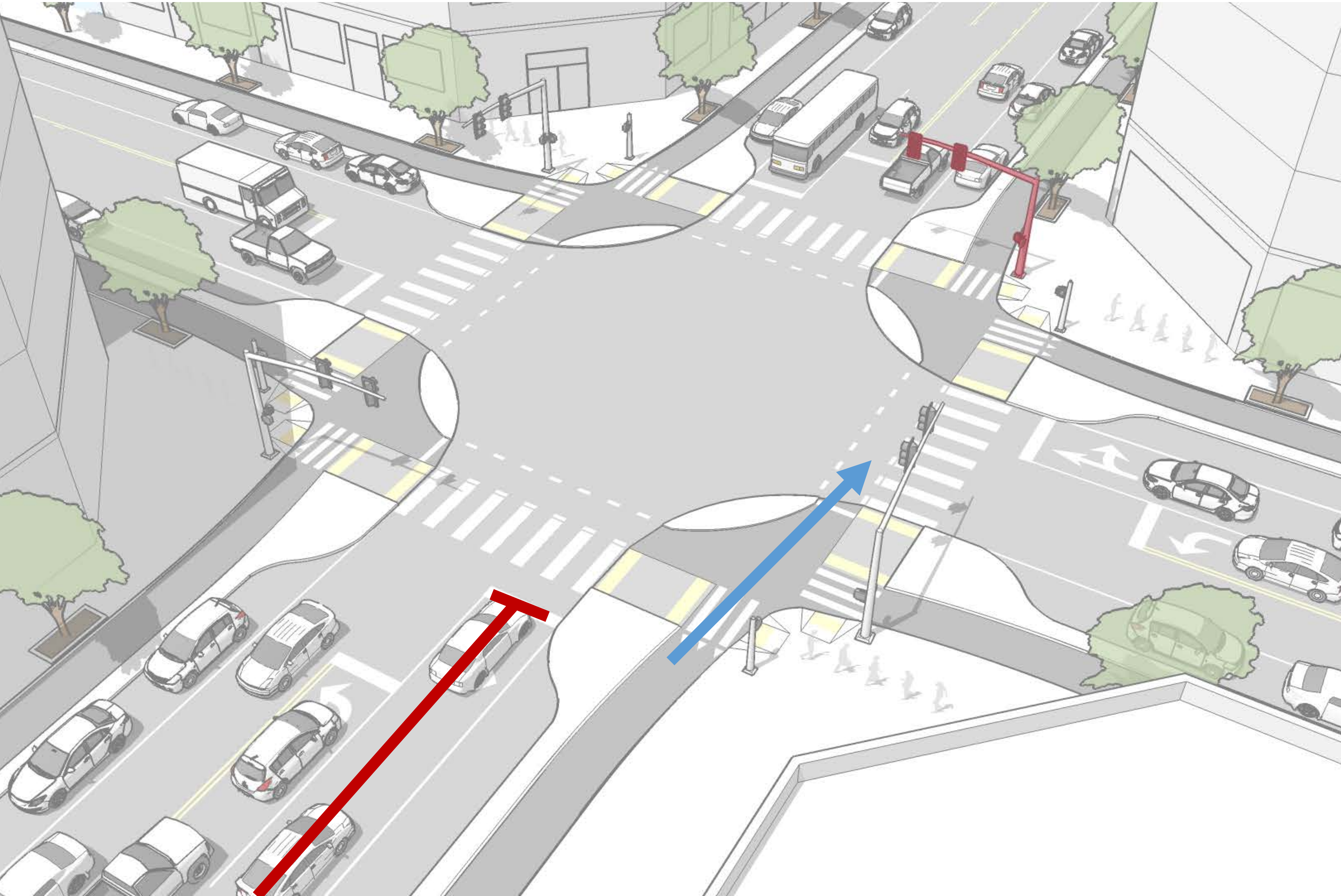


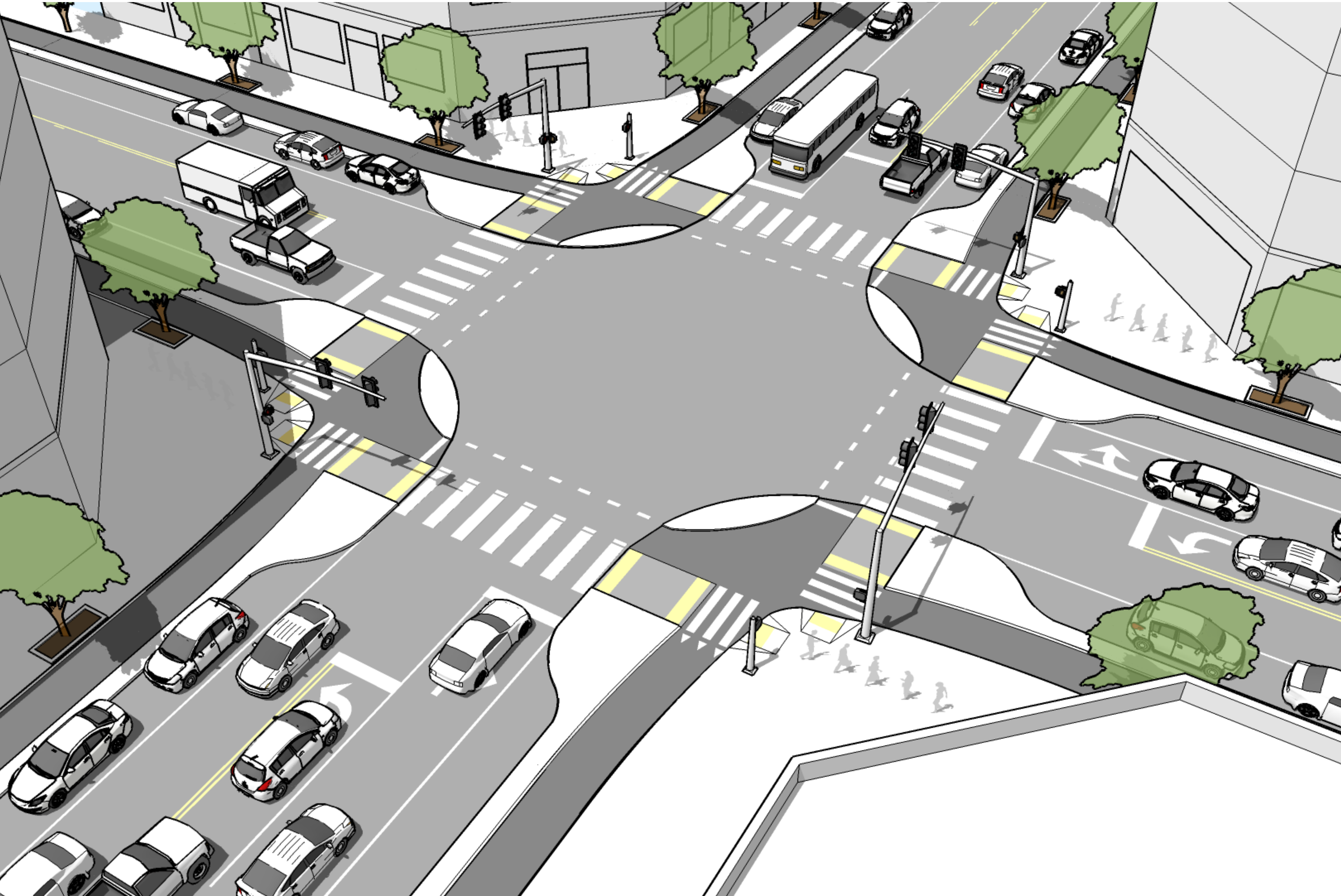



Bicycle
Friendly
Signal
Phasing



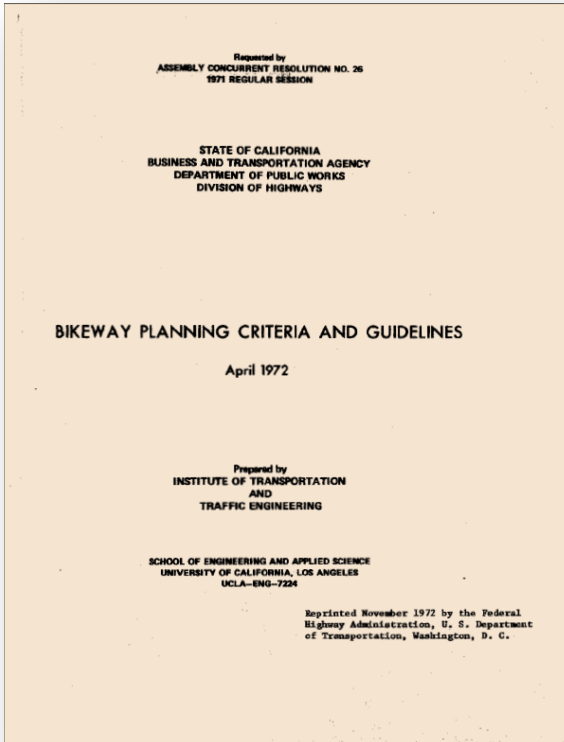






History

History



Requested by
ASSEMBLY CONCURRENT RESOLUTION NO. 26
1971 REGULAR SESSION

STATE OF CALIFORNIA
BUSINESS AND TRANSPORTATION AGENCY
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

BIKEWAY PLANNING CRITERIA AND GUIDELINES

April 1972

Prepared by
INSTITUTE OF TRANSPORTATION
AND
TRAFFIC ENGINEERING

SCHOOL OF ENGINEERING AND APPLIED SCIENCE
UNIVERSITY OF CALIFORNIA, LOS ANGELES
UCLA–ENG–7224

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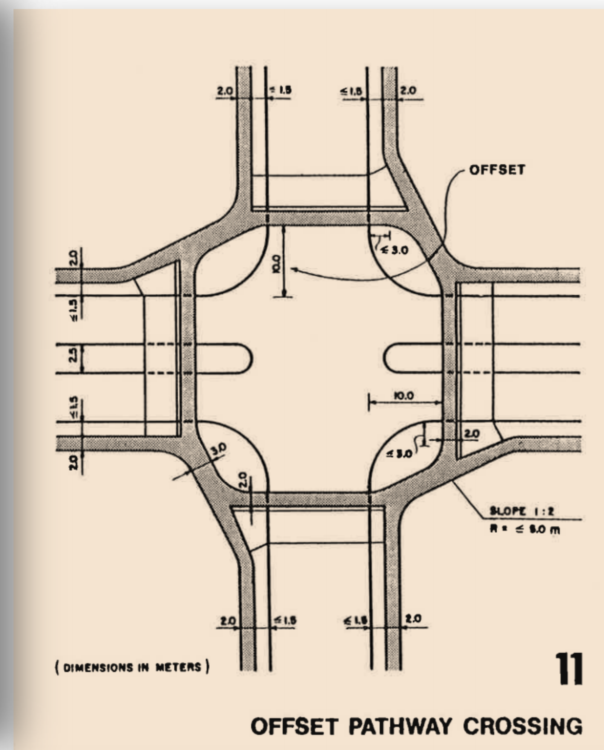
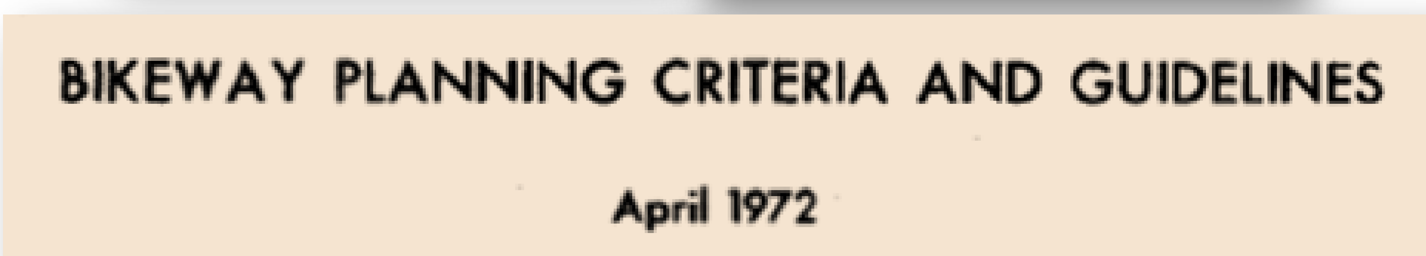




BIKEWAY PLANNING CRITERIA AND GUIDELINES

April 1972

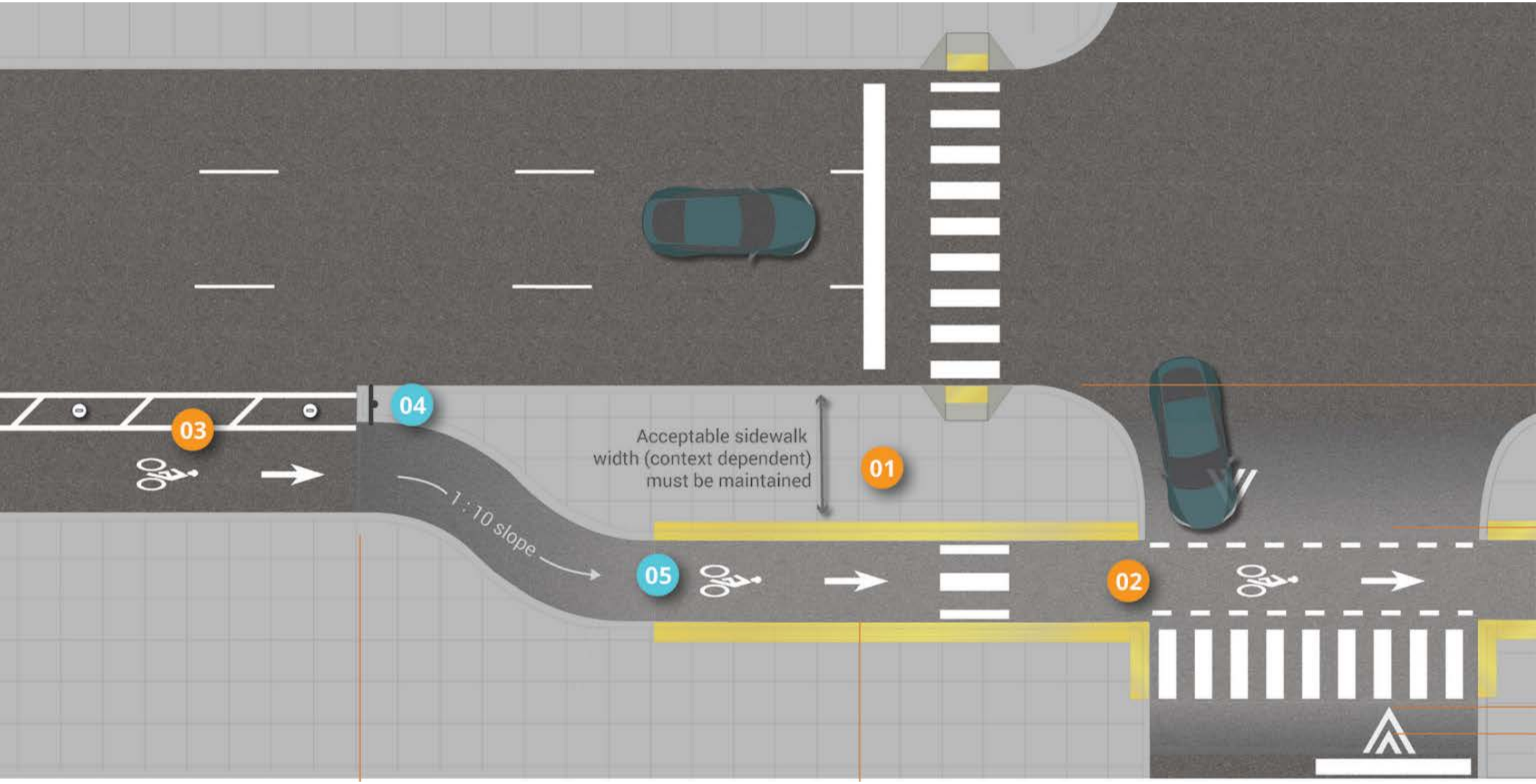
Design Elements Today

Signalization

Forward Stop Bar

Slow Speed Setback Crossing

Slow Speed Setback Crossing



FHWA. Separated Bike Lane Planning and Design Guide. 2015.

Pedestrian Safety Islands

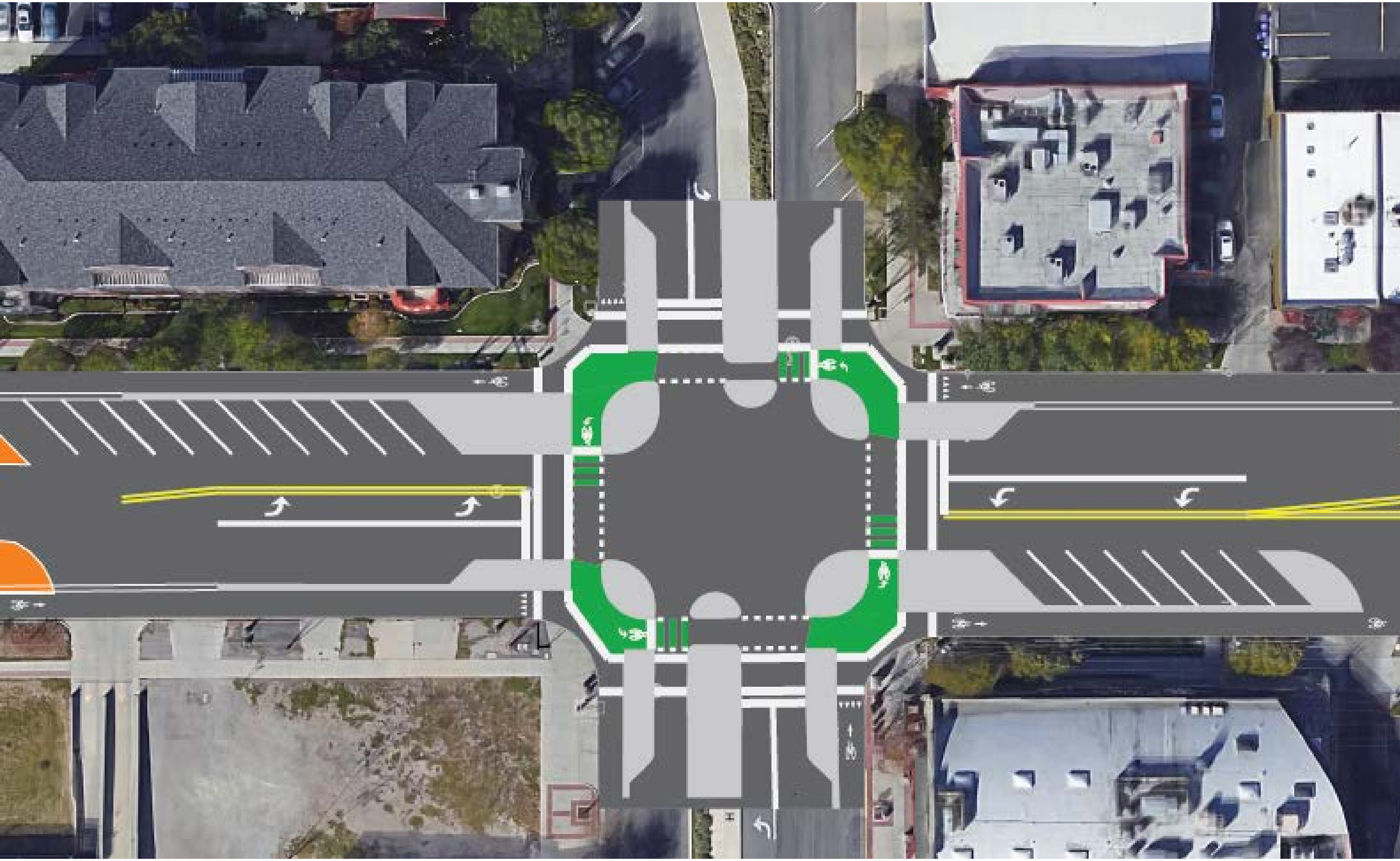
Corner Safety Islands

Current Developments

Austin, TX

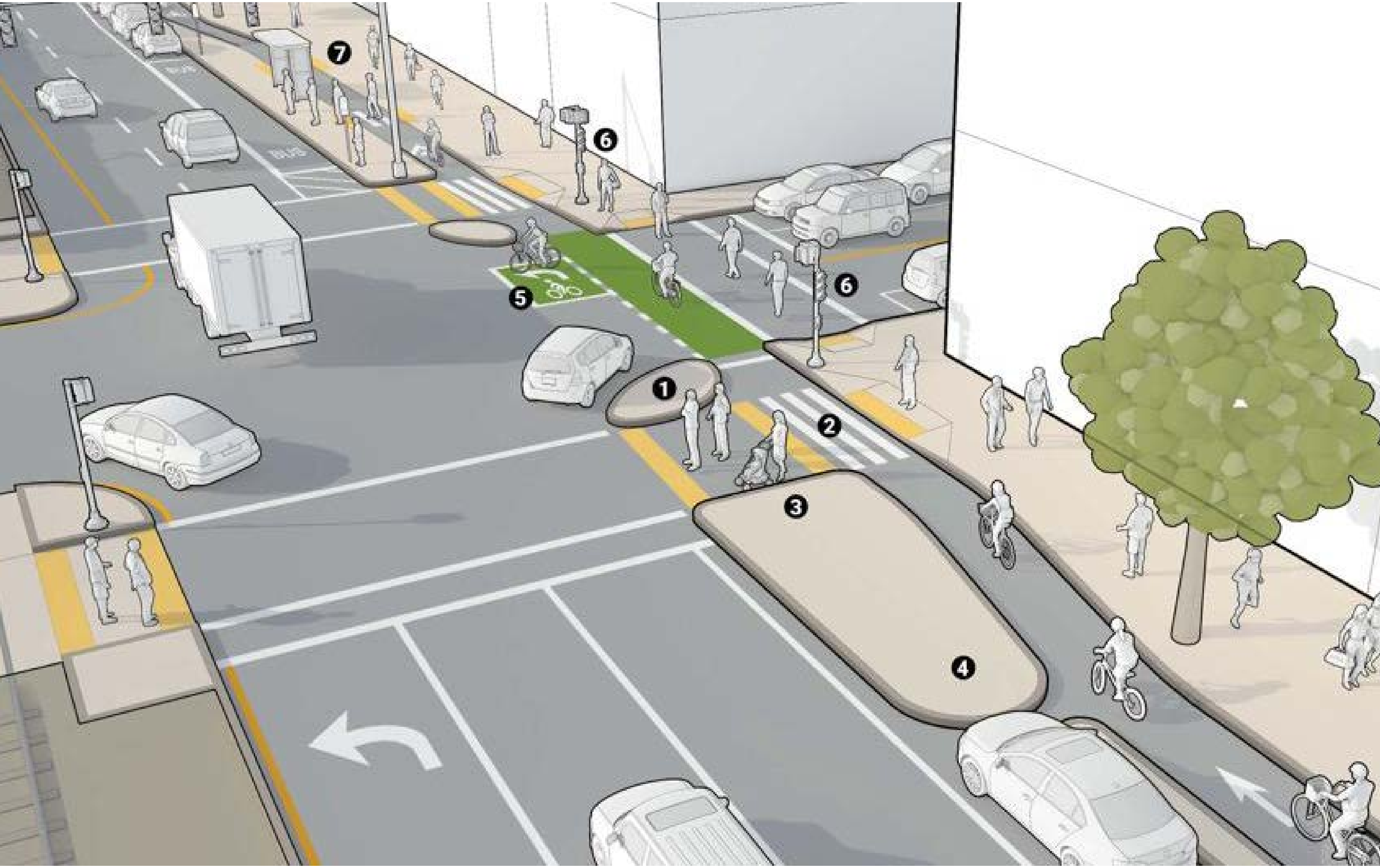
Davis, CA

Davis, CA



Salt Lake City, UT

Salt Lake City, UT



Boston, MA

Thank You

Nick Falbo

Senior Planner, Alta Planning + Design

nickfalbo@altaplanning.com