North Central Texas
November 2021

BICYCLIST SAFETY AT INTERSECTIONS

NOTE OF CAUTION

The knowledge and practice of designing for bicyclists is rapidly changing. Images in these materials and other guidelines may be outdated. Always check for the latest MUTCD interim and experimental TCD's.

Bicyclist Safety at Intersections

IMPERATIVE FOR IMPROVEMENT

WHAT ARE THE OPPORTUNITIES?

- 50 % of trips are ≤ 3 miles
- > 1/3 of U.S. adults say they would commute by bike if safe facilities were available
- 1 out of every 11 U.S. households do not own an automobile

BICYCLIST SKILL & COMFORT

Experienced & Confident

- Navigate on streets
- Some prefer bike lane, shoulders, shared-use paths when available
- Prefer direct route
- Speeds up to 25 mph on level and 45 mph on downgrade
- Longer trips

Casual/Less Confident

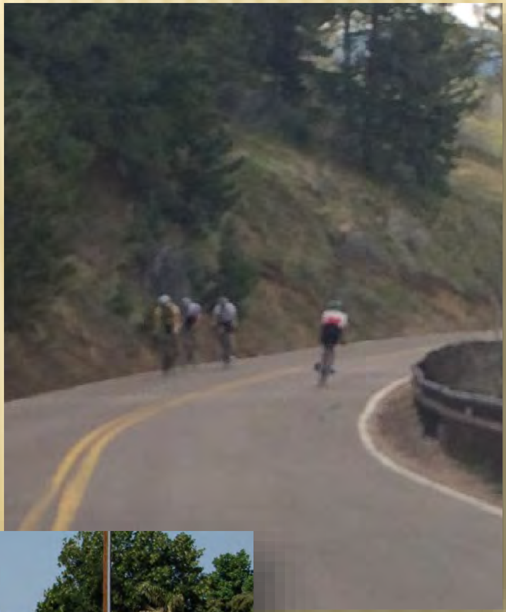
- Difficulty gauging traffic or unfamiliar with rules of road
- Prefer shared use paths or bike lanes on low volume streets
- Prefer separation from traffic
- May ride on sidewalk
- Avoid traffic
- Speeds of 8 to 12 mph
- Trips of 1 to 5 miles

BICYCLIST CHARACTERISTICS

- Reasons for bicycling
  - Recreation 26.0%
  - Exercise or health reasons 23.6%
  - To go home 14.2%
  - Personal errands 13.9%
  - To visit a friend or relative 10.1%
  - Commuting to school/work 5.0%
  - Bicycle ride 2.3%
  - Other 4.9%

BICYCLIST CHARACTERISTICS

- Preferences
  - Feel safe
  - Feel secure
  - Lower speed
  - Lower volume
  - Lower truck %
  - Fewer lanes
- Behaviors
  - Violate traffic control
  - Slow on uphill
  - Fast on downhill



DEATHS AND INJURIES

In 2015

- 818 killed
- 45,000 injured
- Cyclists accounted for 2.3% of all traffic fatalities

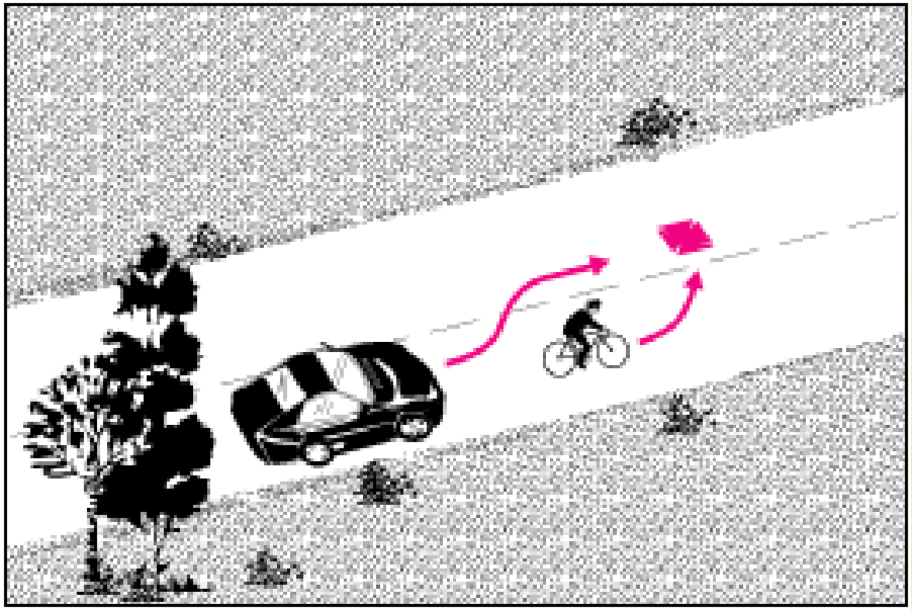
...but make up 1% of all trips.

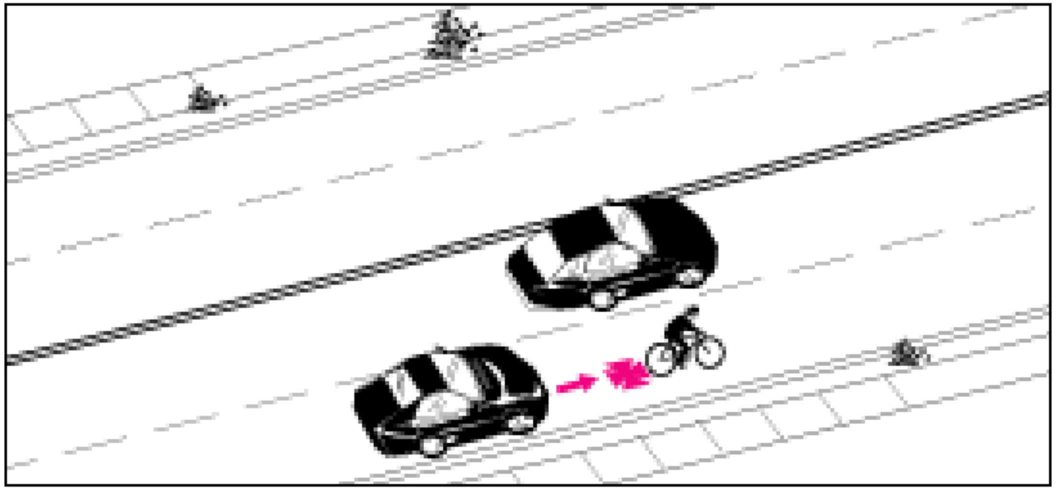
BICYCLE CRASH CHARACTERISTICS

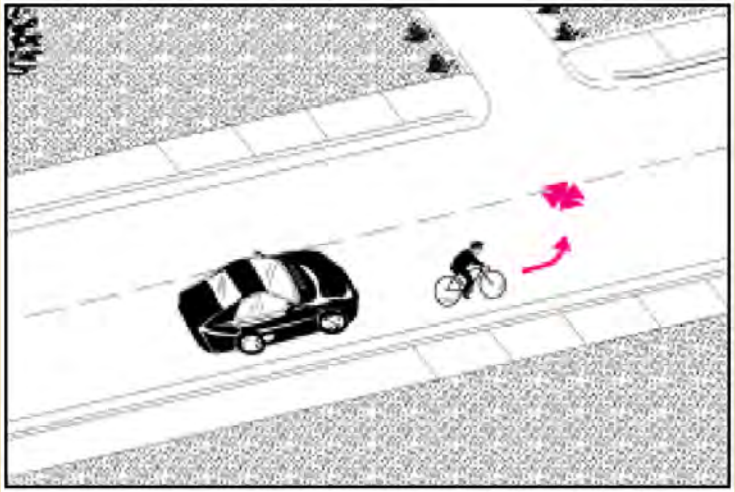
- 57% of <u>fatalities</u> at non-intersection locations
- 58% of <u>injuries</u> at intersections

MOST COMMON CRASHES

- Rural
  - **Turn/merge into path of motorist**
  - Motorist overtaking

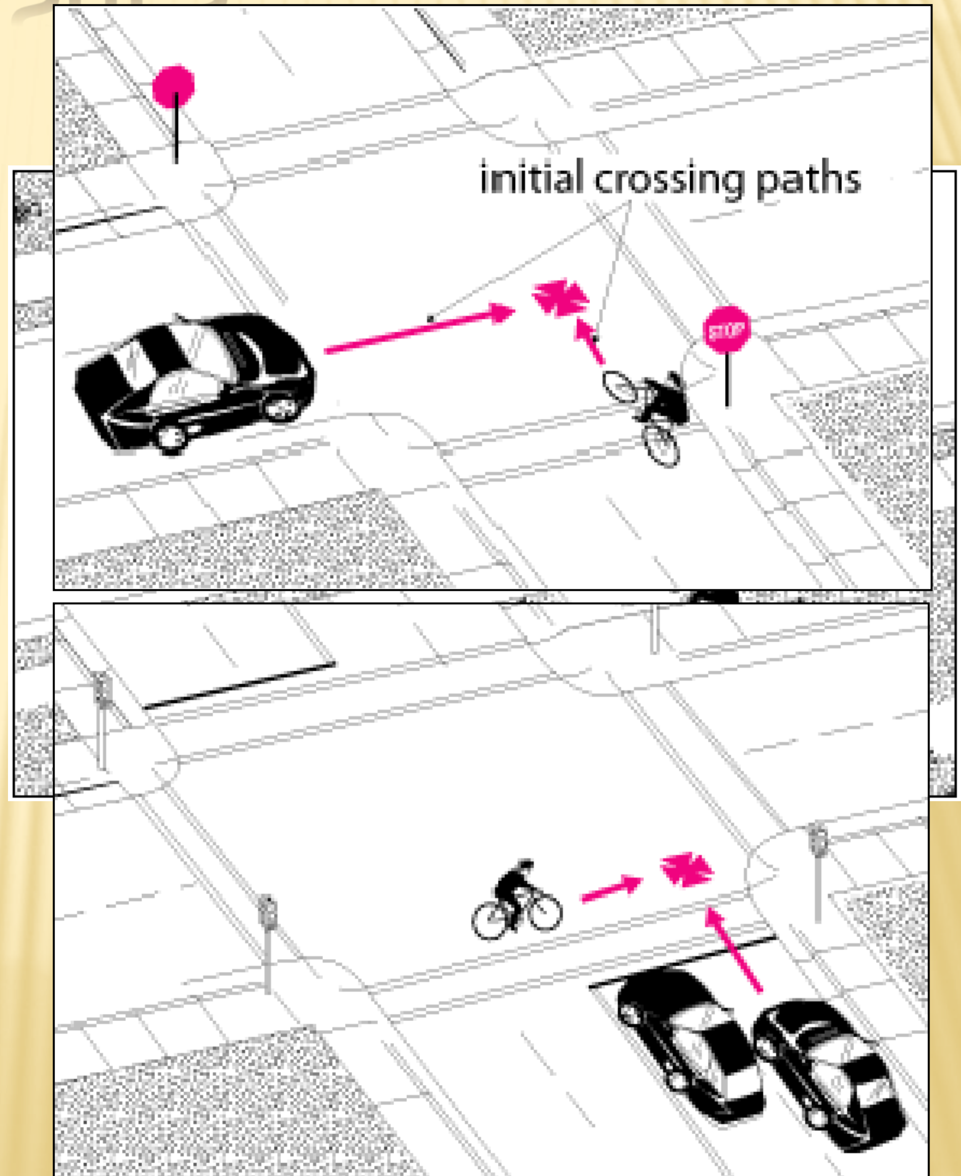






MOST COMMON CRASHES

- Urban
  - **Motorist failed to yield**
  - **Bicyclist failed to yield at midblock**
  - Bicyclist failed to yield at intersection



BICYCLIST DESIGN USER PROFILES

Interested but Concerned

51%-56% of the total population

Often not comfortable with bike lanes, may bike on sidewalks even if bike lanes are provided; prefer off-street or separated bicycle facilities or quiet or traffic-calmed residential roads. May not bike at all if bicycle facilities do not meet needs for perceived comfort.

Somewhat Confident

5-9% of the total population

Generally prefer more separated facilities, but are comfortable riding in bicycle lanes or on paved shoulders if need be.

Highly Confident

4-7% of the total population

Comfortable riding with traffic; will use roads without bike lanes.

LOW STRESS TOLERANCE

HIGH STRESS TOLERANCE

Source: Dill, J., McNeil, N. (2012). Four Types of Cyclists? Examining a Typology to Better Understand Bicycling Behavior and Potential.

LEVELS OF TRAFFIC STRESS (LTS)

- LTS 1: Suitable for almost all
- LTS 2: Suitable to most adult cyclists
- LTS 3: More traffic stress
- LTS 4: Strong and fearless

LEVELS OF TRAFFIC STRESS (LTS)

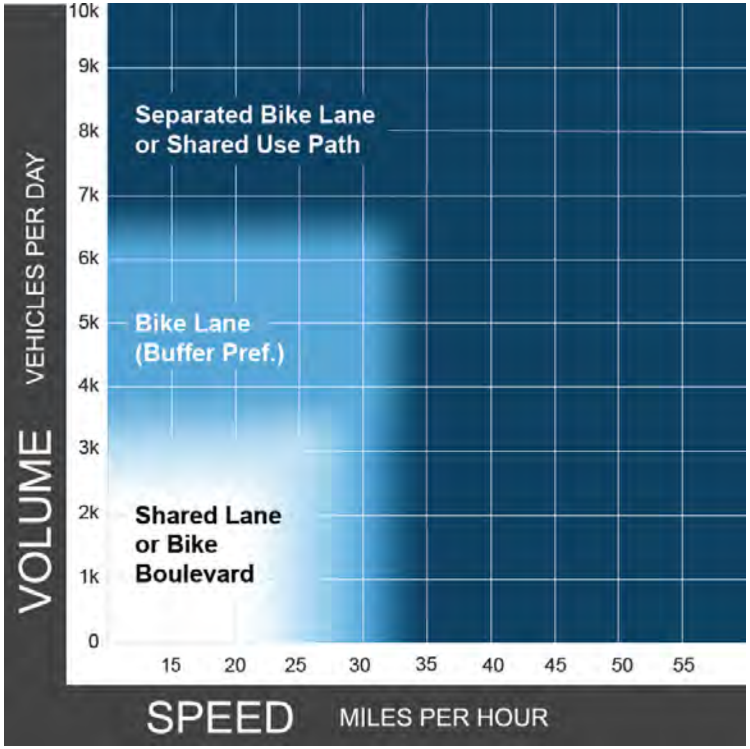
Levels of Traffic Stress			
LTS 1	LTS 2	LTS 3	LTS 4
• Physically separated from traffic or low-volume, mixed-flow traffic at 25 mph or less • Bike lanes 6 ft wide or more • Intersections easy to approach and cross • Comfortable for children	• Bike lanes 5.5 ft wide or less, next to 30 mph auto traffic • Unsignalized crossings of up to 5 lanes at 30 mph • Comfortable for most adults • Typical of bicycle facilities in Netherlands	• Bicycle lanes next to 35 mph auto traffic, or mixed-flow traffic at 30 mph or less • Comfortable for most current U.S. riders • Typical of bicycle facilities in U.S.	• No dedicated bicycle facilities • Traffic speeds 40 mph or more • Comfortable for “strong and fearless” riders (vehicular cyclists)

CASUAL/LESS CONFIDENT

In order for this group to regularly choose bicycling as a mode of transportation, a physical network of visible, convenient, and well-designed bicycle facilities is needed.

AASHTO Guide for the Development of Bicycle Facilities 2012

City, Small Town, and Suburban Roadways



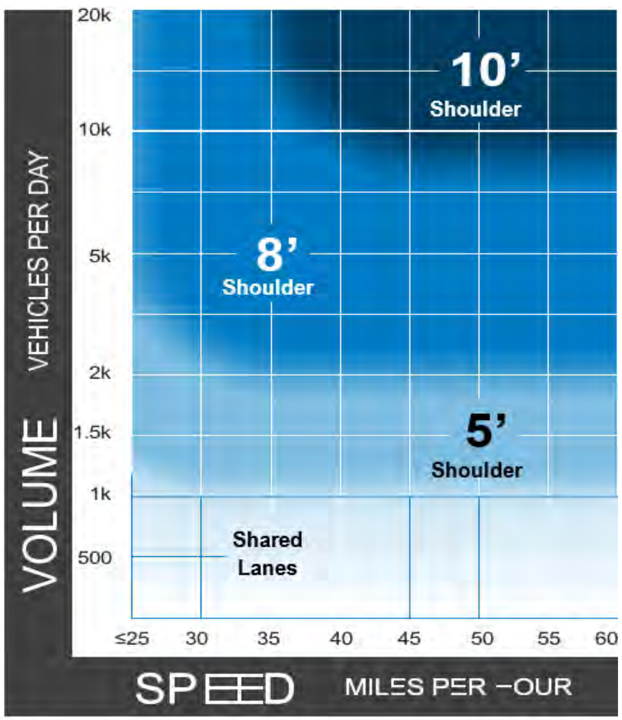
Identifies the **preferred** bikeway type.

<u>Design User Assumption</u>:
Interested but concerned cyclist

<u>Analysis</u>:

Bicycle Level of Traffic Stress

Rural Roadways



Identifies the **preferred** shoulder width.

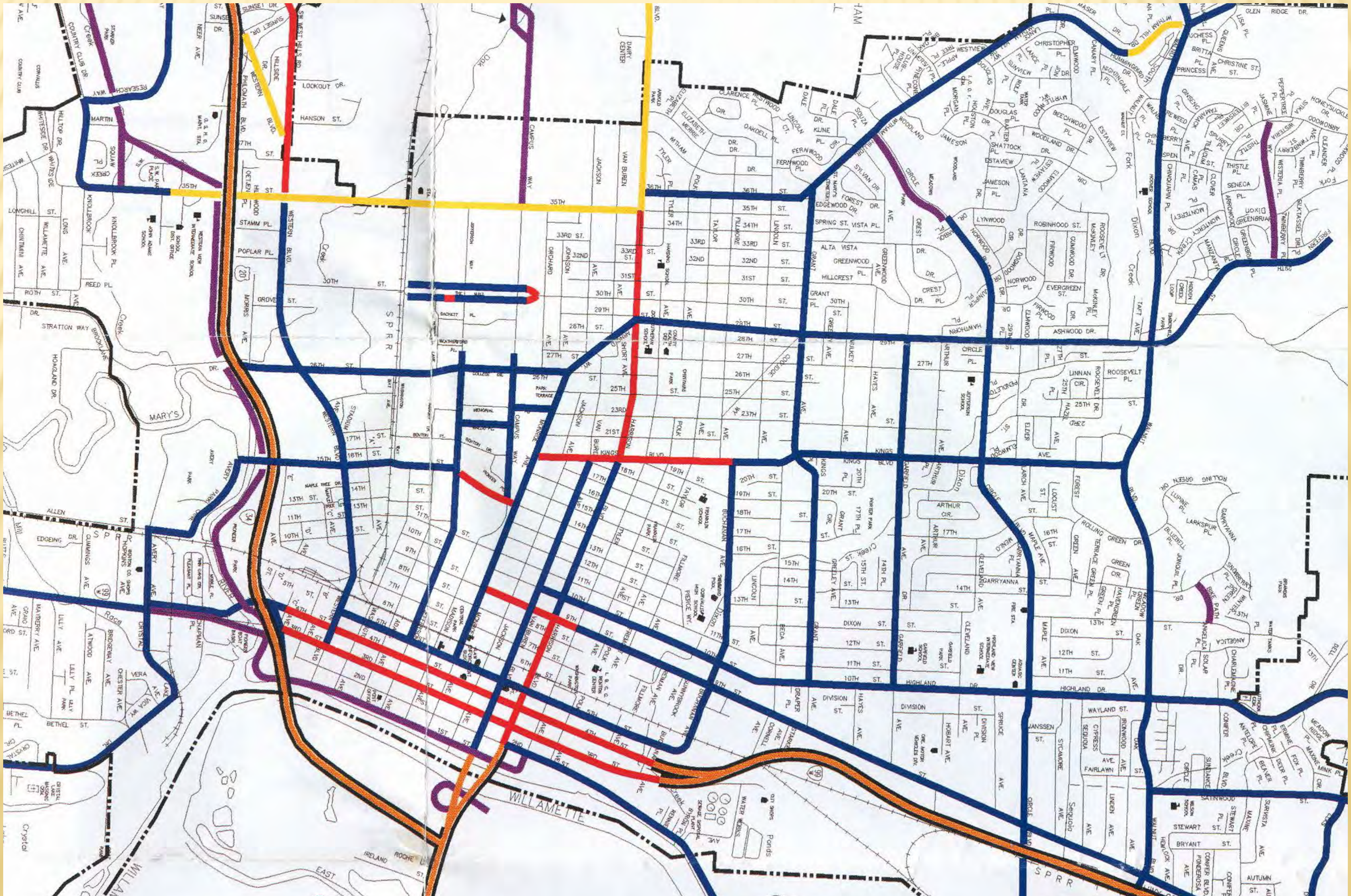
<u>Design User Assumption</u>:

Confident bicyclist

<u>Analysis</u>:

Bicycle Level of Service

WELL-CONNECTED NETWORK



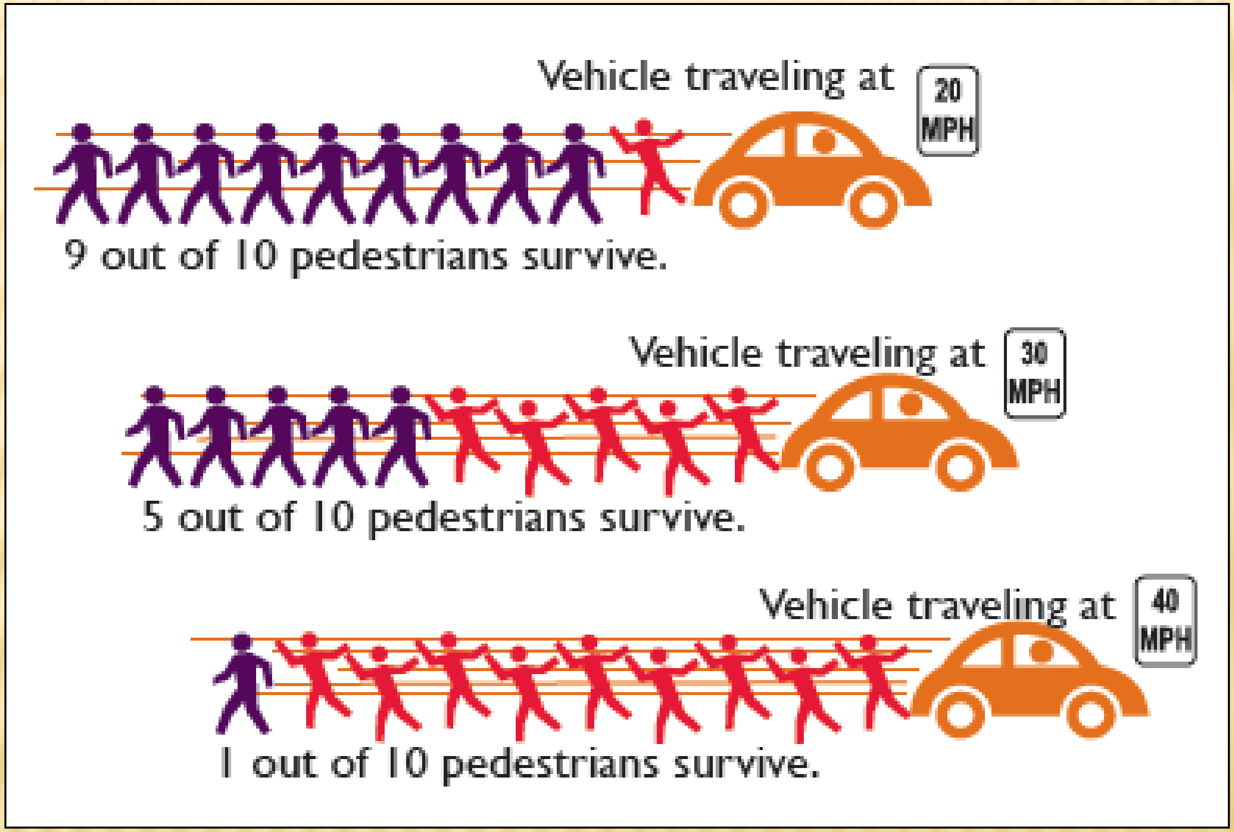
Designing for Bicyclist Safety

CORE SAFETY CONCEPTS

KEY SAFETY FACTORS

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

SPEED



Vehicle traveling at
20 MPH
9 out of 10 pedestrians survive.
Vehicle traveling at
30 MPH
5 out of 10 pedestrians survive.
Vehicle traveling at
40 MPH
1 out of 10 pedestrians survive.

NUMBER OF LANES

VISIBILITY/CONSPICUITY

TRAFFIC VOLUME & COMPOSITION

CONFLICT POINTS

PROXIMITY

BIKE CONTROL

CONNECTIVITY

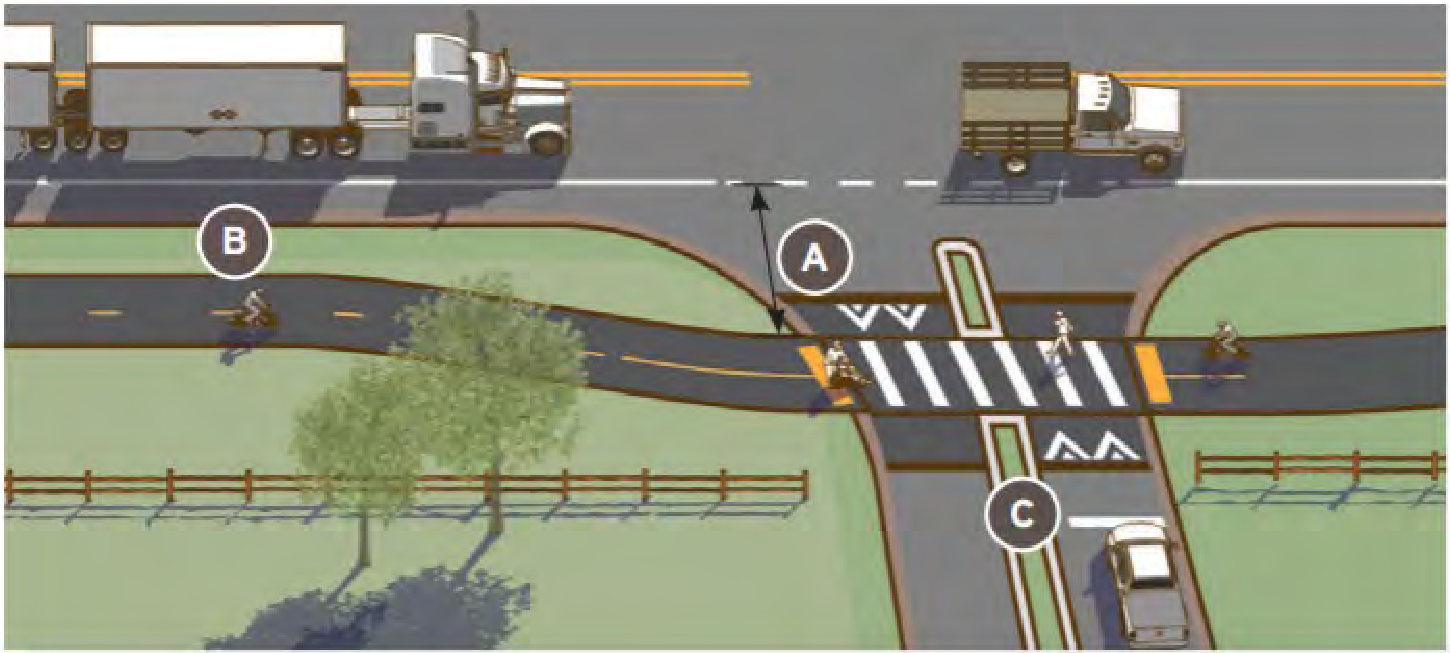
KEY SAFETY FACTORS

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

Bicyclist Safety at Intersections

SHARED-USE PATH CROSSINGS

SIDE-STREET CROSSINGS



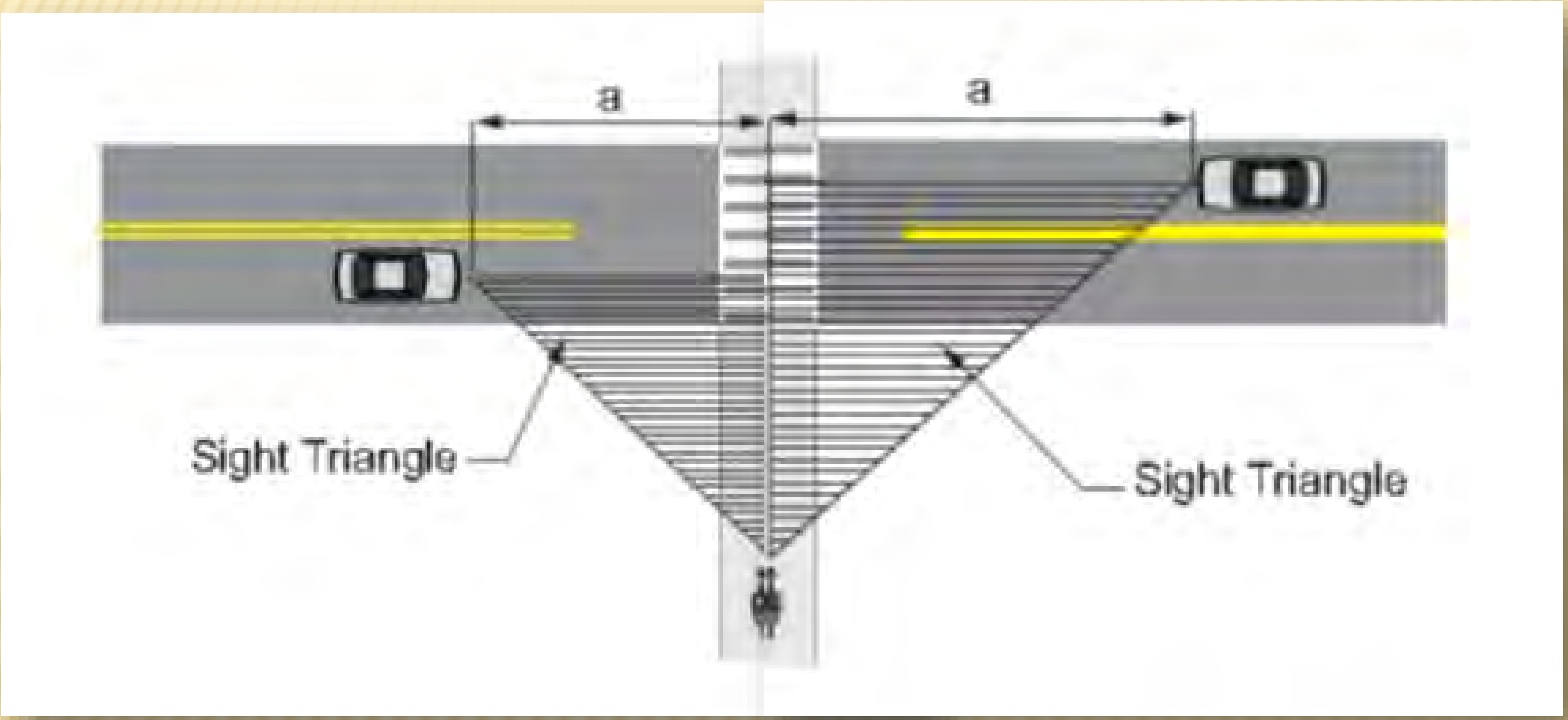
Adjacent Road Speed Limit (Mi/h)	Recommended Sidepath Separation Distance at Crossings
< 25 mi/h	6.5 ft (2.0 m)
35–45 mi/h	6.5–16.5 ft (2.0–5.0 m)
≥ 55 mi/h	16.5–24 ft (5.0–7.0 m)

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

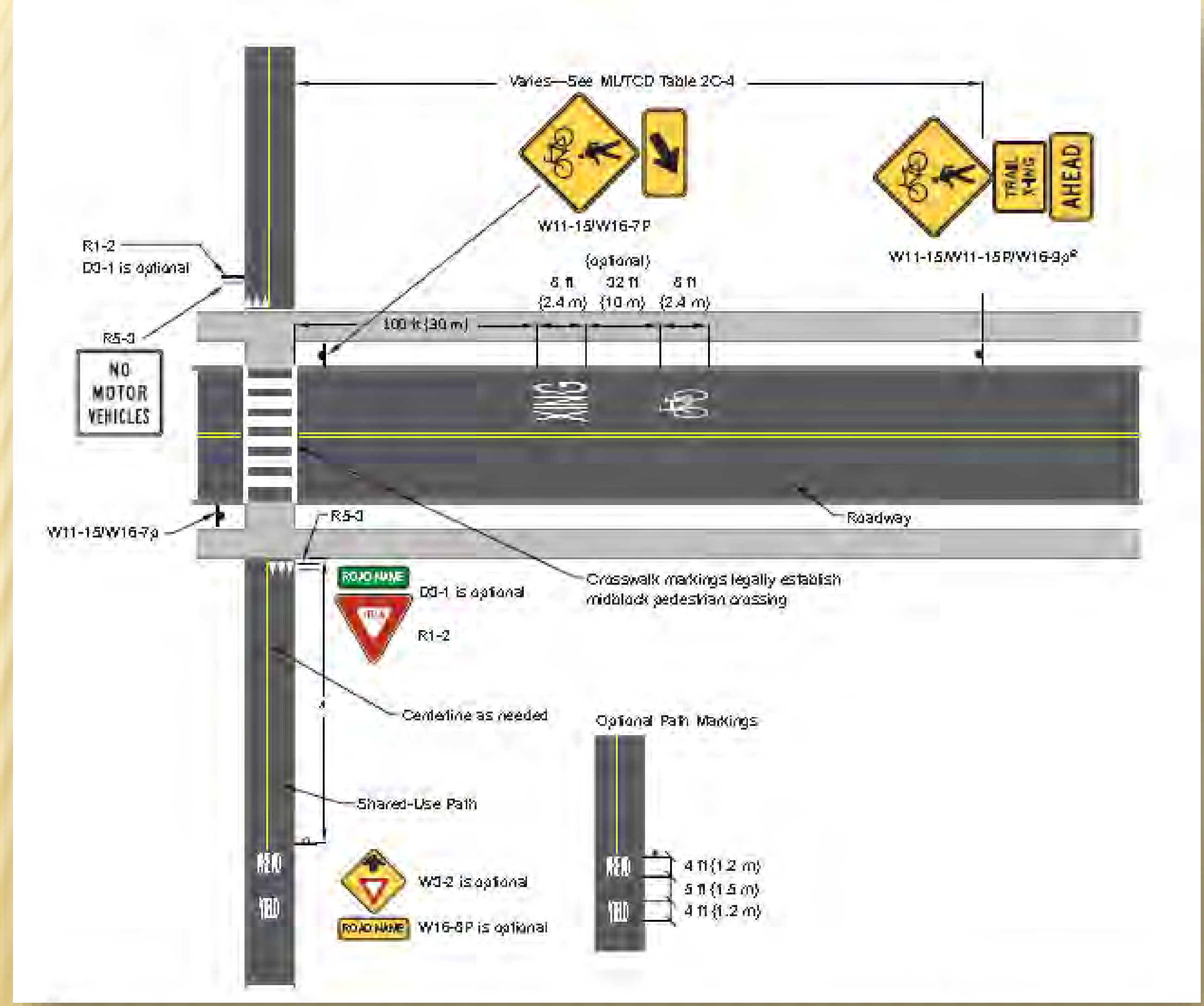
MID-BLOCK CROSSING DESIGN PROCESS

1. Geometric alignment & terrain considerations
2. Roadway characteristics (lane, speed, volumes)
3. Evaluate sight triangles
4. Determine which leg has priority
5. Assess potential crossing treatments

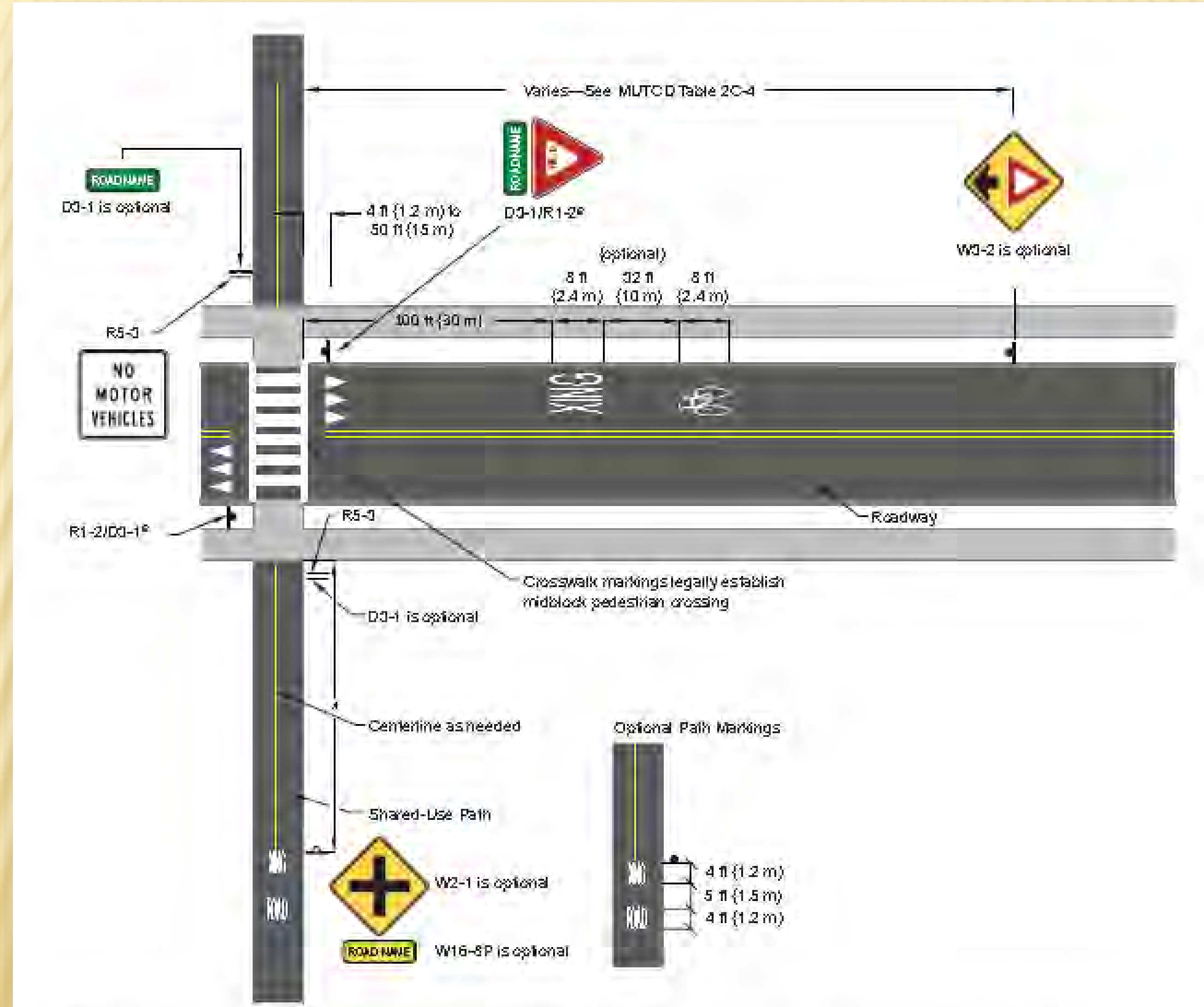
SIGHT TRIANGLES



PATH YIELDS TO ROADWAY

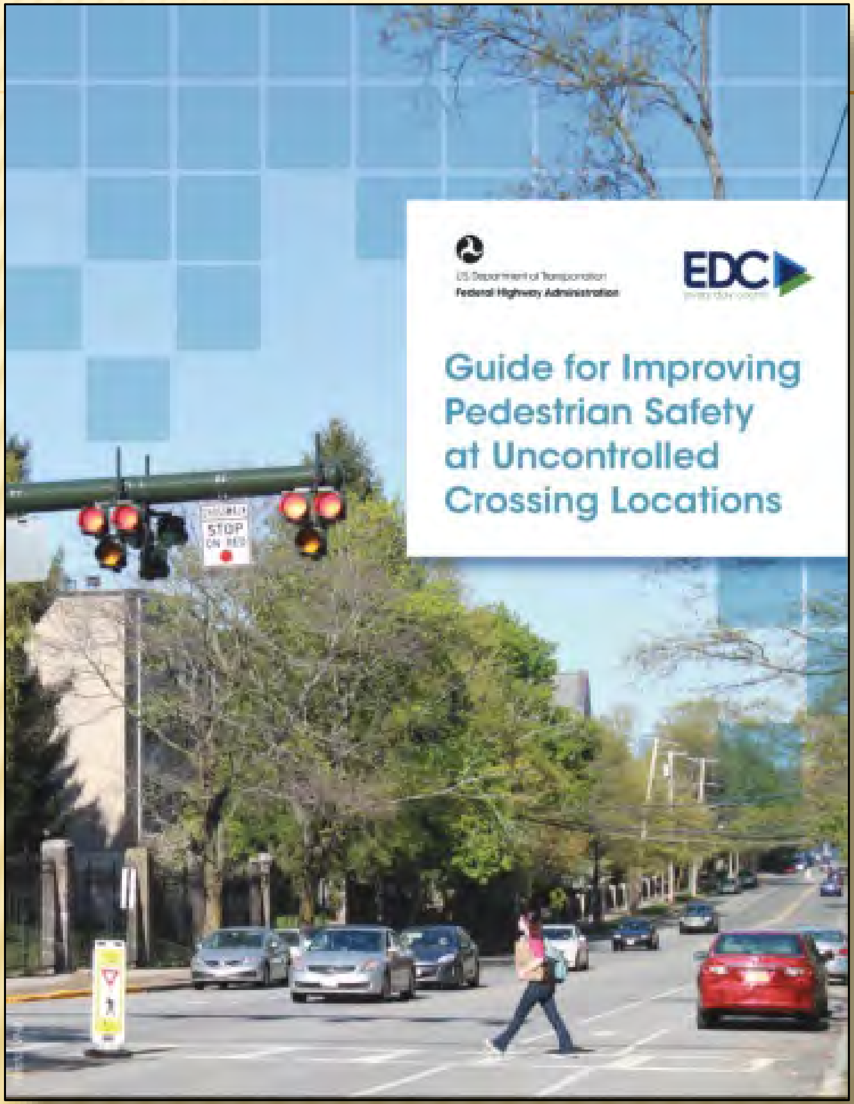


ROAD YIELDS TO PATHWAY



Crossing Countermeasures

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



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)	❶ 2 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6 7 9	① 5 6 7 9	① 5 6 ❾
3 lanes with raised median (1 lane in each direction)	❶ 2 3 4 5	❶ ❸ 5 7 9	① ❸ 5 ❼ ❾	① 3 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❼ ❾	① ❸ 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❾
3 lanes w/o raised median (1 lane in each direction with a two-way left-turn lane)	❶ 2 3 4 5 6 7 9	❶ ❸ 5 6 7 9	① ❸ 5 6 ❾	① 3 4 5 6 7 9	① ❸ 5 6 ❼ ❾	① ❸ 5 6 ❾	① ❸ 4 5 6 7 9	① ❸ 5 6 ❾	① ❸ 5 6 ❾
4+ lanes with raised median (2 or more lanes in each direction)	❶ ❸ 5 7 8 9	❶ ❸ 5 7 8 9	① ❸ 5 8 ❾	① ❸ 5 7 8 9	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 8 ❾
4+ lanes w/o raised median (2 or more lanes in each direction)	❶ ❸ 5 6 7 8 9	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 8 ❾

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"

BIKEHAWK AT PHB CROSSINGS

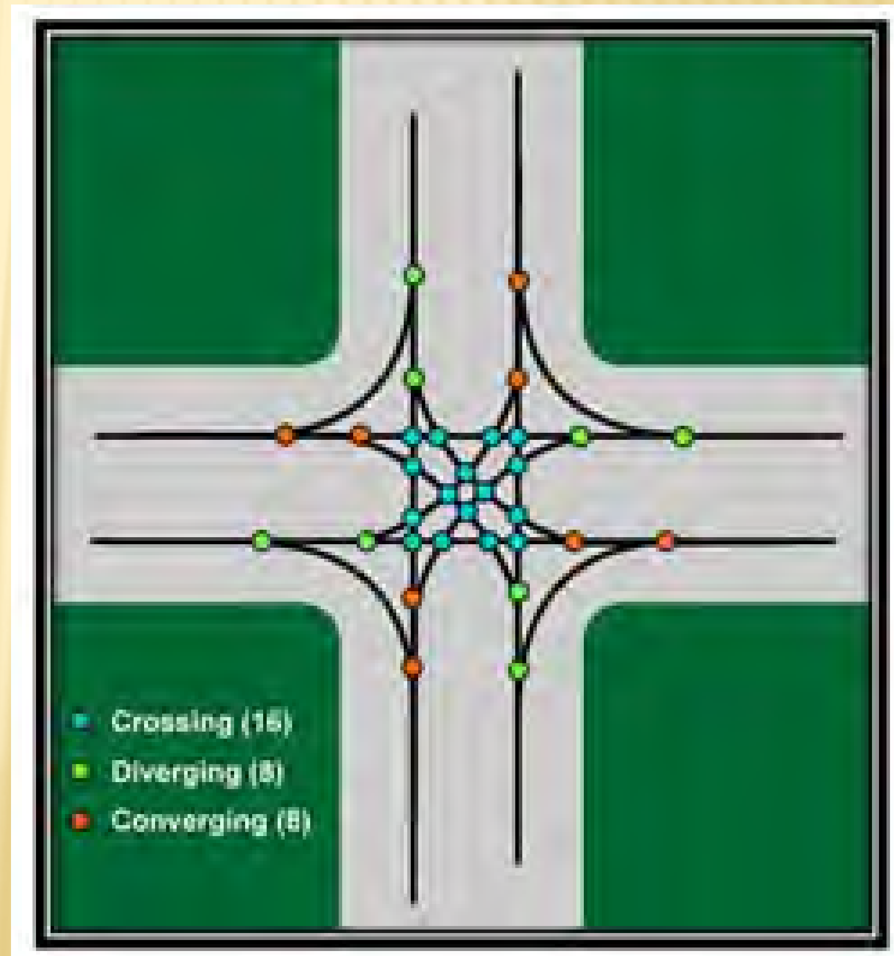
Normal PHB with Bike Facilities and R9-5 for cyclists to use pedestrian signals

Bicyclist Safety at Intersections

INTERSECTION DESIGN PRINCIPLES

INTERSECTION CONFLICTS

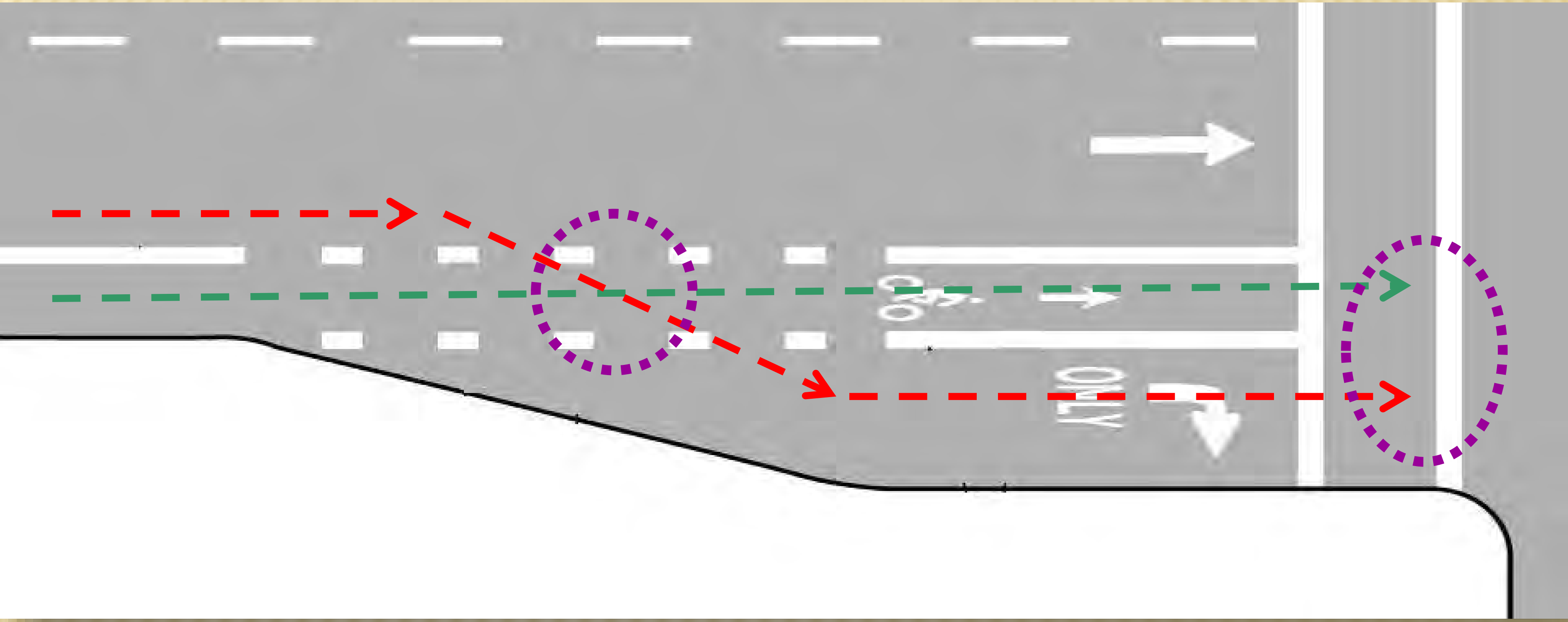
- Typical conflicts for both pedestrians and motorists, plus:
  - Right-turn/thru movement
  - Weaving to left turn



Albuquerque, New Mexico

Albuquerque, New Mexico

RIGHT-TURN/THRU CONFLICT



WOULD YOU DARE?

WOULD YOU DARE?

WOULD YOU DARE?

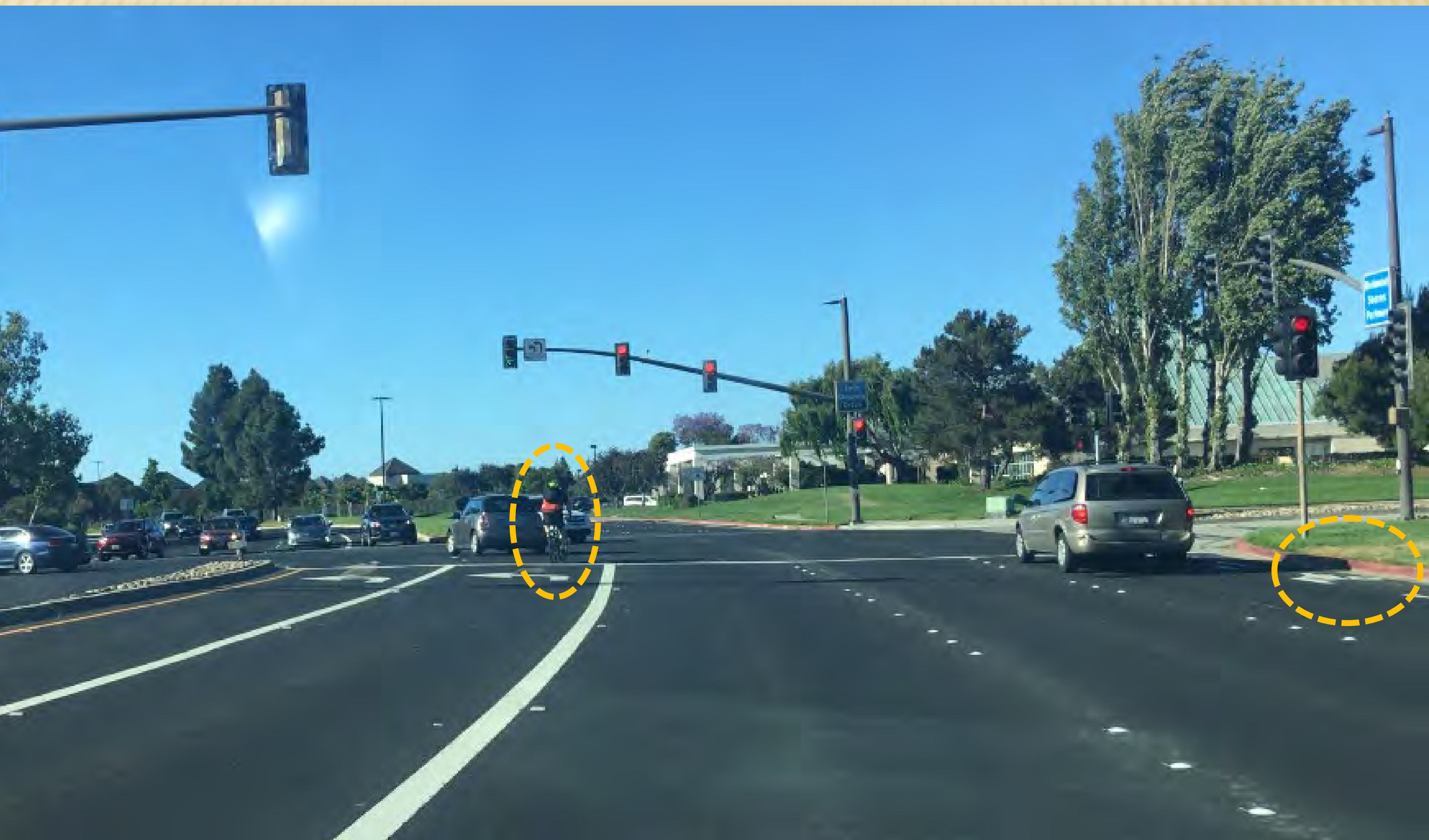
WOULD YOU DARE?

WOULD YOU DARE?

LEFT-TURN CONFLICT

Madison, Wisconsin

LEFT-TURN CONFLICT



INTERSECTION DESIGN PRINCIPLES

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

DON'T GIVE UP AT THE INTERSECTION

R3-17aP

R3-17bP

Bicyclist Safety at Intersections

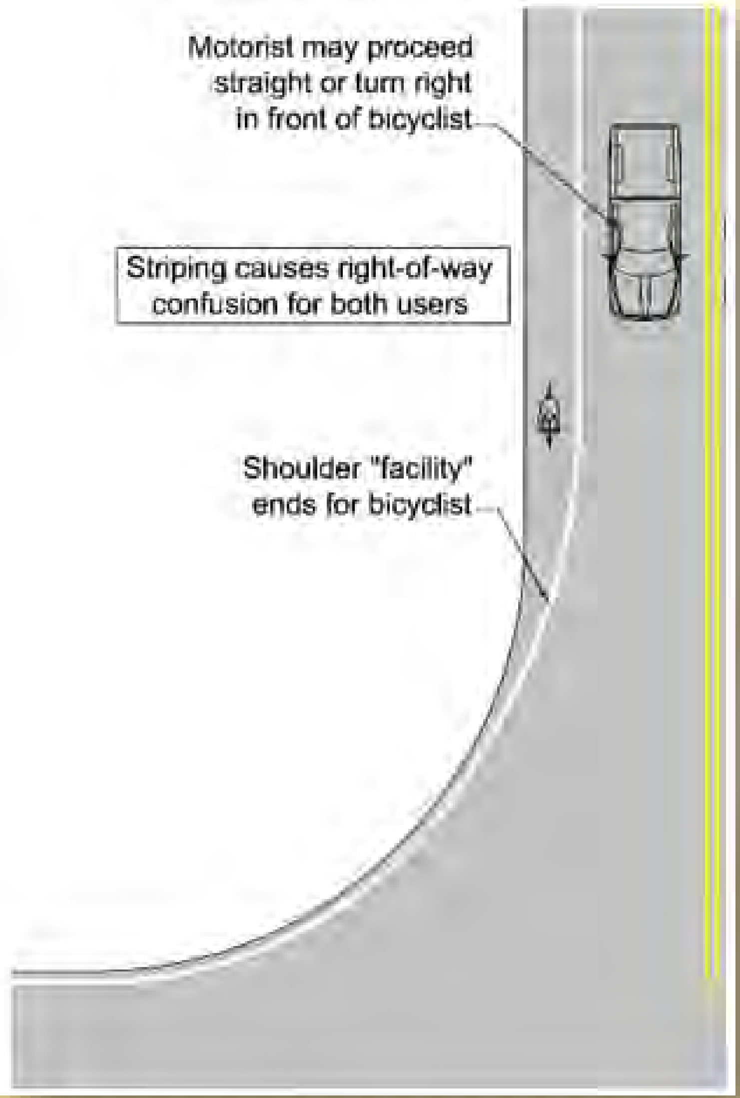
INTERSECTION COUNTERMEASURES

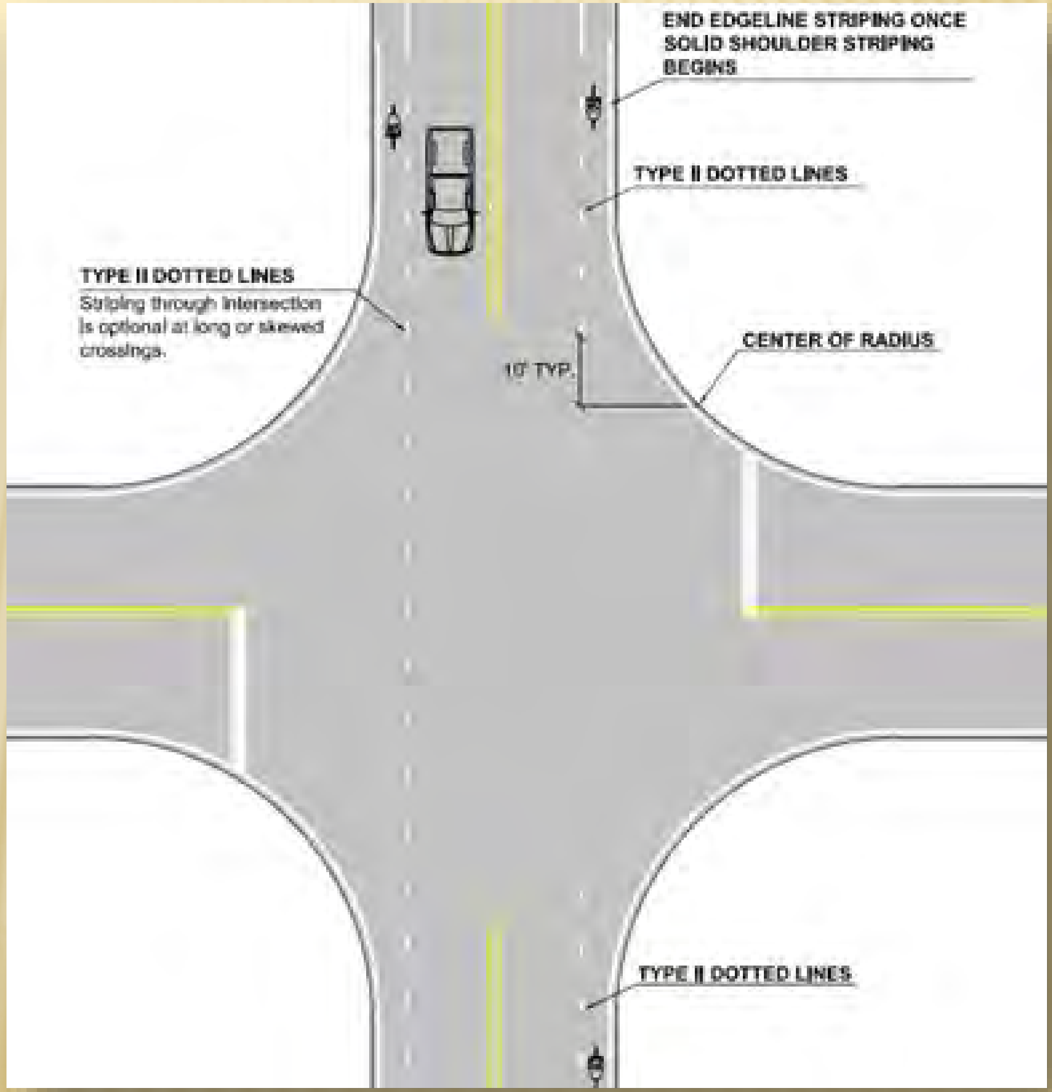
RIGHT-TURN COUNTERMEASURES

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





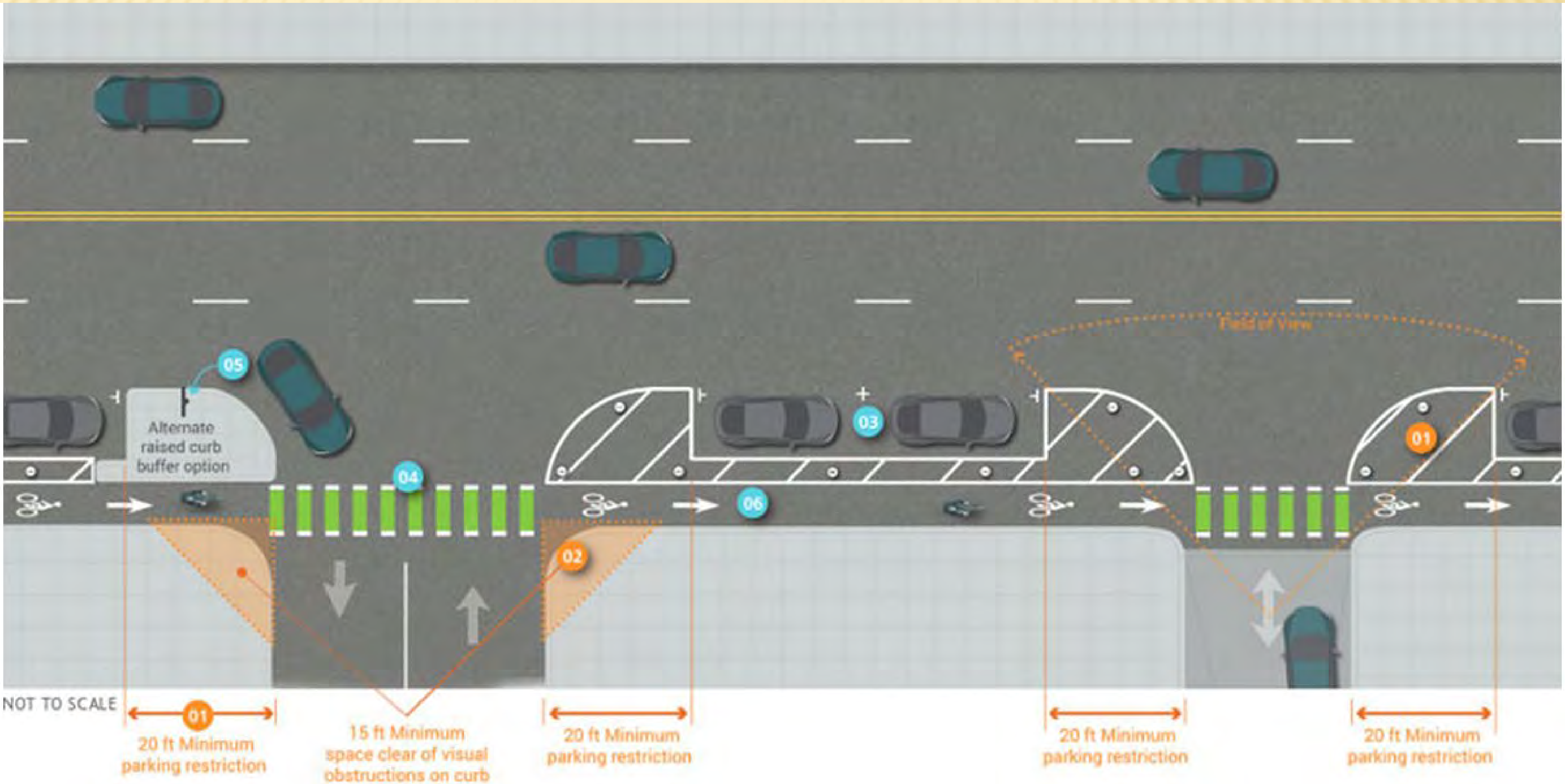
CONSPICUITY W/ PAVEMENT MARKINGS

- Add green pavement marking – bike lanes & sharrows

CONSPICUITY W/ PAVEMENT MARKINGS

- Add green pavement marking – bike lanes & sharrows

SIGHT LINES AND PARKING (DRIVEWAYS)

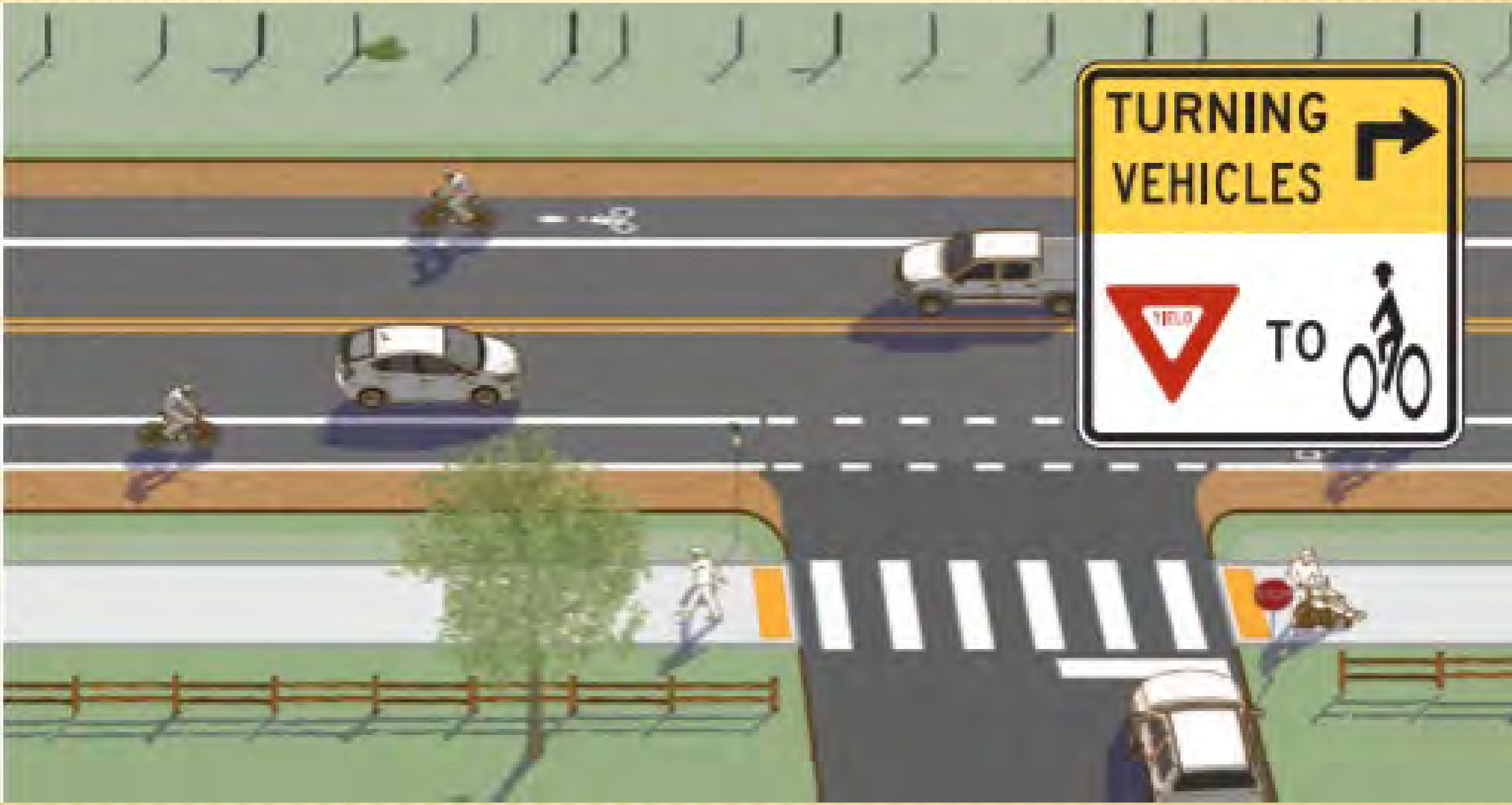


INTERSECTION WITH SHARED LANES

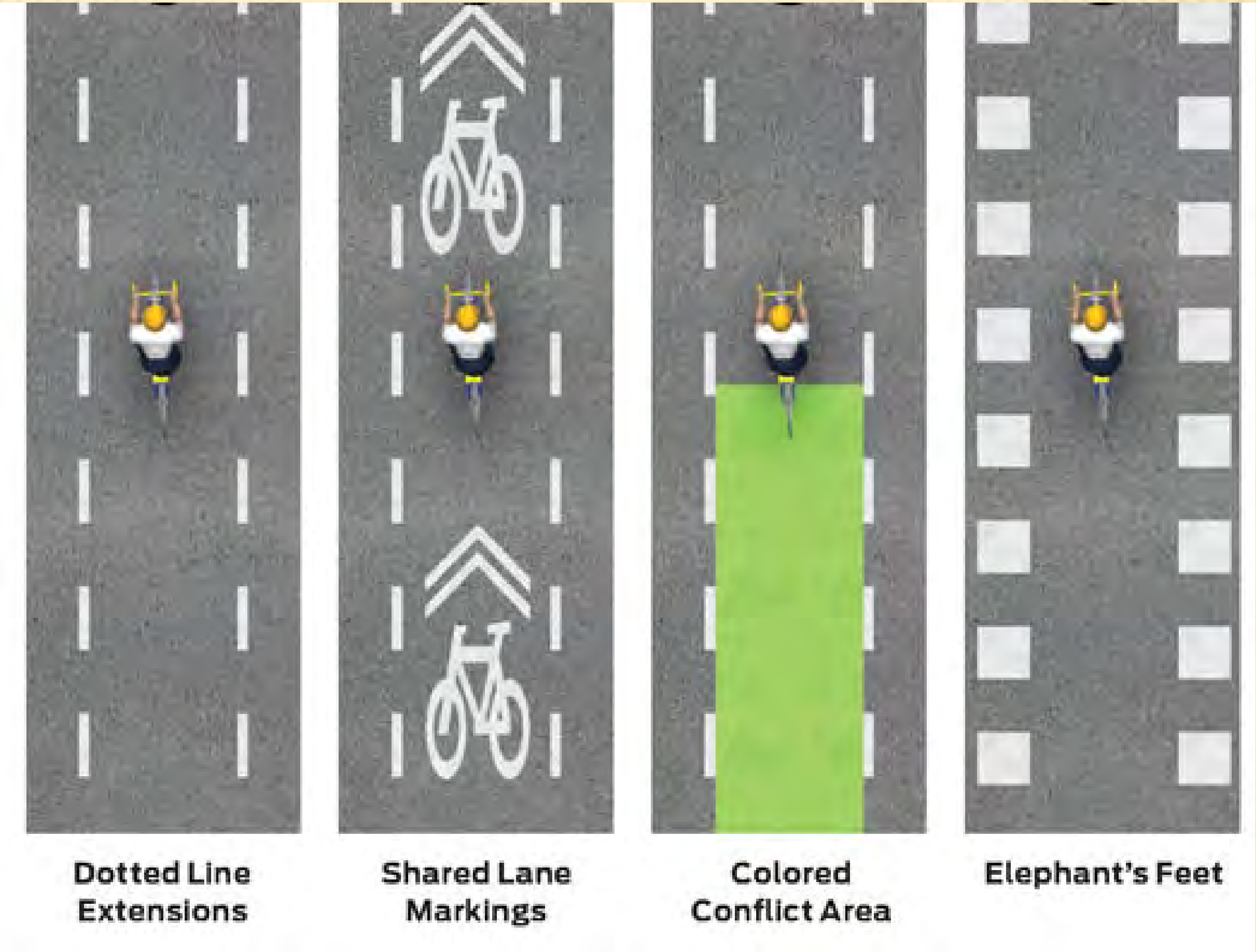
- Additional/all lanes are shared at intersection

BIKE LANE THRU INTERSECTION

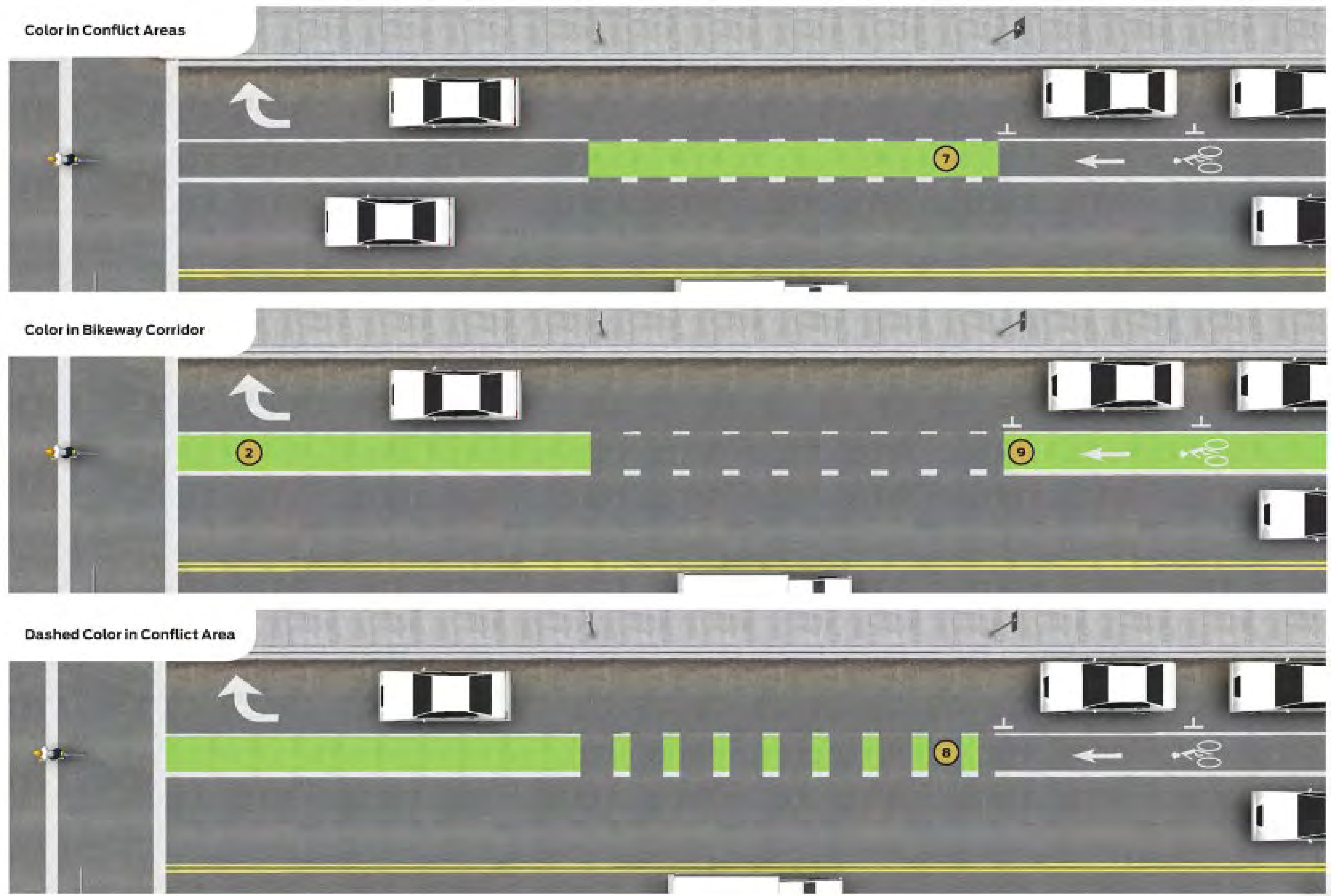
BIKE LANE THRU INTERSECTION



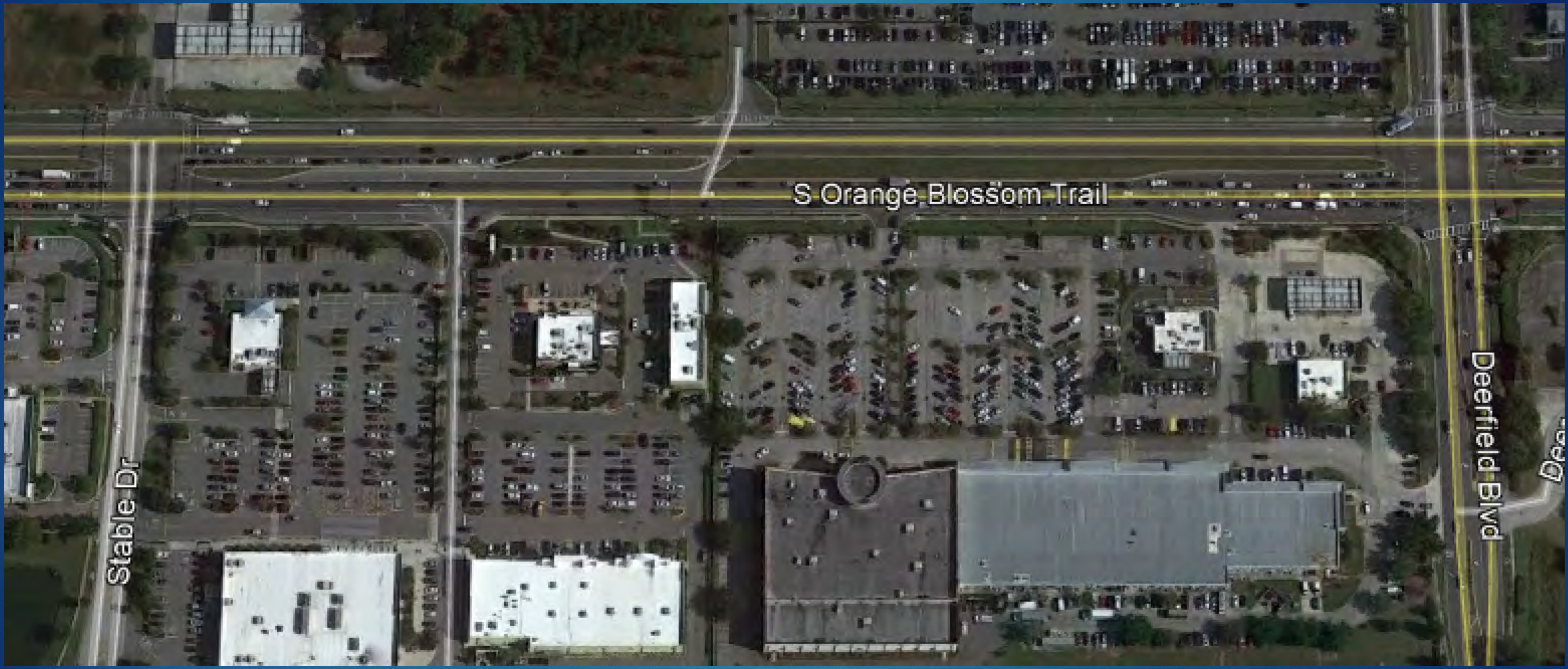
HIGHLIGHT CONFLICT ZONE



HIGHLIGHT CONFLICT ZONE



Case Study—Orange Blossom Trail



Case Study—Orange Blossom Trail

Case Study—Orange Blossom Trail

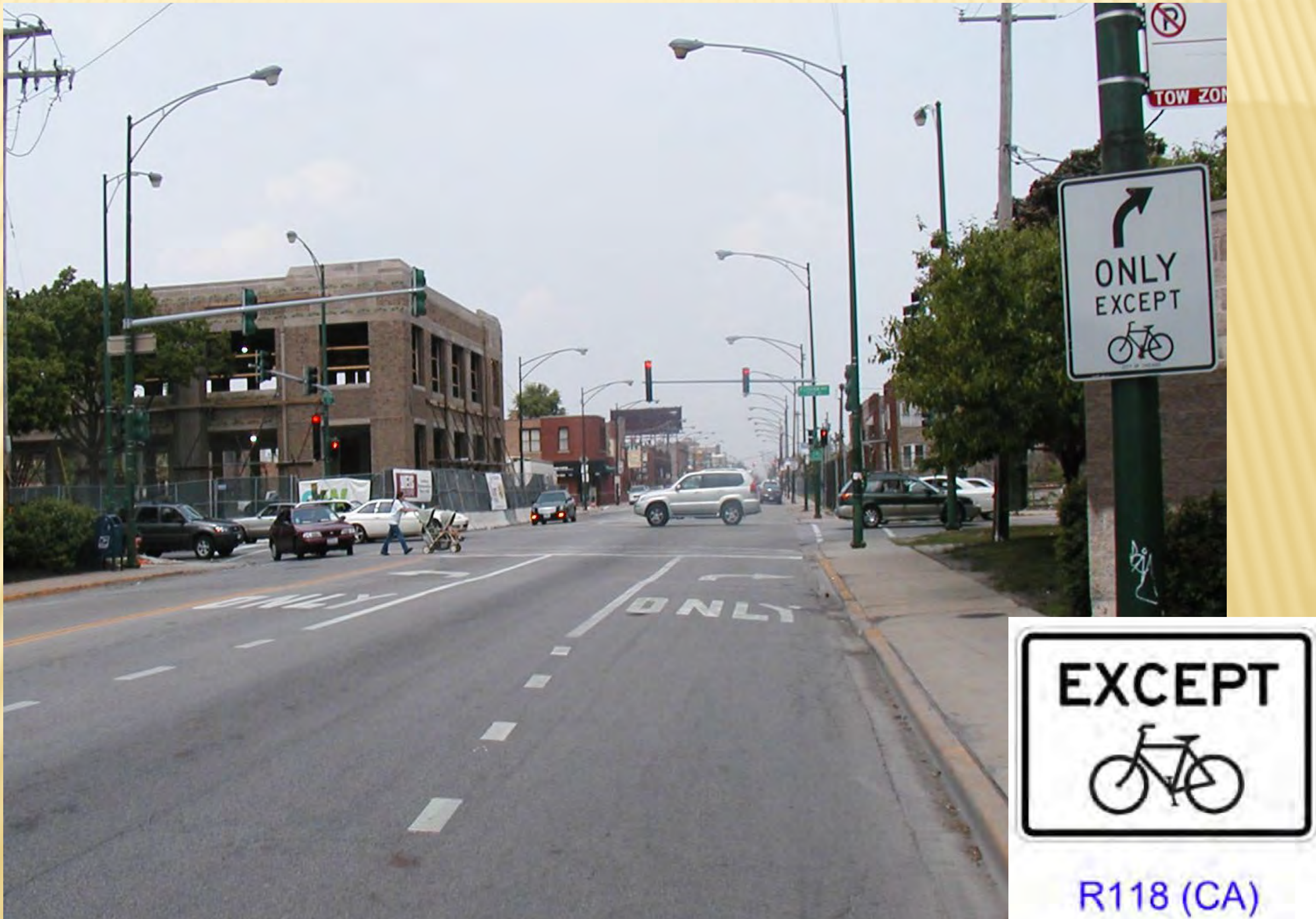
Case Study—Orange Blossom Trail

BIKE LANE THRU INTERSECTION

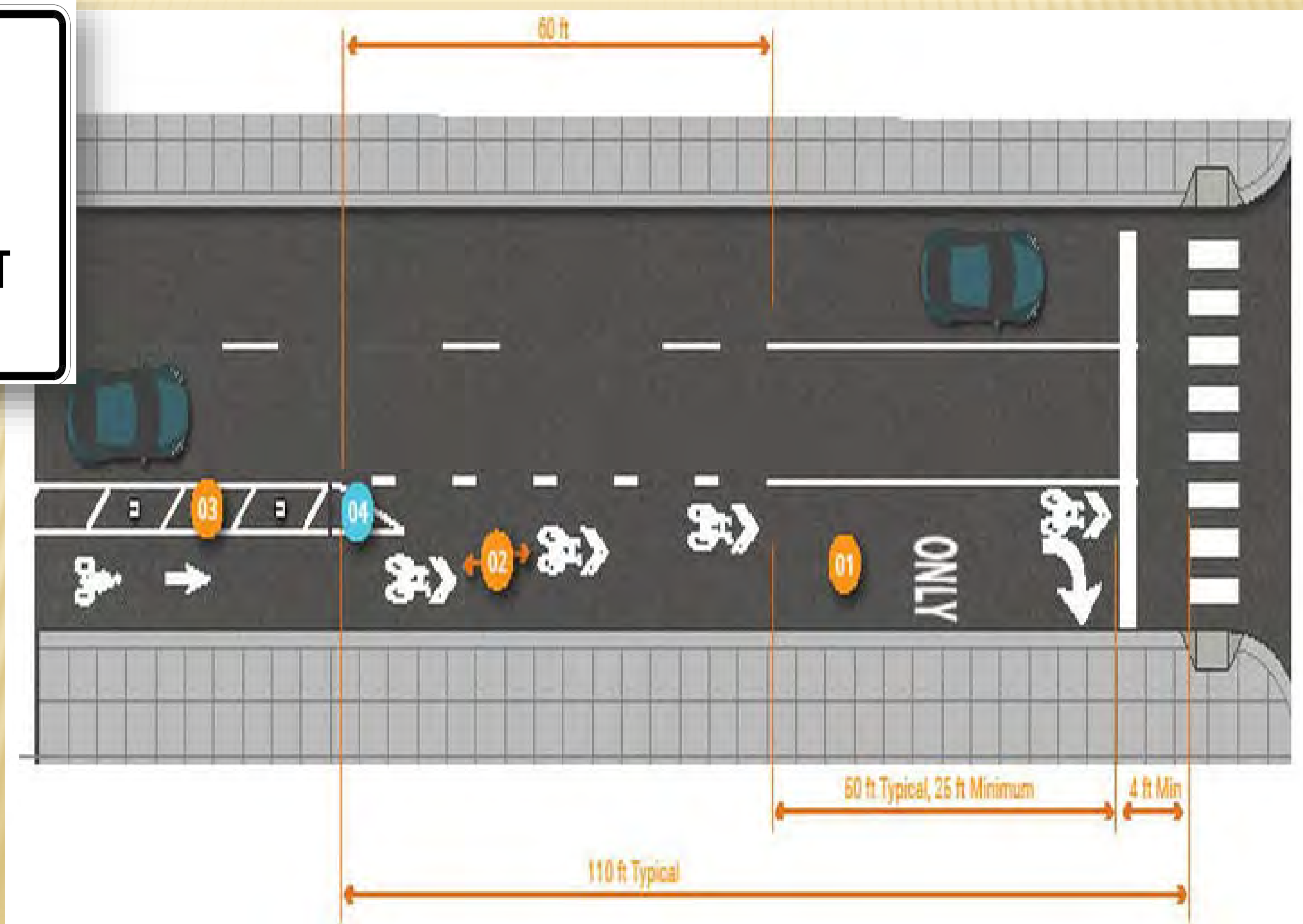
BIKE LANE THRU INTERSECTION

BIKE LANE THRU INTERSECTION

IS THIS CONSISTENT WITH MUTCD?



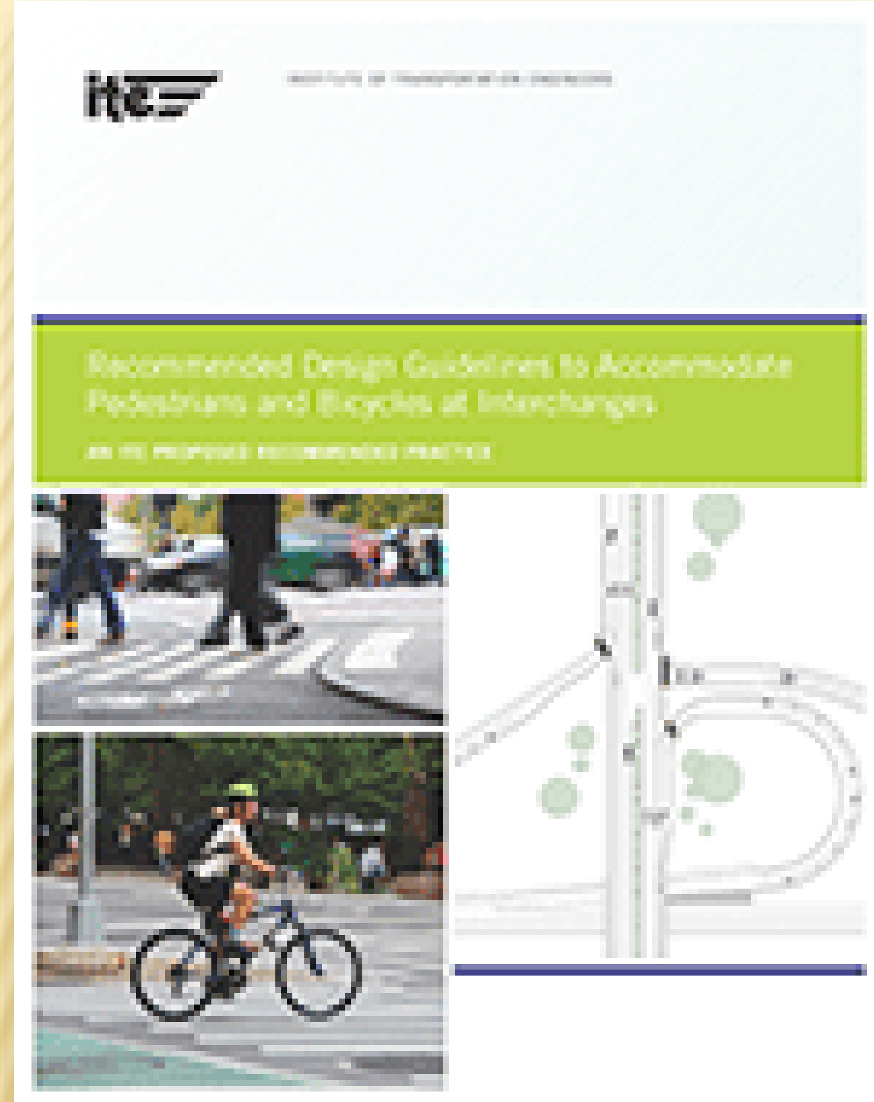
RIGHT TURN SHARED LANE



RIGHT-TURN SHARED LANE

Madison, Wisconsin

INTERCHANGE RAMPS

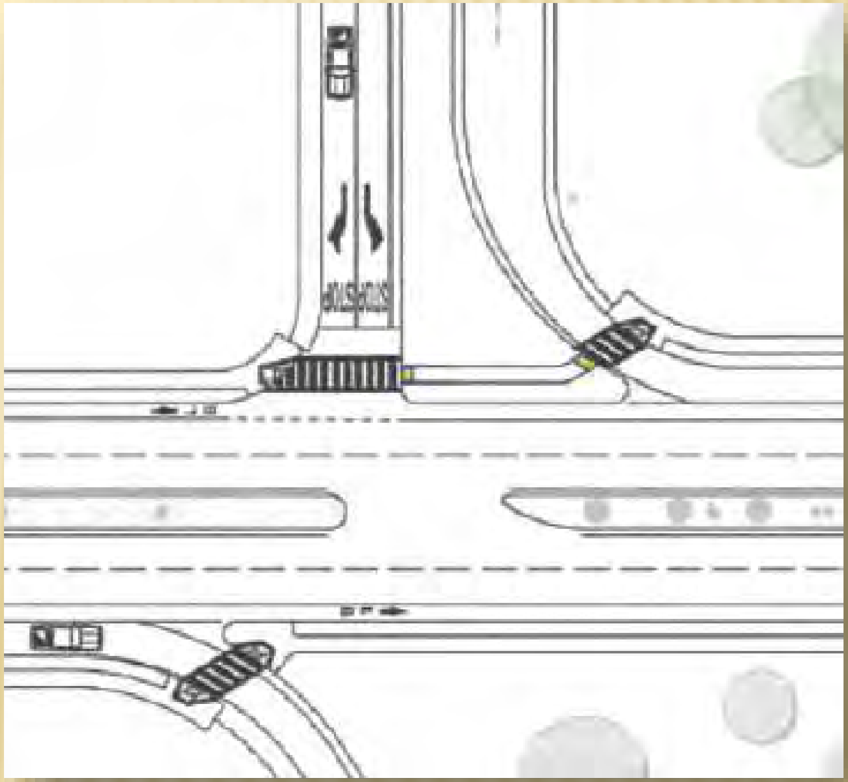


Recommended Design Guidelines to Accommodate Pedestrians and Bicycles at Interchanges

ITE 2016

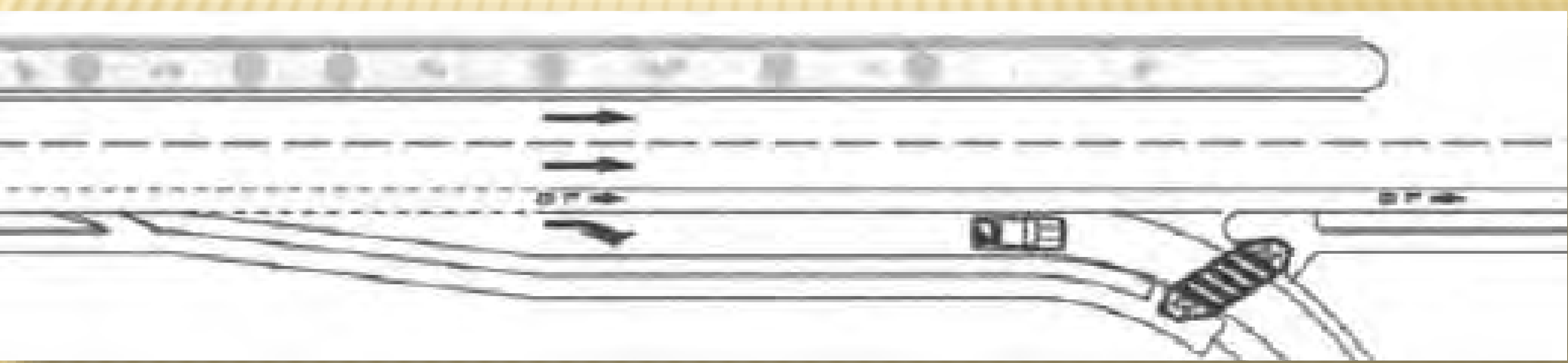
GUIDING PRINCIPLES FOR PEDESTRIANS

- Ramp geometry
- Locate crosswalk
  - Best visibility
  - Before accelerate
- Crosswalk short w/out excessive deviation
- Widen sidewalks shared with bicyclists

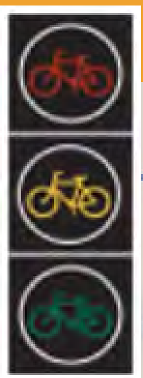


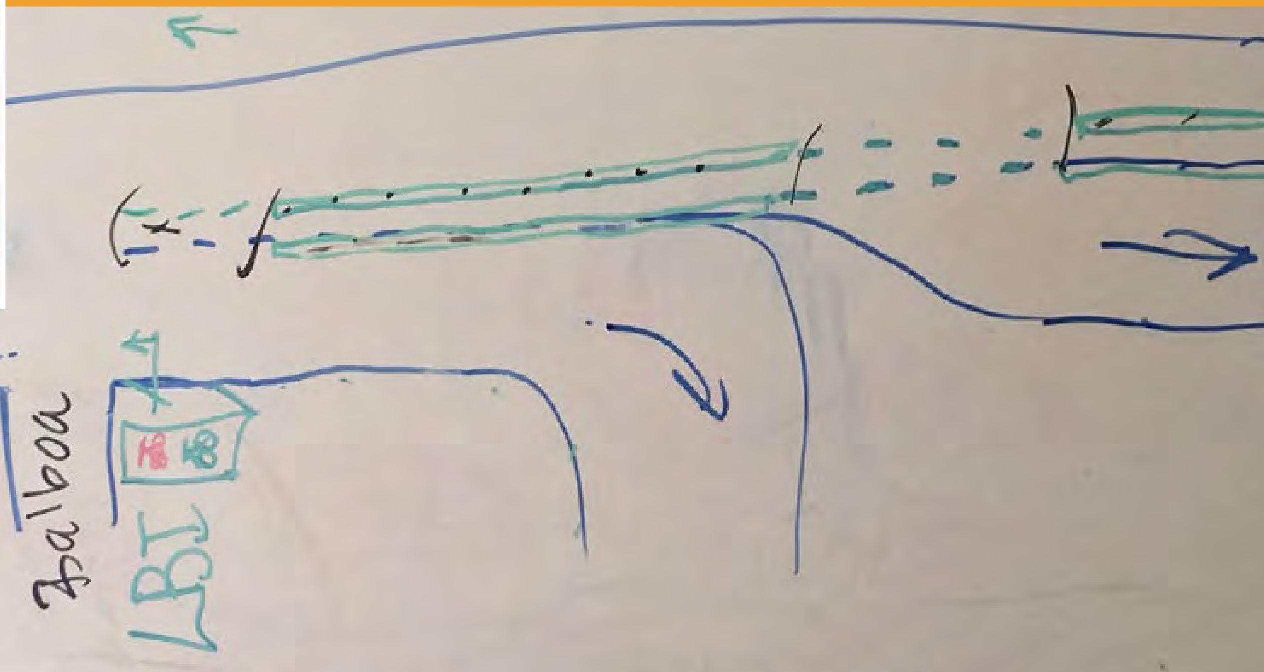
GUIDING PRINCIPLES FOR BICYCLISTS

- Buffer where bicyclists are between moving vehicles more than 200 ft
- Provide bike "exit" option ahead of on-ramps
- Define a weaving area



Center
American Financial
Network, Inc. Coast...
Coast Highway
Pacific Coast Hw
Newport Blvd
Newport Blvd
Balboa Coves
Balboa Coves
Old New




Balboa
LBI

LEFT-TURN COUNTERMEASURES

TWO-STAGE LEFT TURN BOX

NACTO

TWO-STAGE LEFT-TURN QUEUE BOX

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

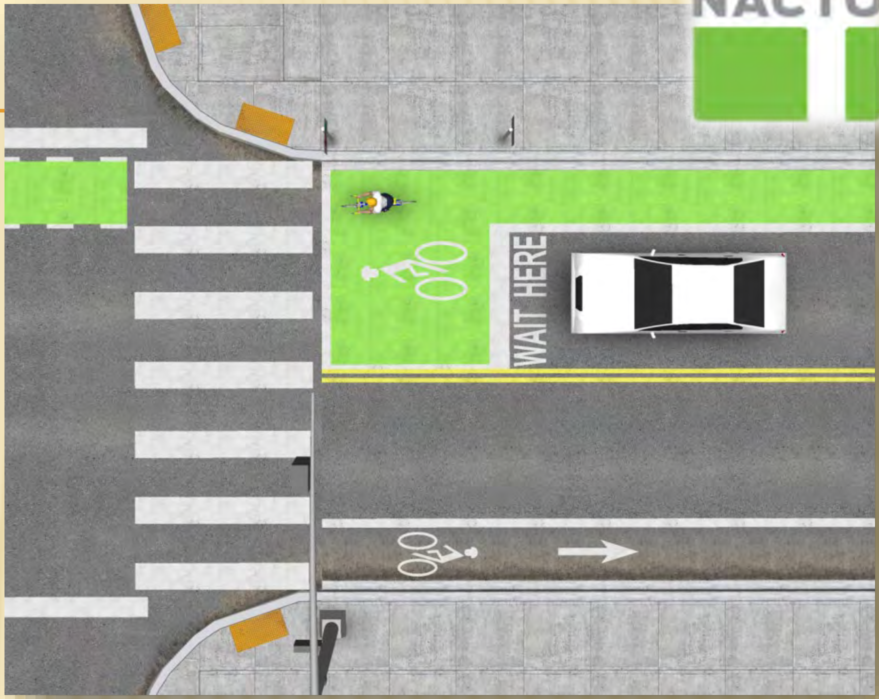
SALT LAKE CITY, UT (PHOTO: SALT LAKE CITY PUBLIC WORKS)

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

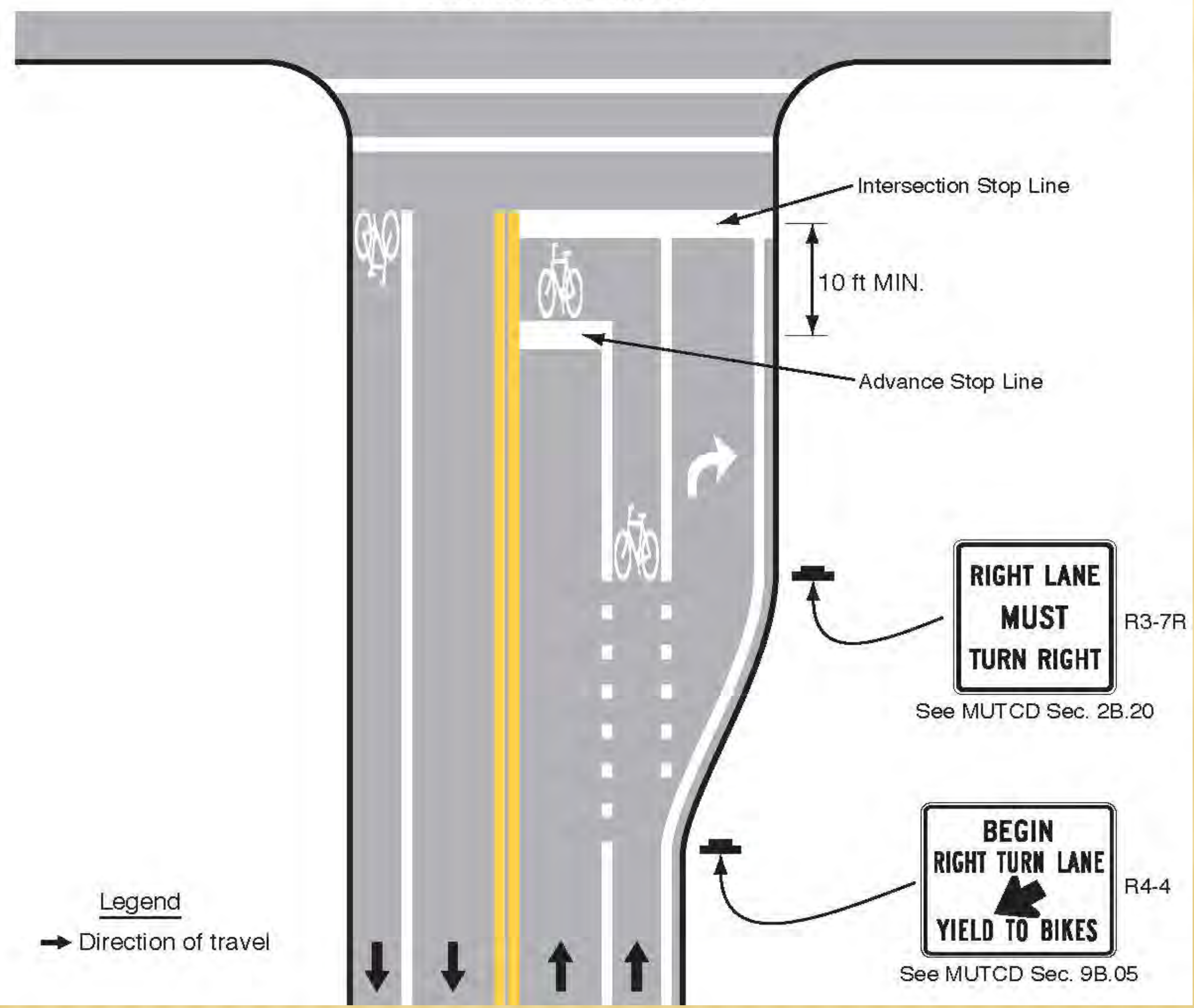
BIKE BOX



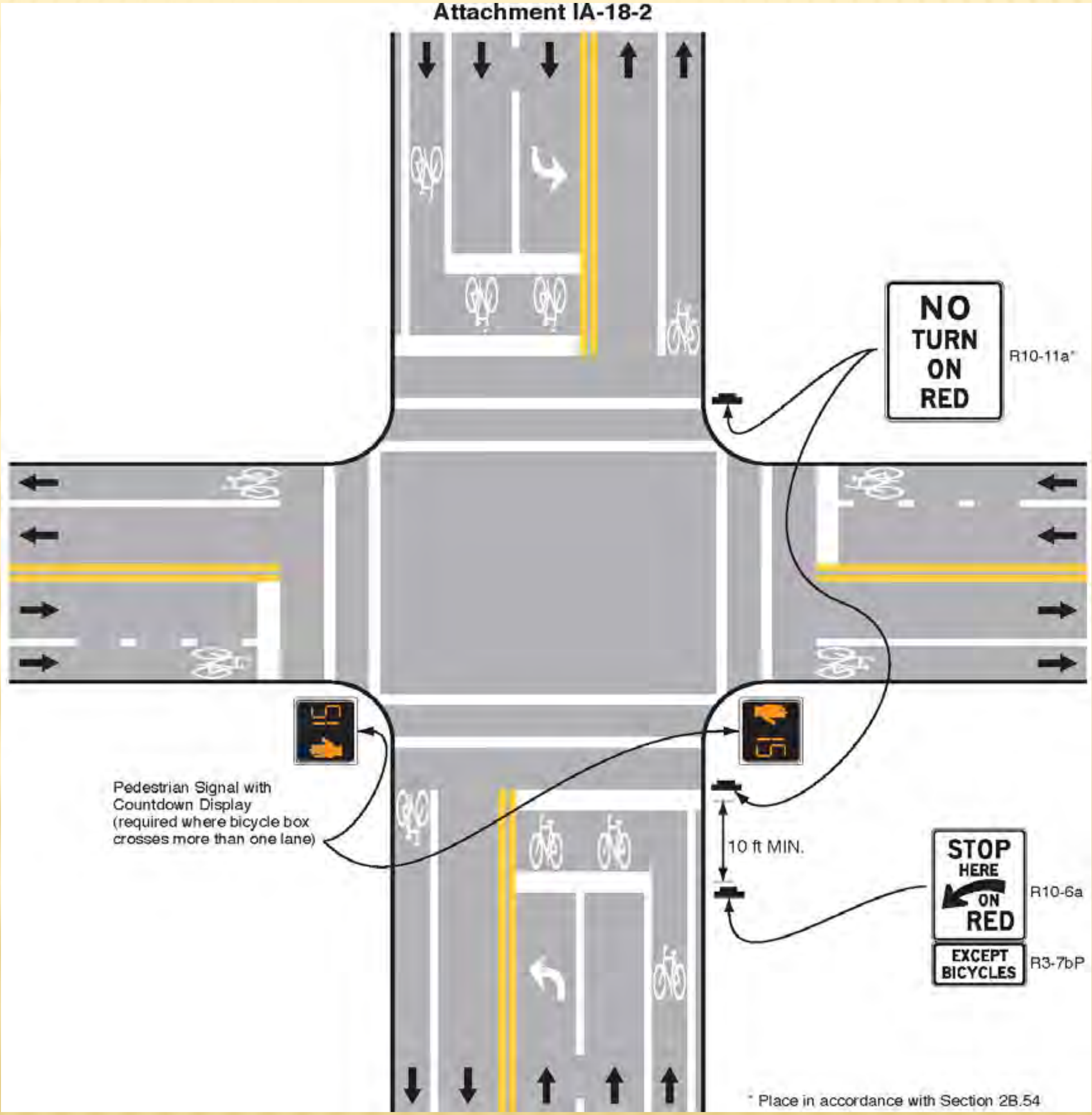
- Required elements:
  - Advance stop line at 10’
  - Bike symbol in the box
  - RTOR prohibited
  - Setback from crosswalk
  - 50 feet of bike lane on approach
  - STOP HERE ON RED (R10-6/R10-6a) with EXCEPT BICYCLE text plaque
  - Countdown ped signal if box crosses multiple lanes
  - Yellow change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

BIKE BOX

Attachment IA-18-1



BIKE BOX



Attachment IA-18-2
NO TURN ON RED
R10-11a*
Pedestrian Signal with Countdown Display (required where bicycle box crosses more than one lane)
10 ft MIN.
STOP HERE ON RED
R10-6a
EXCEPT BICYCLES
R3-7bP
* Place in accordance with Section 2B.54

ROUNDABOUT INTERSECTIONS

MAKING ROUNDABOUTS WORK

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


Bike Walk Encinitas

Bike lane ends at splitter island

Slower speeds and fewer conflict points

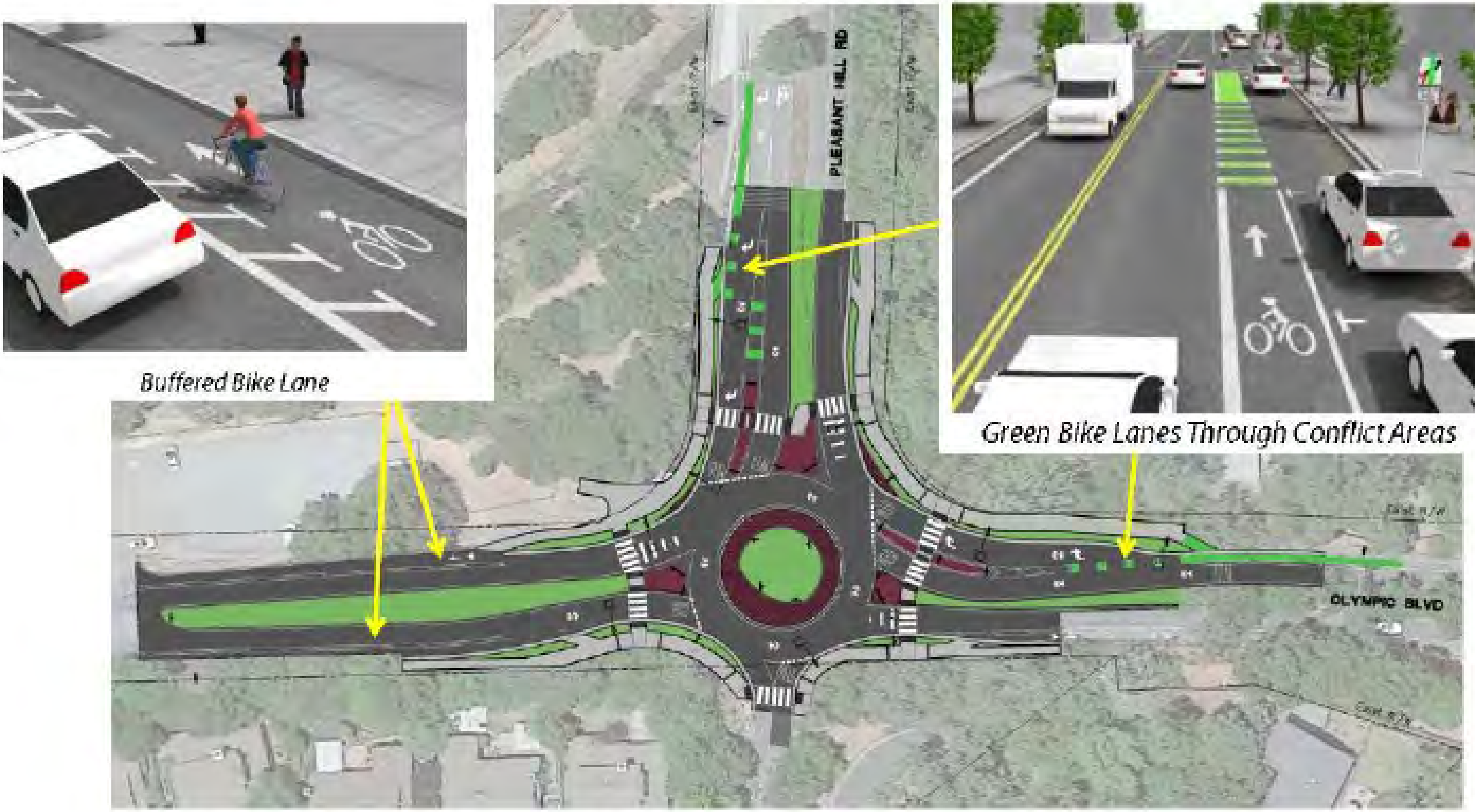
Slower speeds and fewer conflict points

Bend, Oregon

Bike lane begins

Bike ramp

BIKEWAY MARKINGS AT ROUNDABOUTS

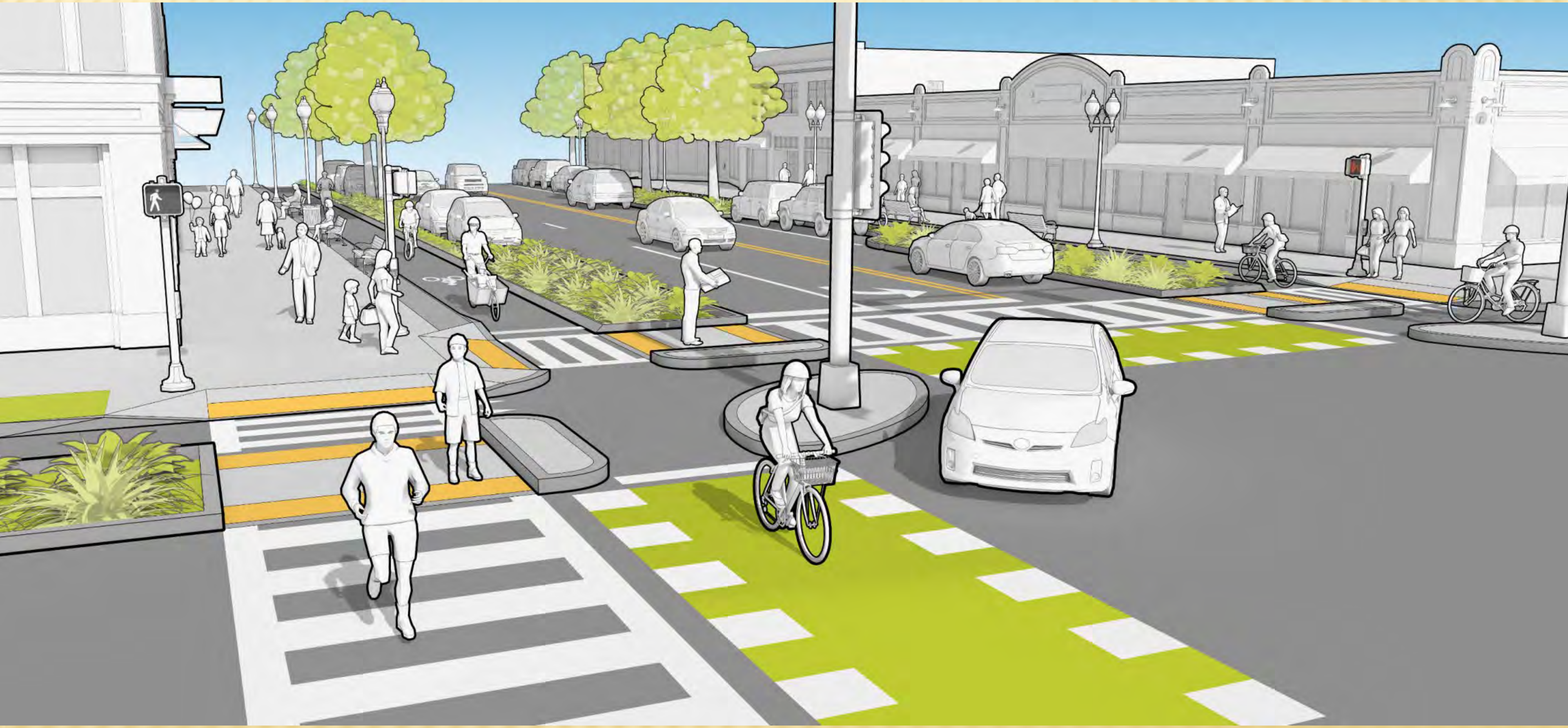


Pleasant Hill Road / Olympic Blvd Roundabout Project
Lafayette, CA

omni·means

PROTECTED INTERSECTIONS

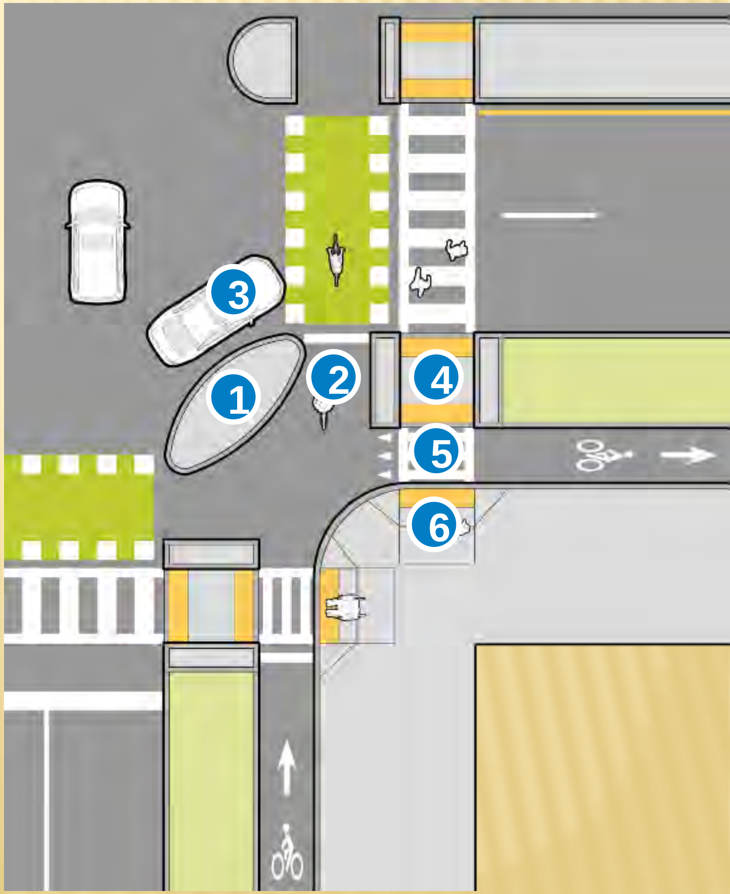
"PROTECTED" INTERSECTIONS



"PROTECTED" INTERSECTIONS

PROTECTED INTERSECTIONS

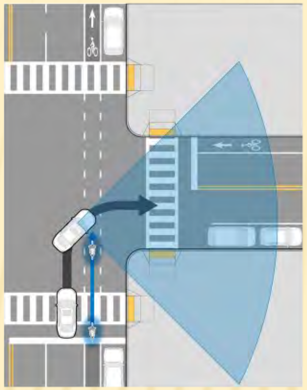
1. Corner refuge island
2. Forward bicycle queuing area
3. Motorist yield zone
4. Pedestrian crossing island
5. Pedestrian crossing of separated bike lane
6. Pedestrian curb ramp



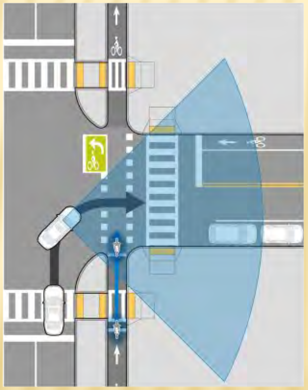
massDOT

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.

NACTO

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.

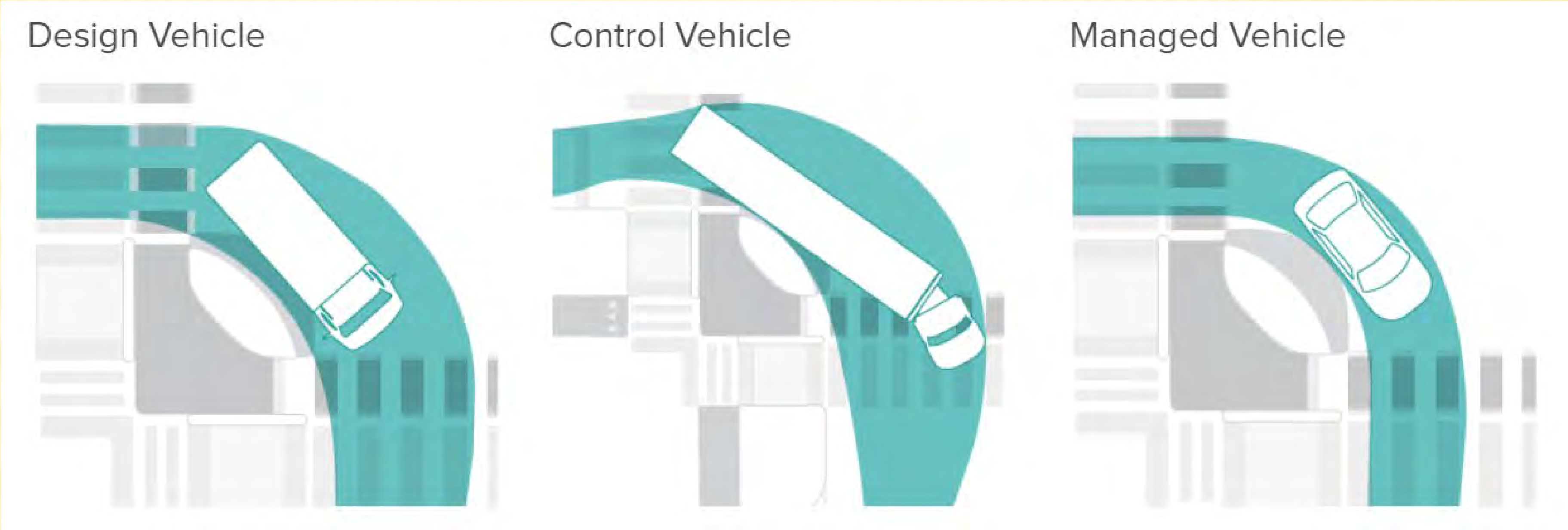
NACTO

VISIBILITY AT CONFLICT POINTS

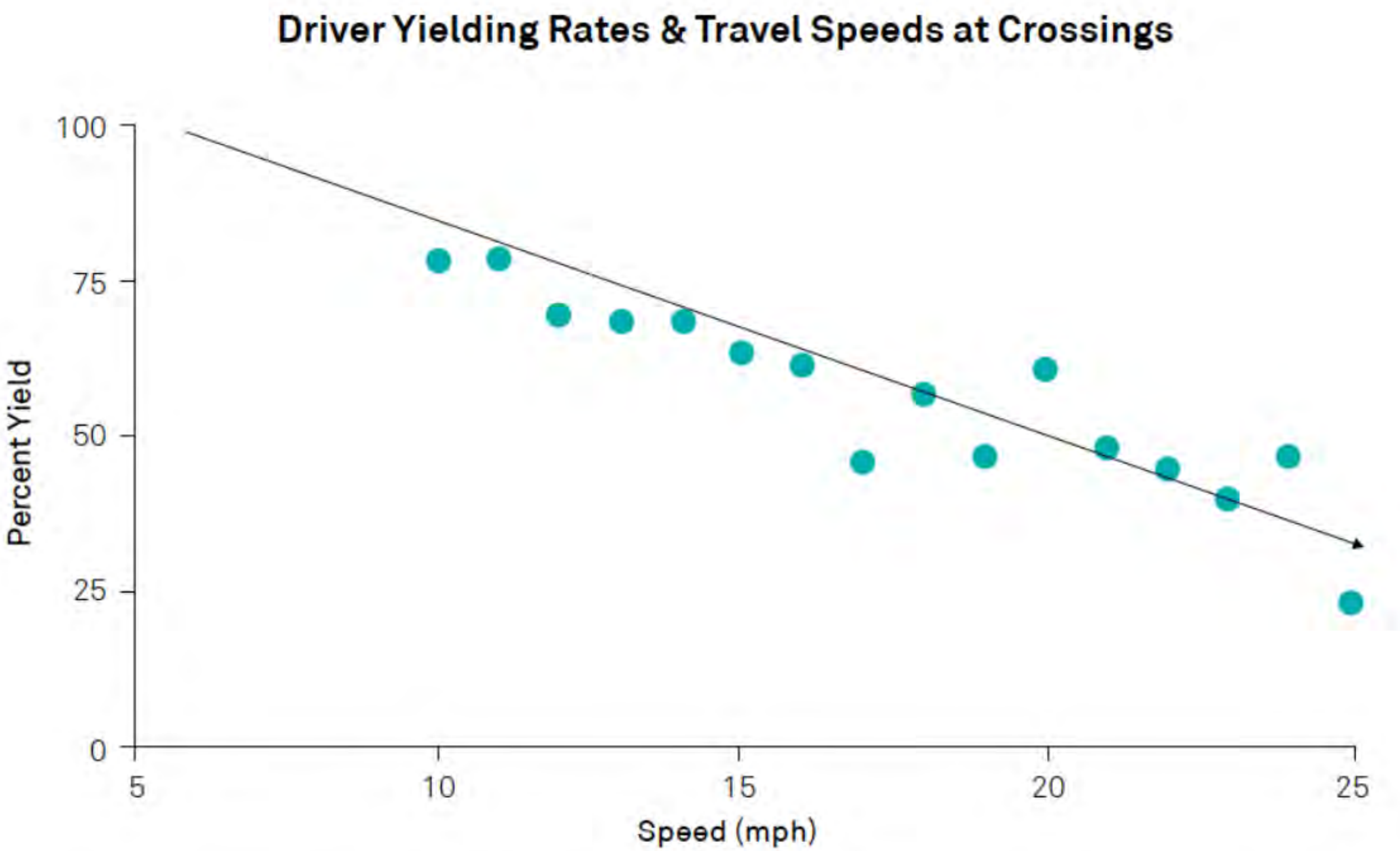
protected intersection

conventional bike lane

CORNER RADIUS



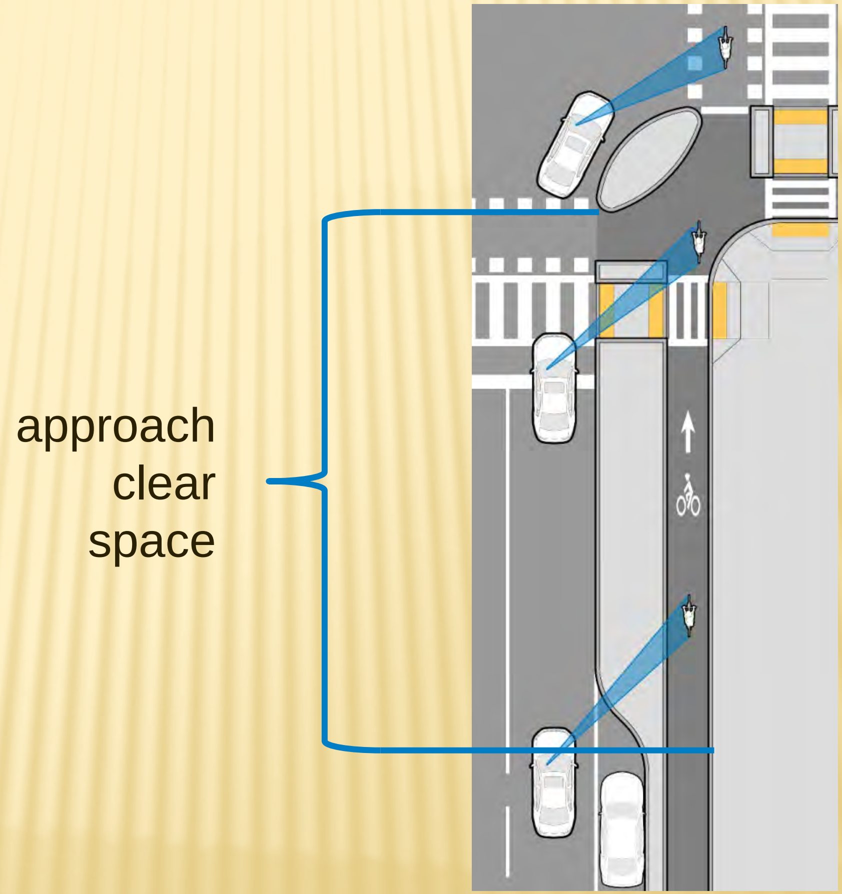
YIELDING RATE & TRAVEL SPEEDS



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’

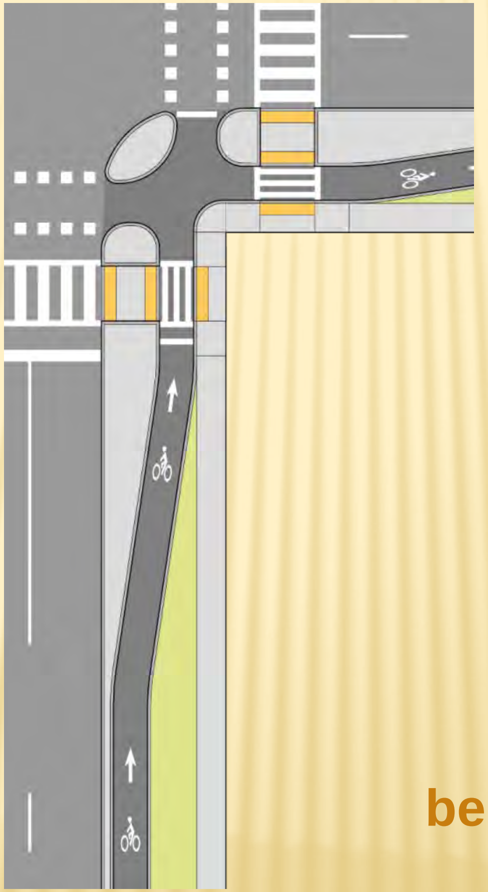


massDOT

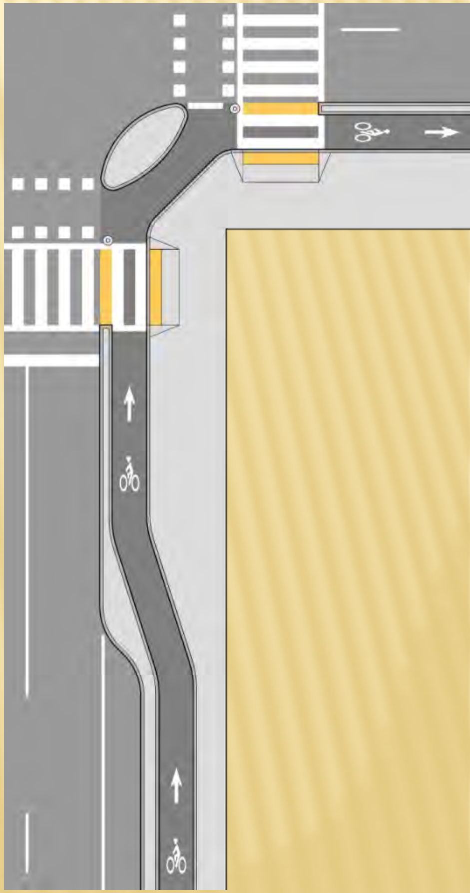
DEFLECTION

- 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



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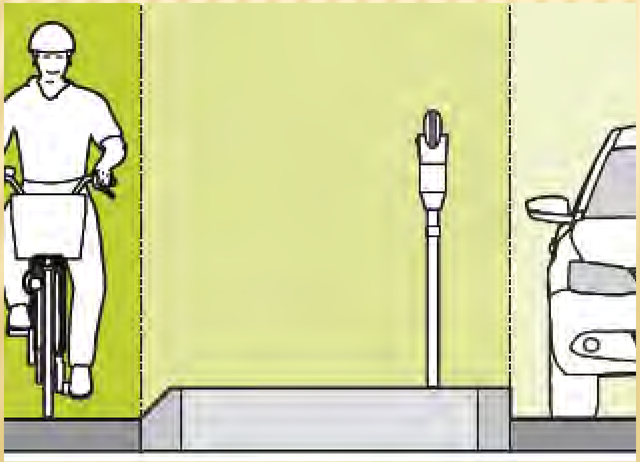
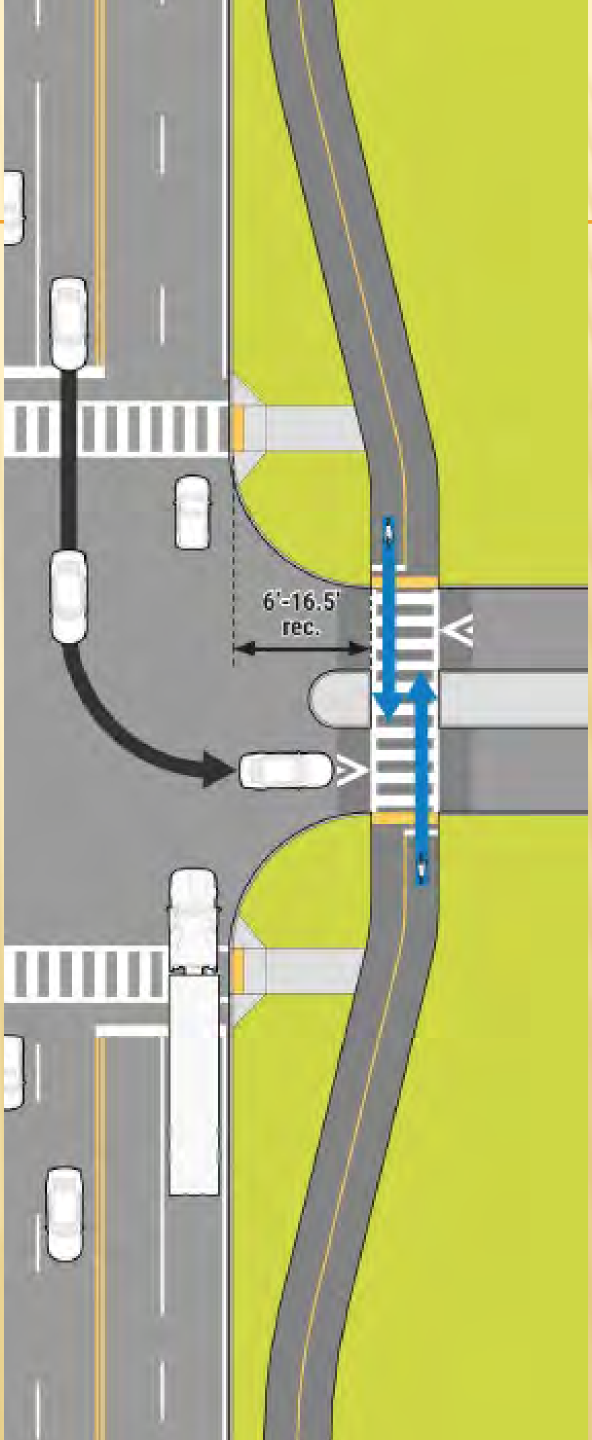
STREET BUFFER WIDTH

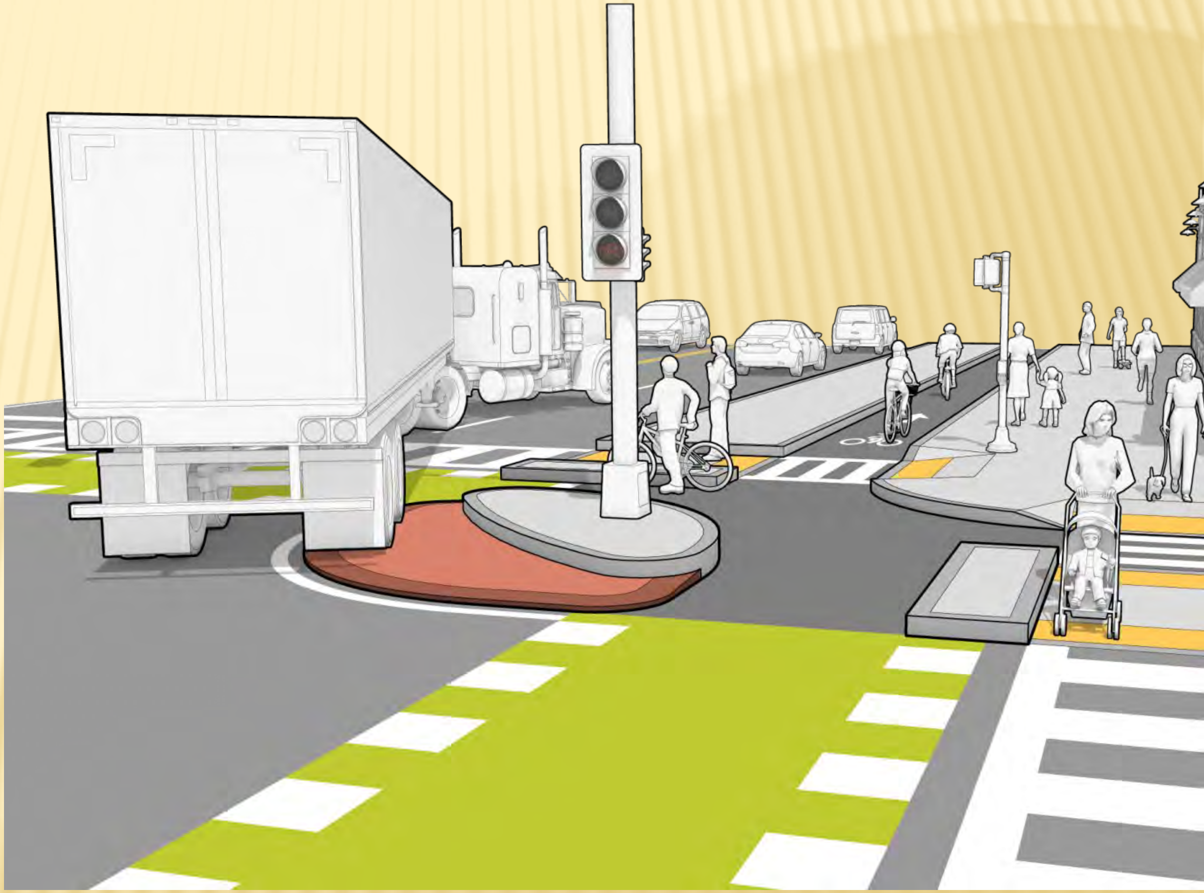
- 6' preferred
- 2' when constrained
- 1' along raised SBL
- 6-16.5' optimum for intersections





SLOW RIGHT TURNING SPEEDS

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



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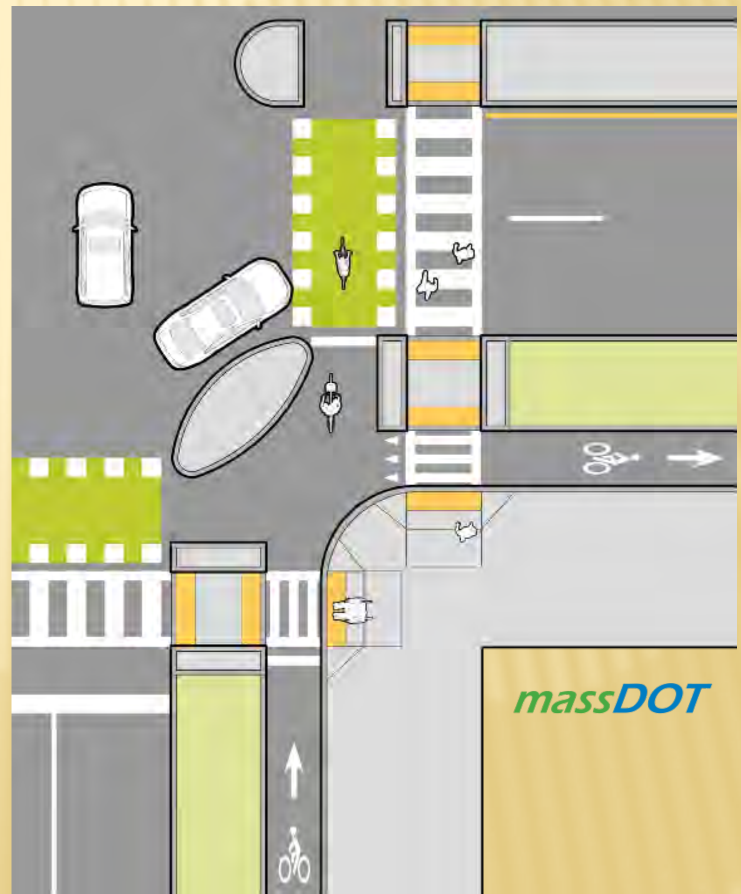
ADA ISSUES

- 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



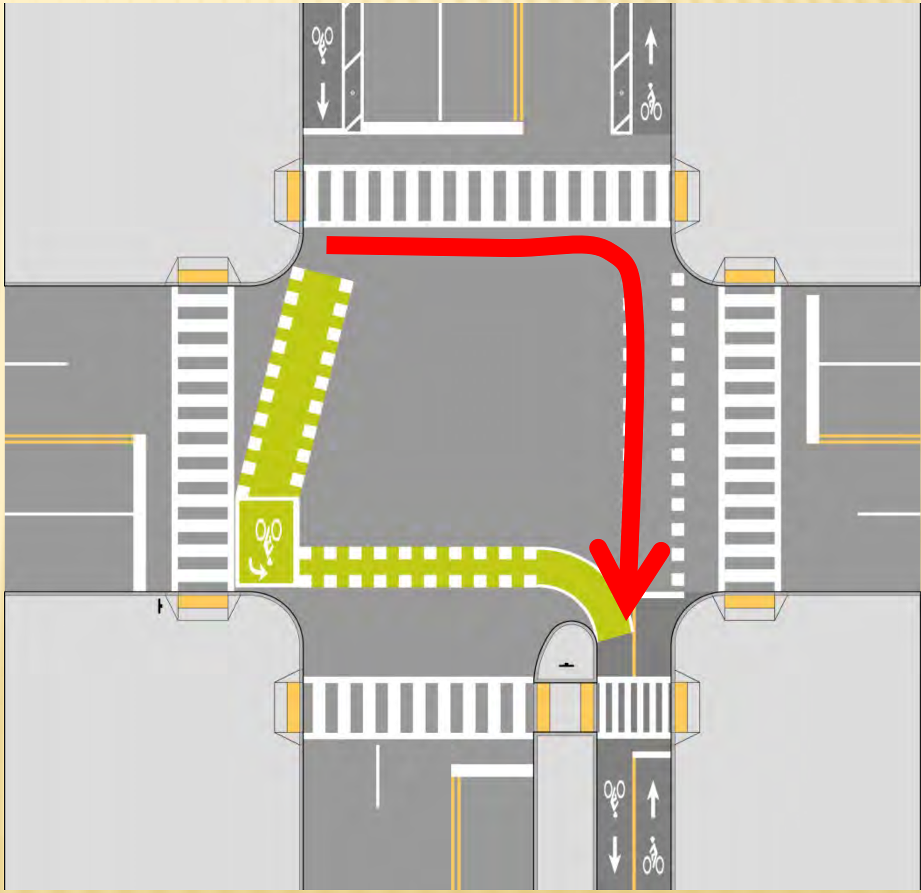
TRANSITIONS

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



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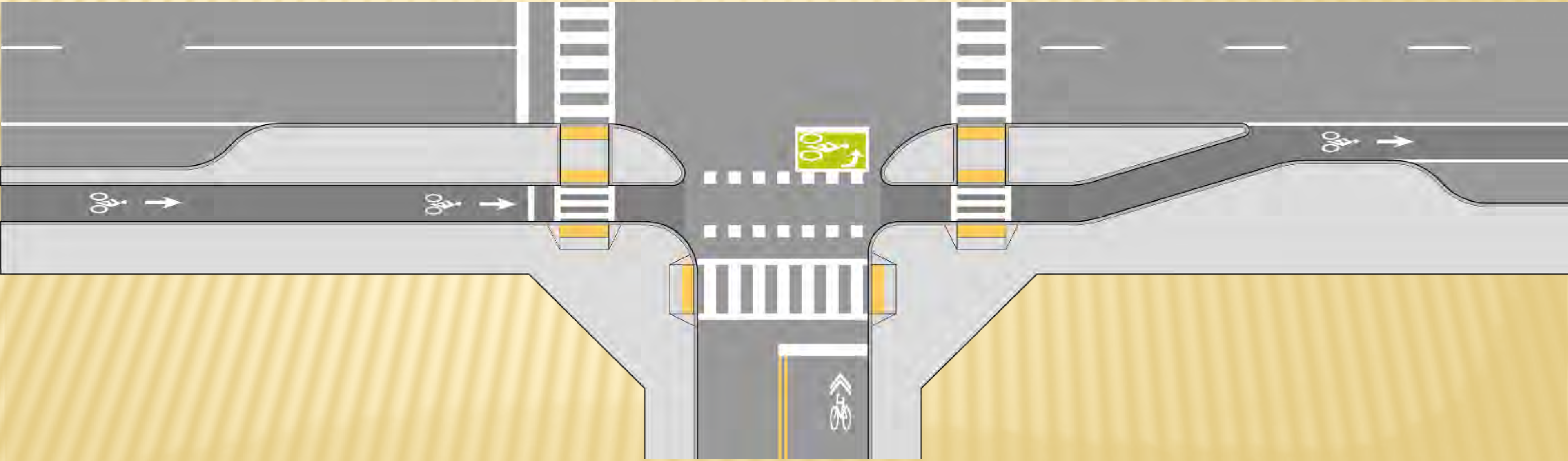
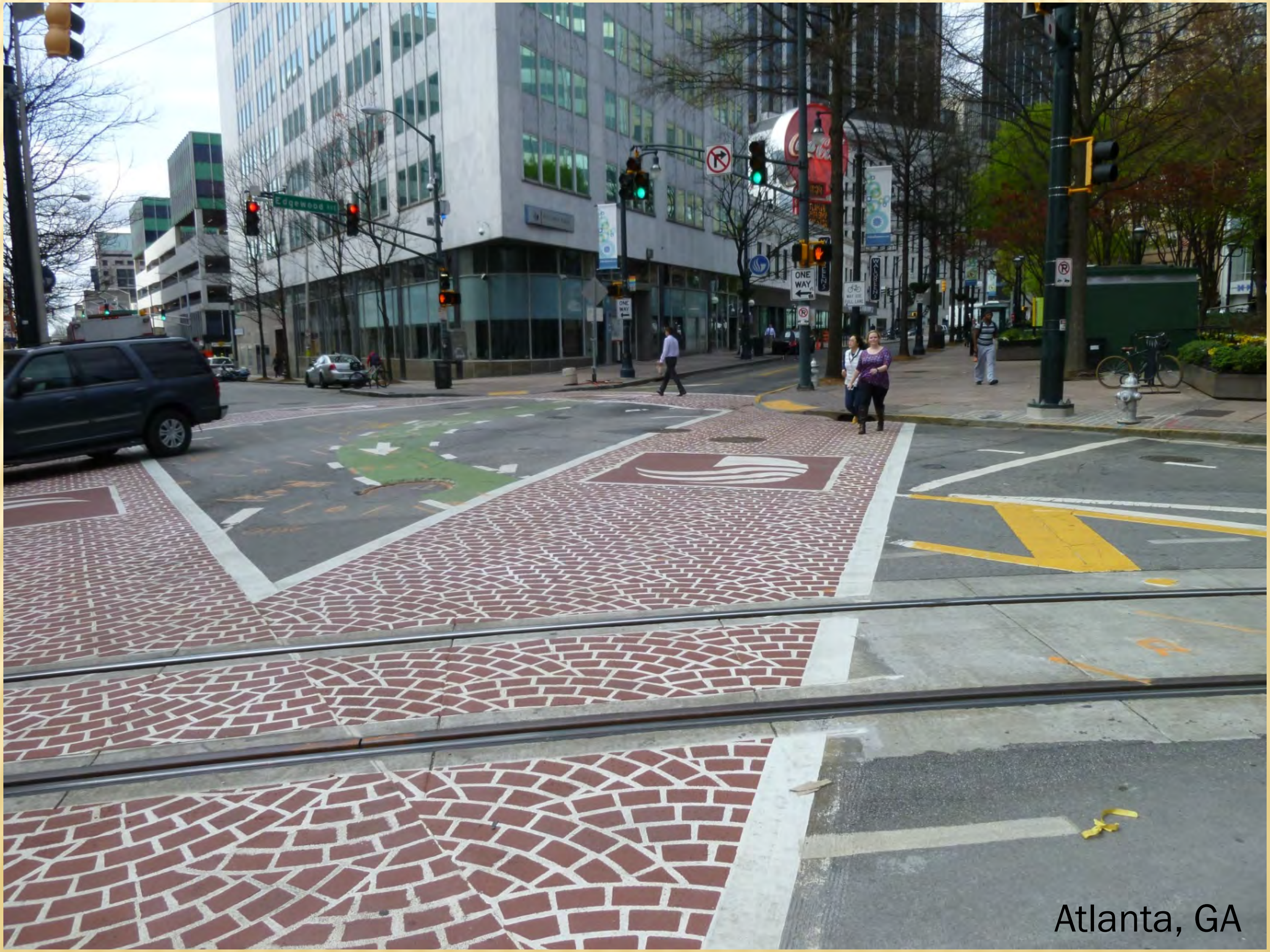
EXAMPLE TRANSITIONS

into a conventional bike lane

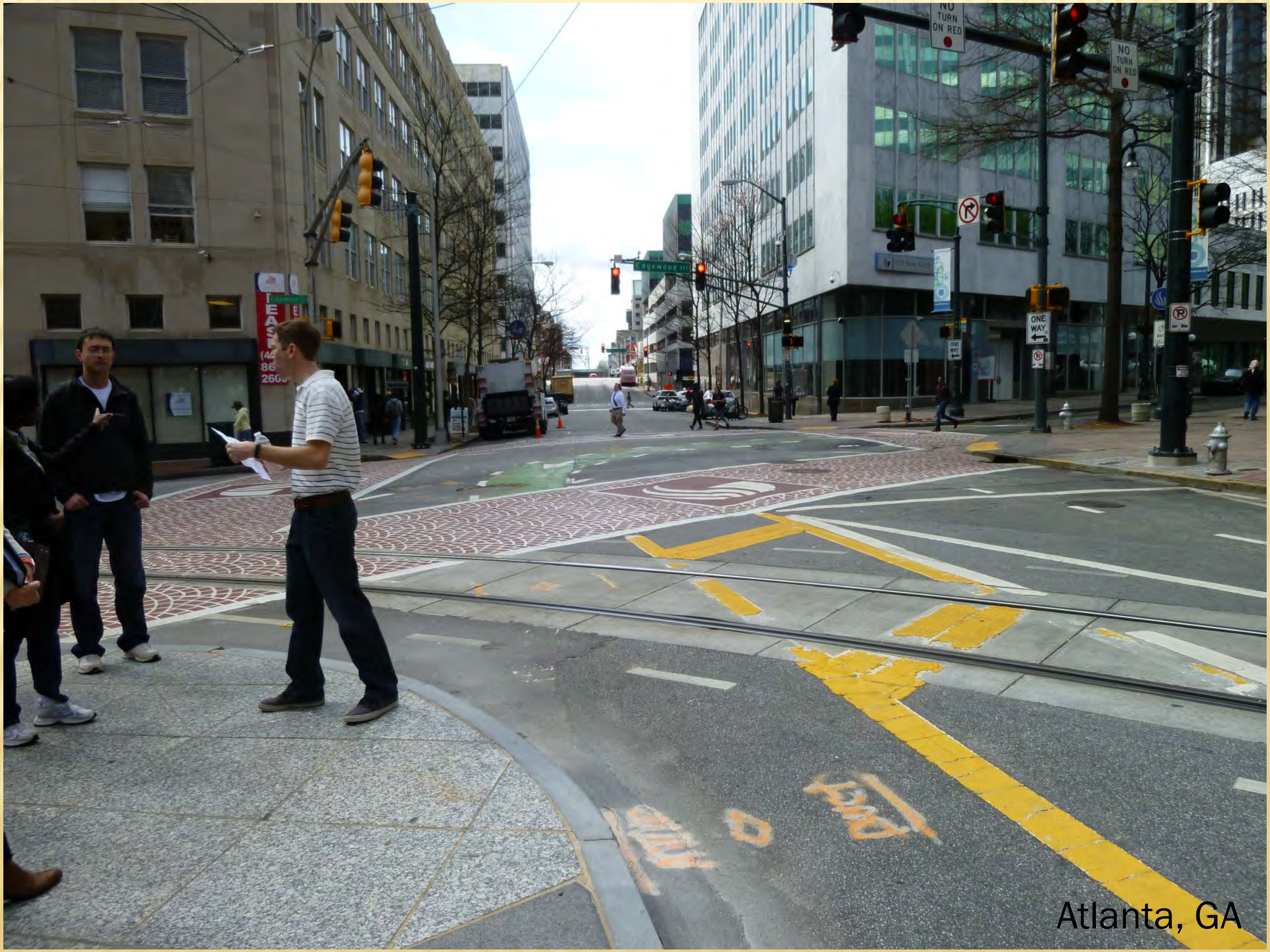


ACCESS TO/FROM SIDE STREET

ACCESS TO/FROM SIDE STREET



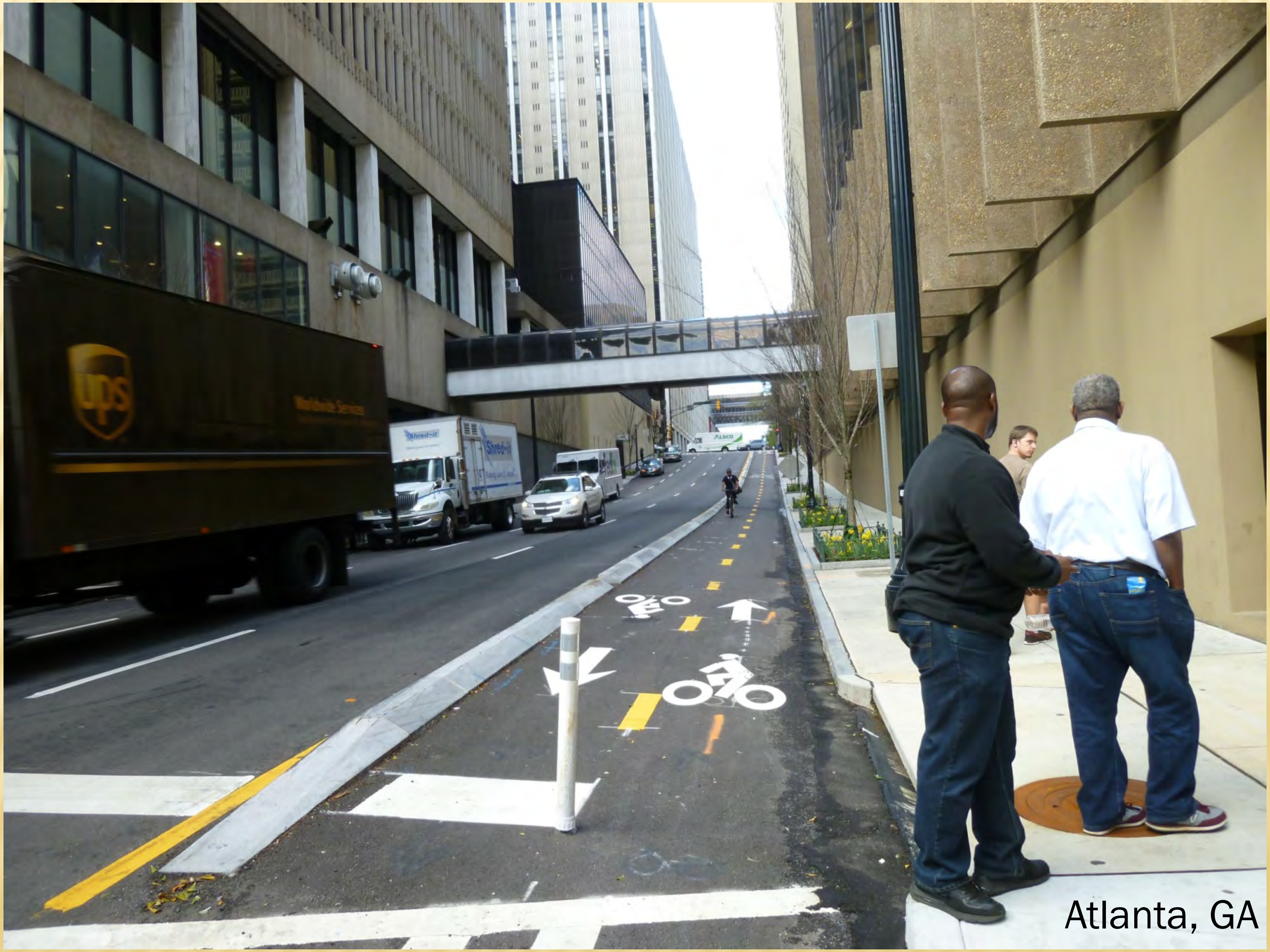
ACCESS TO/FROM SIDE STREET



Atlanta, GA

ACCESS TO/FROM SIDE STREET

STEEP GRADE TO INTERSECTION



Atlanta, GA

STEEP GRADE TO INTERSECTION

Atlanta, GA

Bicyclist Safety at Intersections

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

CLEARANCE & ALL RED INTERVALS

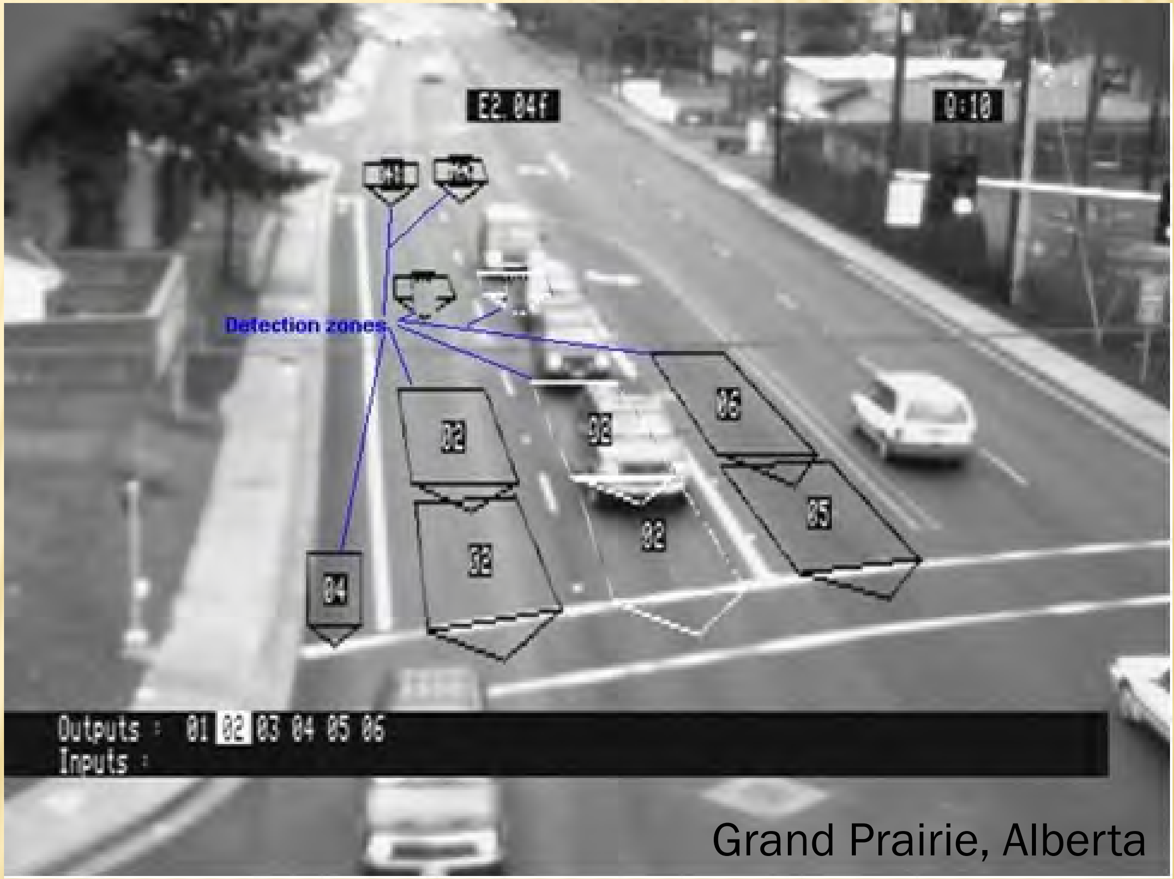
BICYCLE SIGNAL FACE

Application for:

- Bicyclist non-compliance
- Provide a leading or lagging bicycle interval
- Continue the bicycle lane on the right-hand side of an exclusive turn lane
- Augment the design of a segregated counter-flow
- Unusual or unexpected arrangements of the bicycle movement through complex intersections, conflict areas, or signal control.

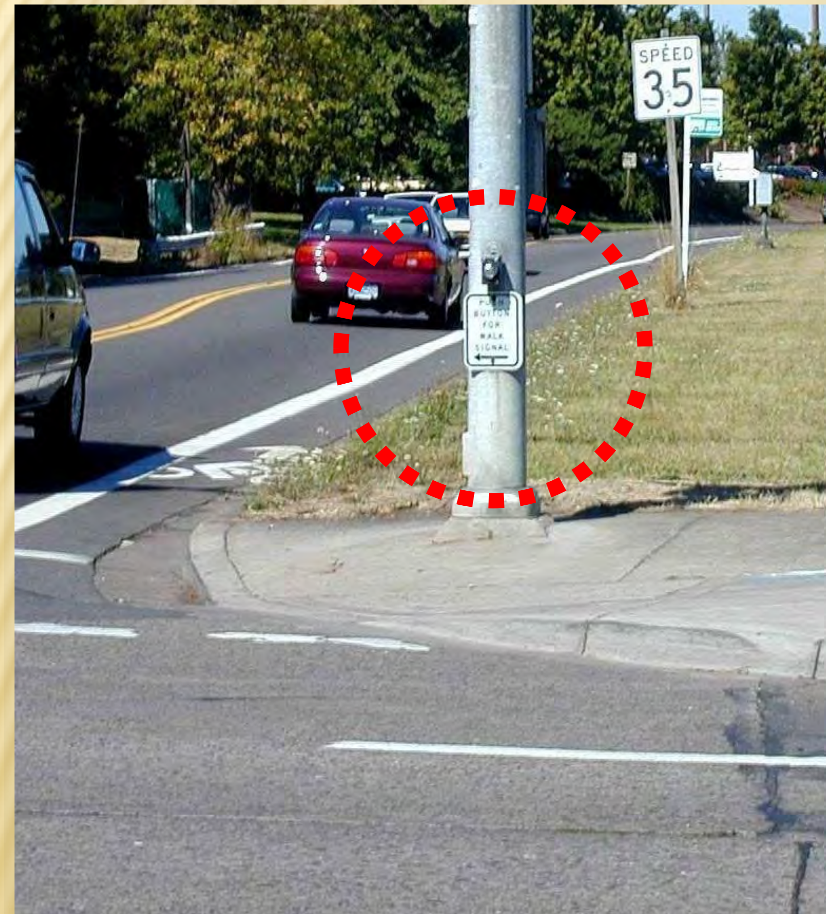
BICYCLE DETECTION

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

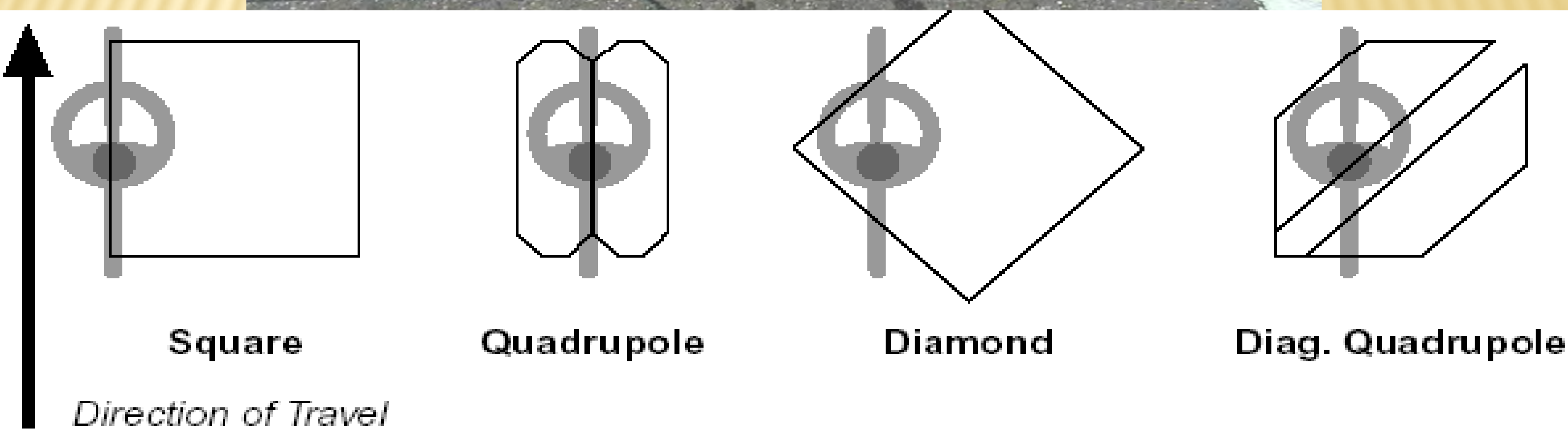


Grand Prairie, Alberta

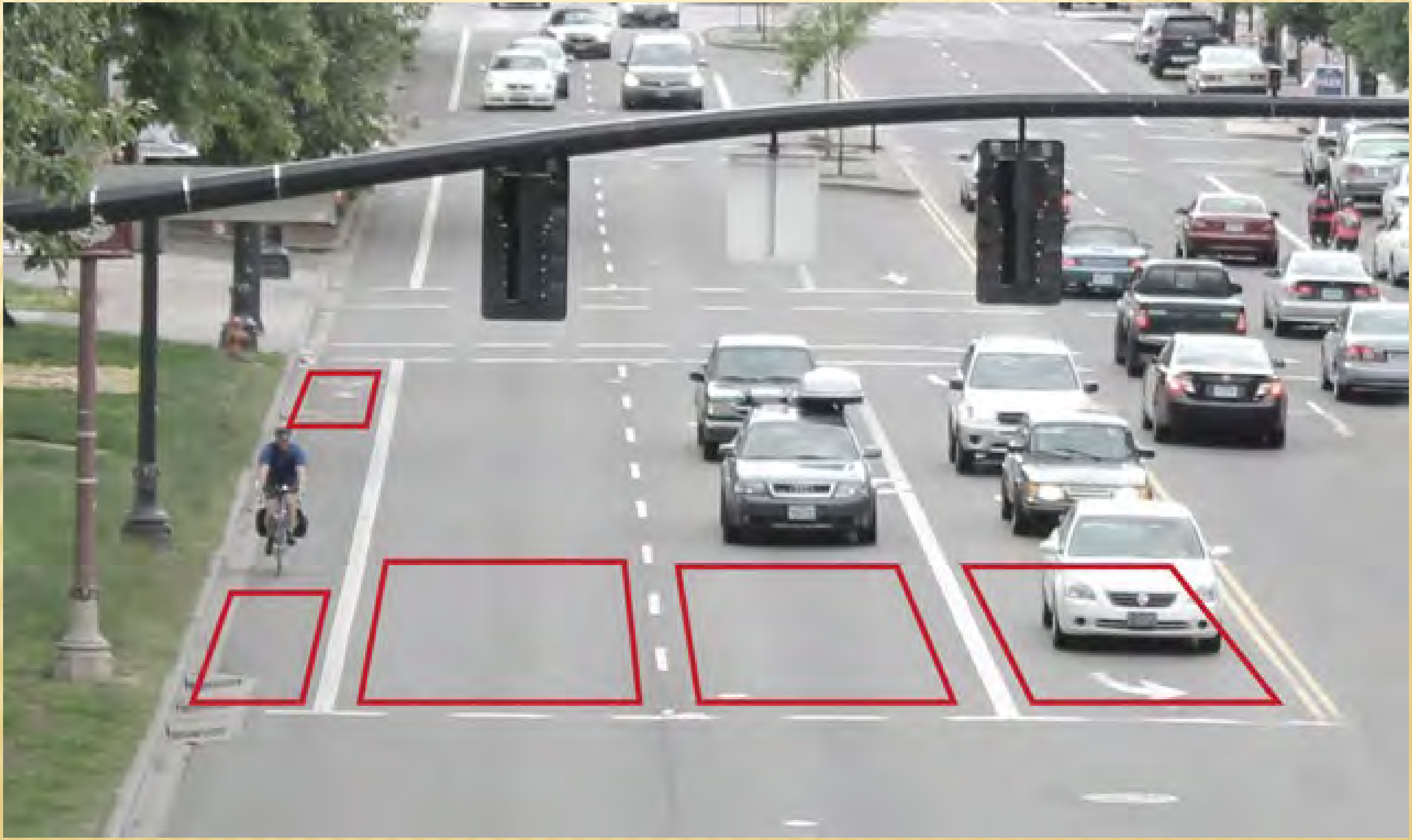
PUSH BUTTONS



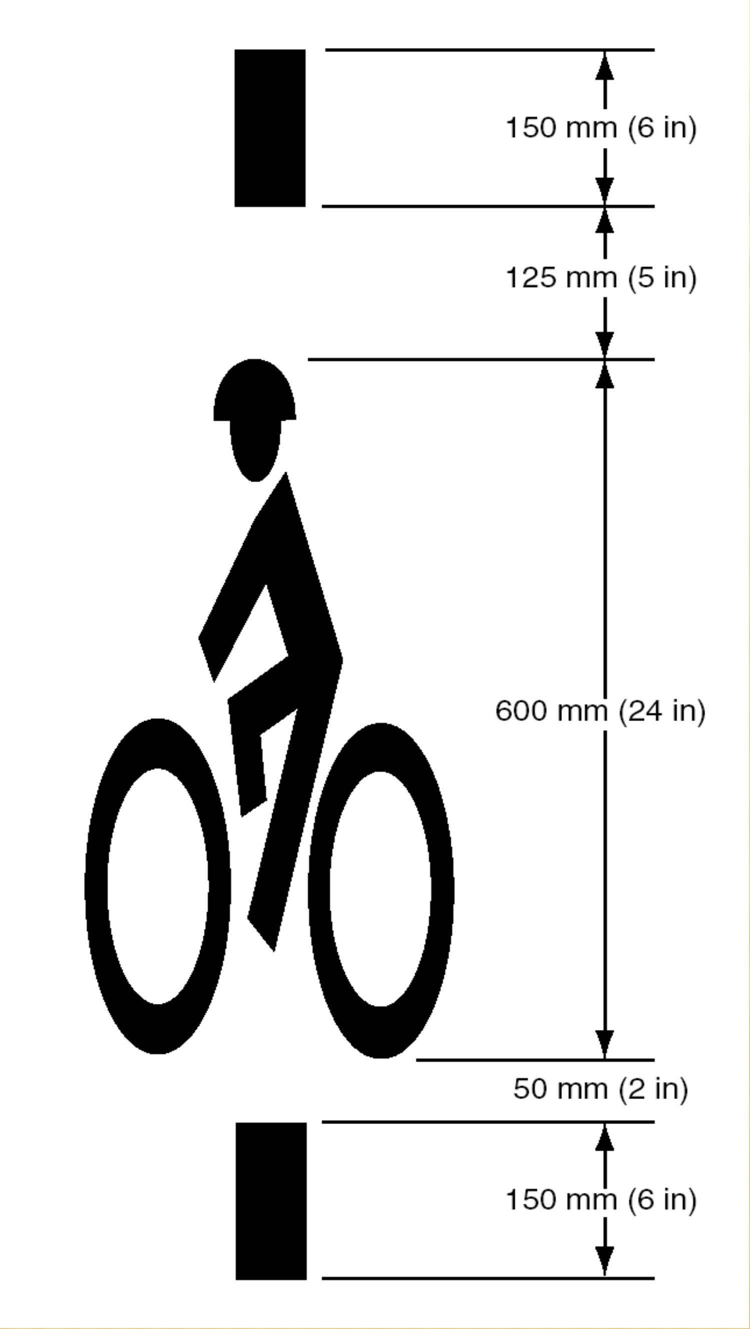
LOOP DETECTION



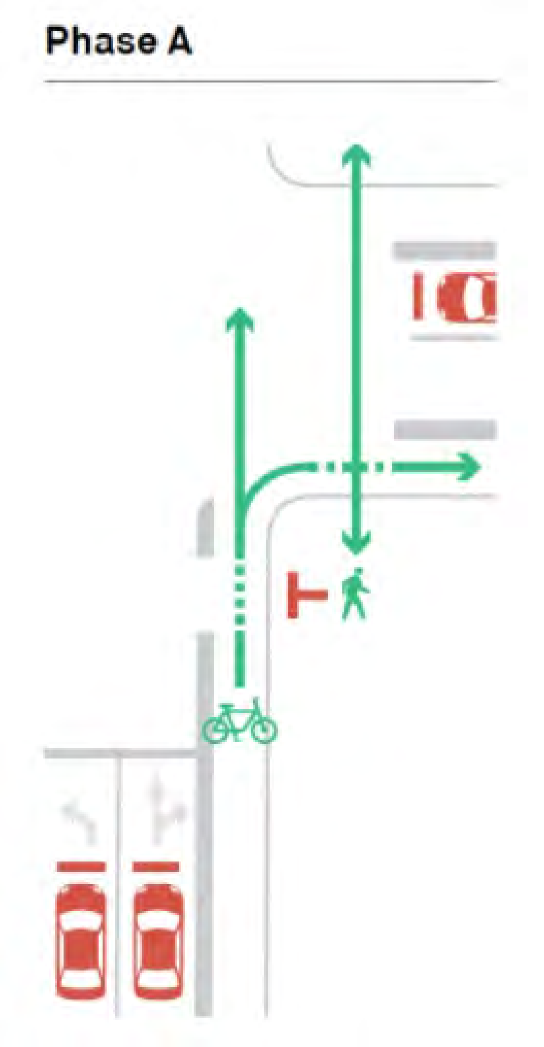
PASSIVE DETECTION



MUTCD standard for signal loop marking for bicyclists
(Section 9C.05)



LBI & LAGGING LEFT TURN



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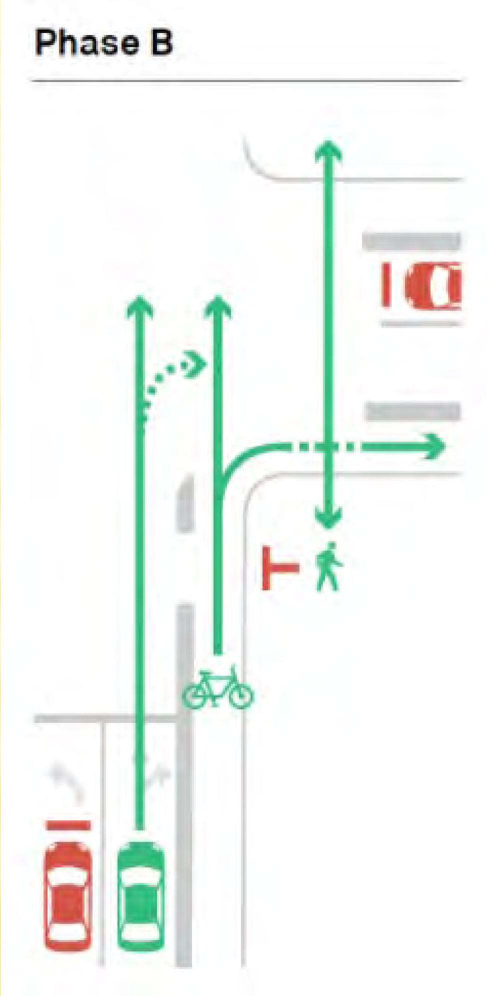
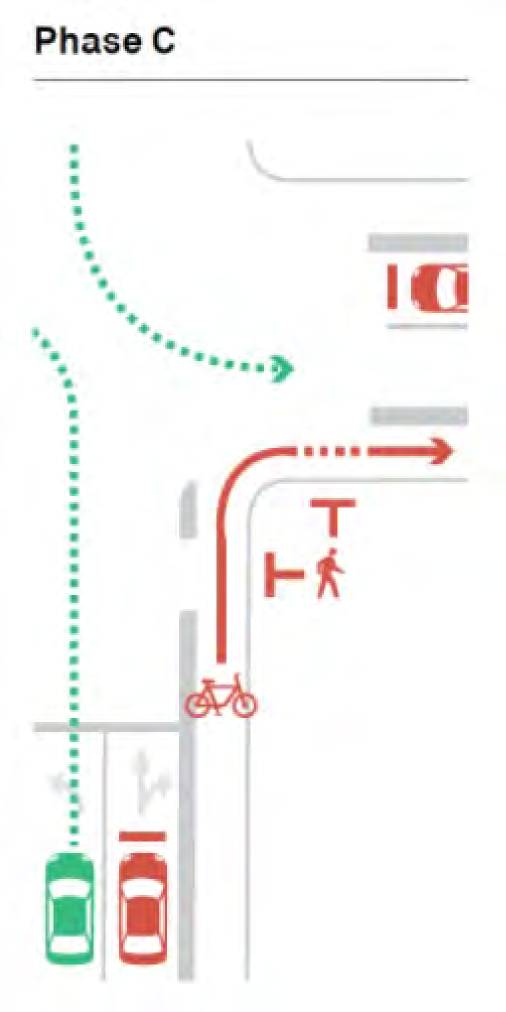
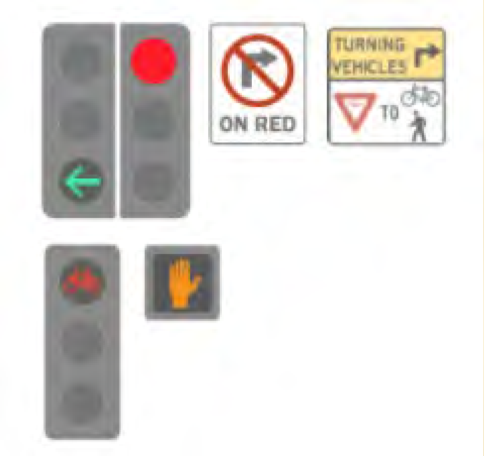
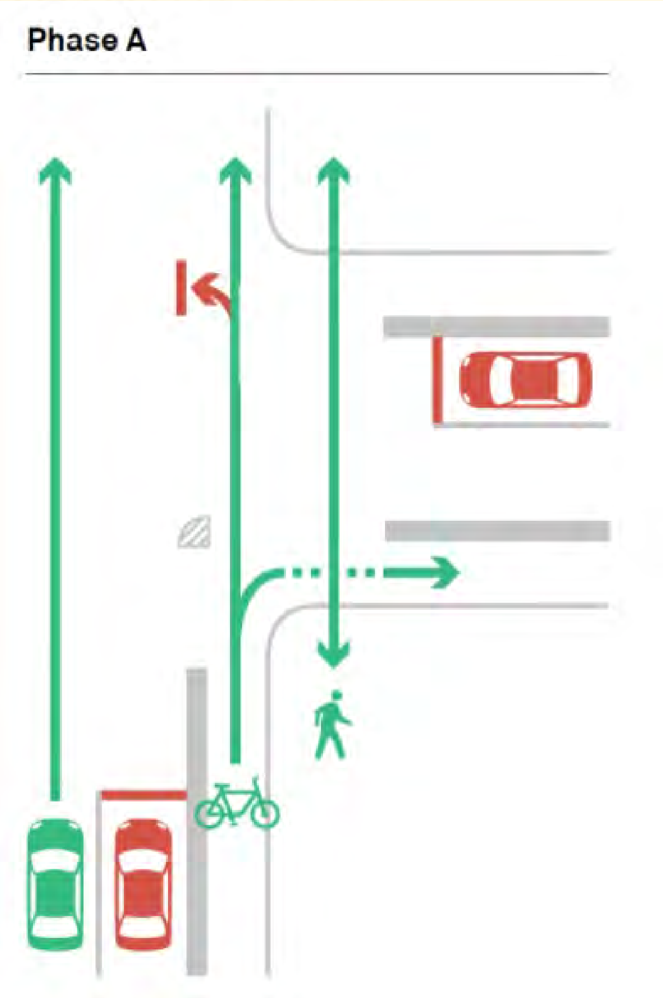


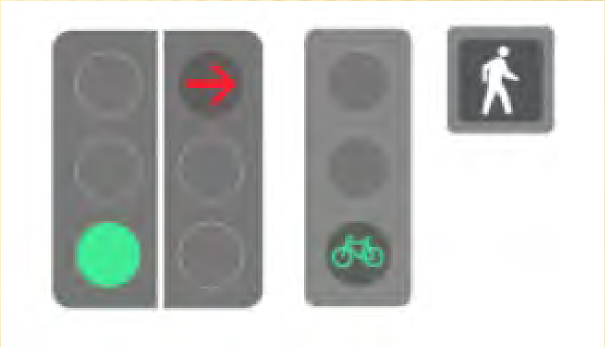
LBI & LAGGING LEFT TURN





PROTECTED PERMISSIVE





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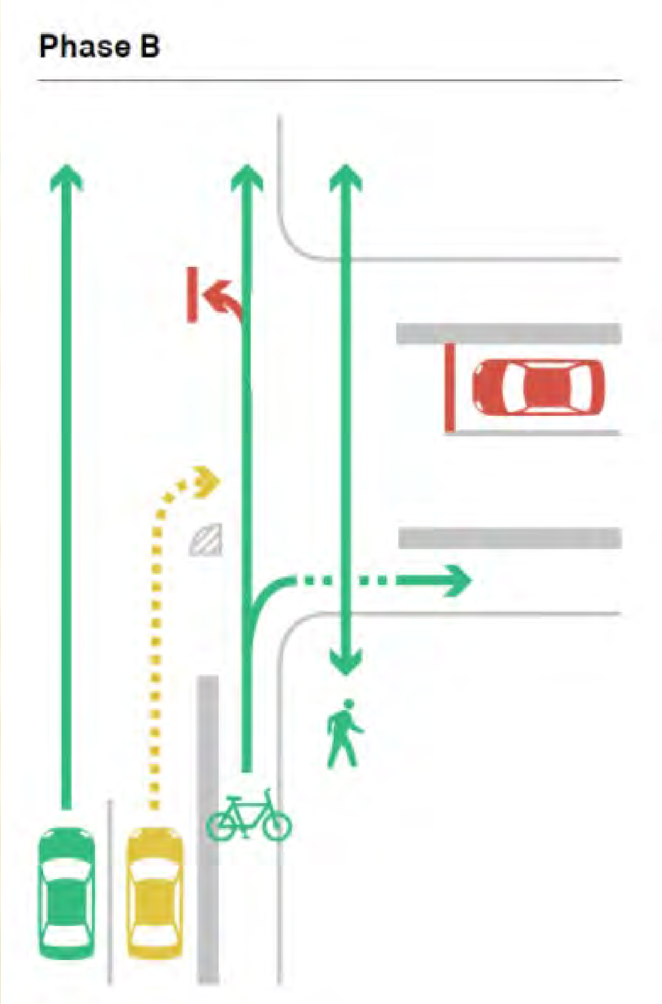

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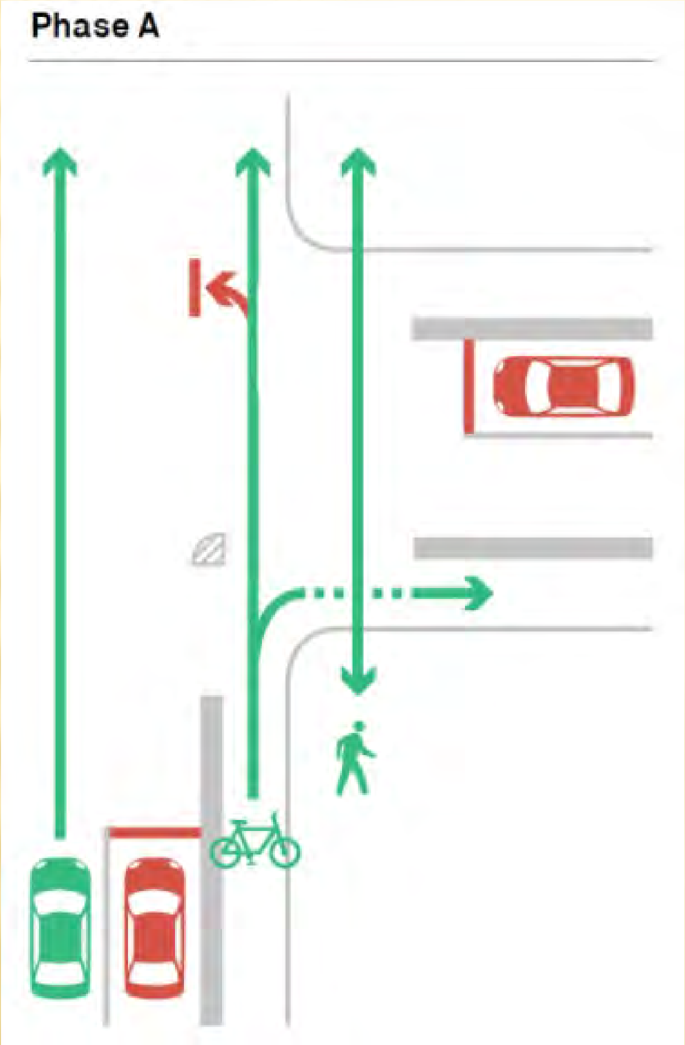
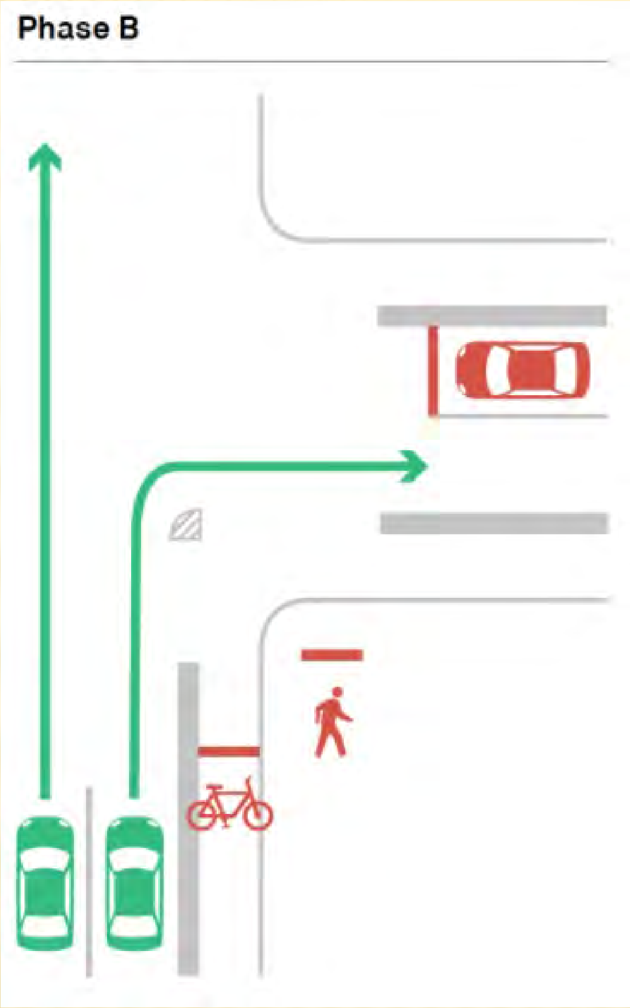


PROTECTED



Bicyclist Safety at Intersections

ANALYSIS AND EVALUATION

SAFETY EVALUATION TOOLS

- Highway Safety Manual
- Bicycle Intersection Safety Indices
- Highway Capacity Manual
- Road Safety Audit
- BIKESAFE

HSM METHODOLOGY

- Urban & Suburban Segments

$$N_{biker} = N_{br} \times f_{biker}$$

  - N_{biker} – vehicle-bicycle collision frequency
  - N_{br} – crash frequency, excluding bikes and peds
  - f_{biker} – bicycle crash adjustment factor

    -- < or > 30 mph posted speed

    -- road type (2U, 3T, 4U, 4D, 5T)

    -- values range from 0.002 to 0.050

HSM METHODOLOGY

- Urban & Suburban Intersections

$$N_{bikei} = N_{bi} \times f_{bikei}$$

- N_{bikei} -- vehicle-bicycle collision frequency
- N_{bi} -- predicted intersection crashes (no bikes/peds)
- f_{bikei} – bicycle crash adjustment factor

  -- intersection type (3ST, 3SG, 4ST, 4SG)

  -- values range from 0.011 to 0.018

CMF LIMITATIONS

Countermeasure: Install bicycle lanes

CMF	CRF(%)	Quality	Crash Type	Crash Severity	Area Type	Reference	Comments
1.05	-5	★★★☆☆	All	All	Urban	Jensen, 2008	
0.944	5.6	★★★☆☆	All	All	Urban	Chen et al., 2012	
1.509	-50.9	★★★☆☆	Vehicle/bicycle	All	Urban	Chen et al., 2012	
1.057	-5.7	★★★☆☆	All	All	Urban	Chen et al., 2012	Includes signalized, all-way stop controlled, ... [read more]
1.281	-28.1	★★★☆☆	Vehicle/bicycle	All	Urban	Chen et al., 2012	Includes signalized, all-way stop controlled, ... [read more]

CMF LIMITATIONS

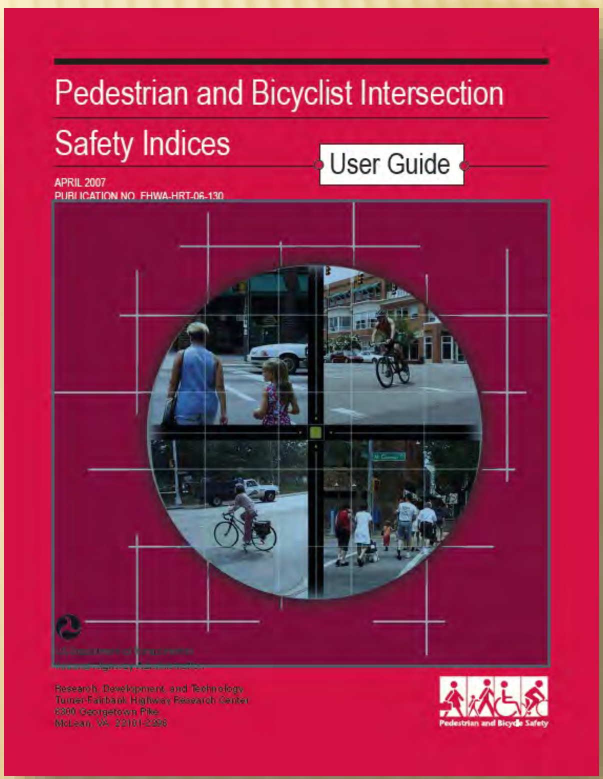
Countermeasure: Installation of bicycle lanes at signalized intersections

CMF	CRF(%)	Quality	Crash Type	Crash Severity	Area Type	Reference	Comments
1.37	-37	★★☆☆☆	Vehicle/bicycle	All	Urban and suburban	Turner et al., 2011	
0.8	20	★★☆☆☆	Vehicle/bicycle	All	Urban and suburban	Turner et al., 2011	
0.63	37	★★☆☆☆	Vehicle/bicycle	All	Urban and suburban	Turner et al., 2011	Crossing crashes at 90 degrees ... [read more]
1.33	-33	★★☆☆☆	Vehicle/bicycle	All	Urban and suburban	Turner et al., 2011	Crash Type: Cyclist through, left ... [read more]
1.01	-1	★★☆☆☆	Vehicle/bicycle	All	Urban and suburban	Turner et al., 2011	Crash Type: Rear end & ... [read more]

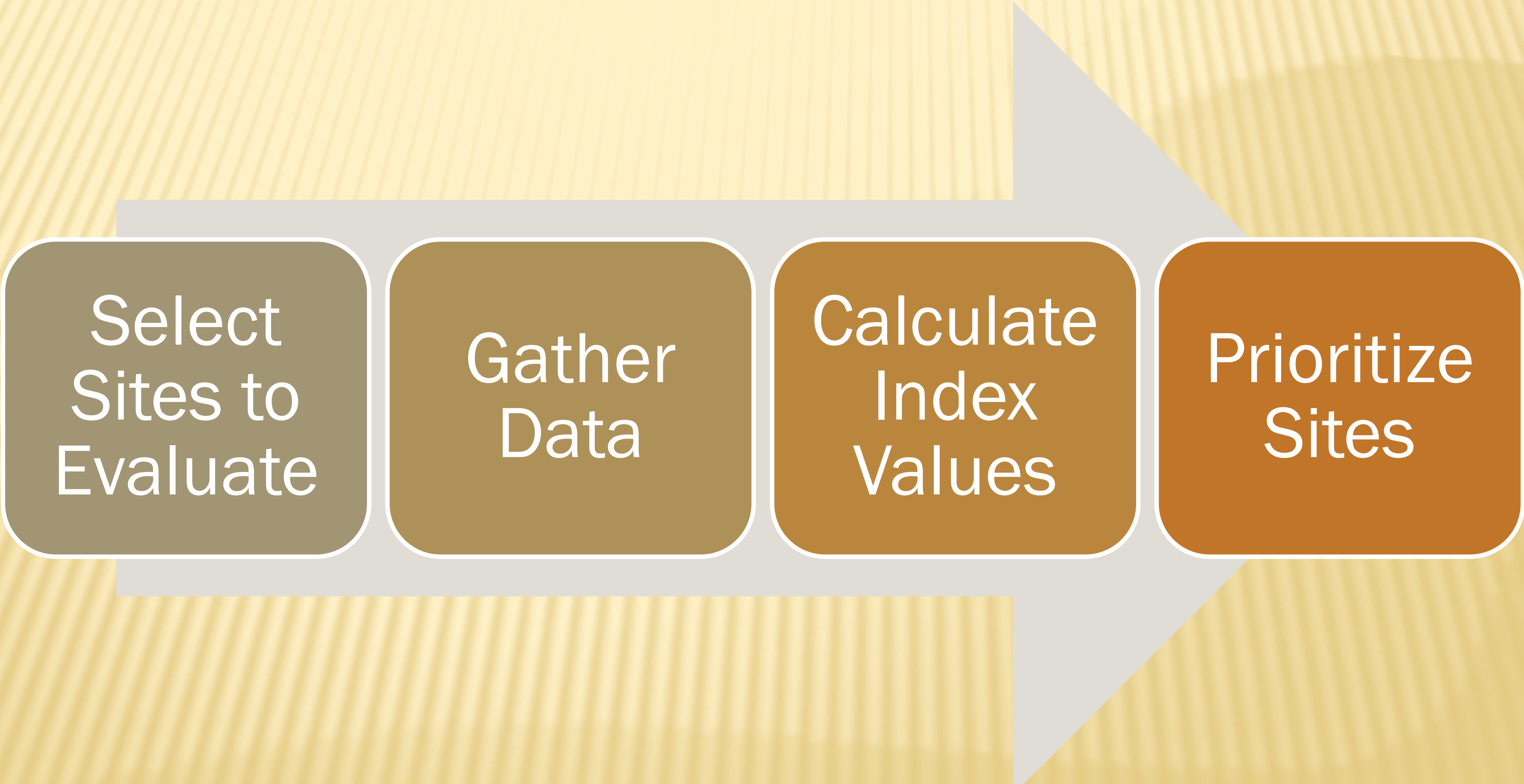
BICYCLIST INTERSECTION SAFETY INDICES

Prioritize intersections crossings and intersection approaches for bicycle safety improvements

- Score of 1 (safest) to 6 (least safe)
- Score for each movement (thru, left turn, right turn)



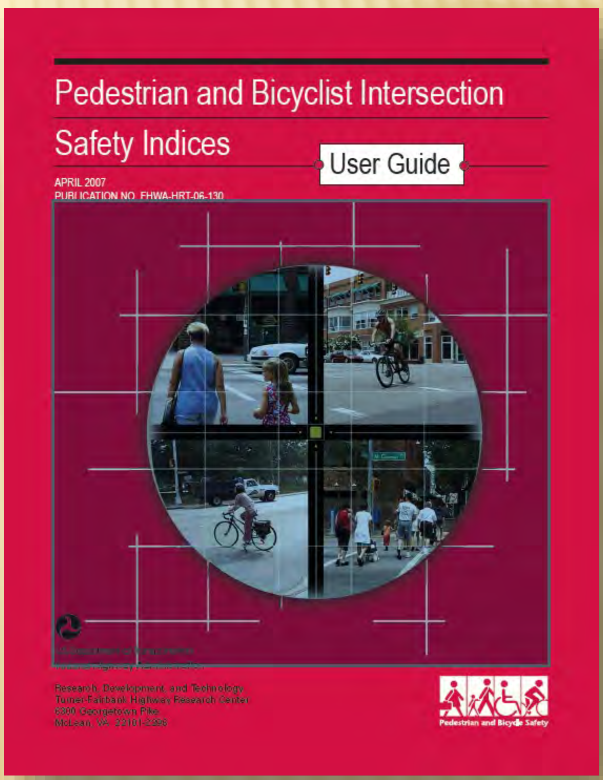
BICYCLIST INTERSECTION SAFETY INDICES



BICYCLIST INTERSECTION SAFETY INDICES

Inputs:

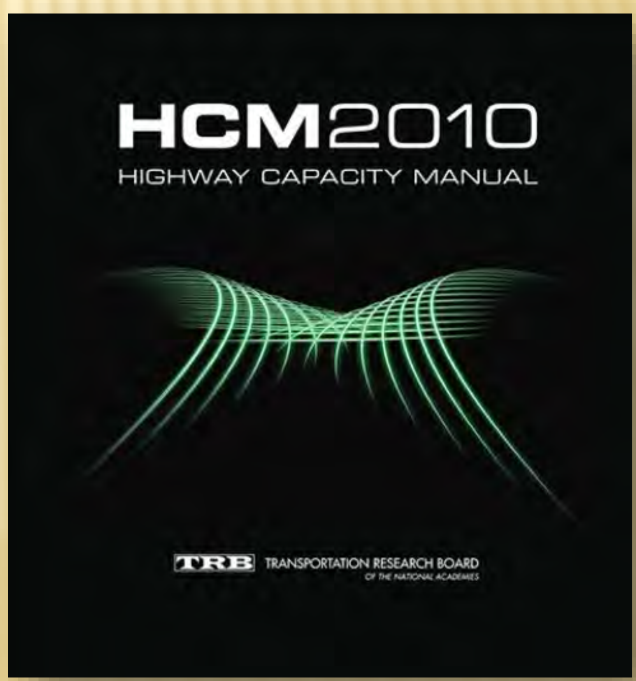
- ADT on main and cross streets.
- Number of through vehicle lanes on cross street.
- Number, type, and configuration of traffic lanes on main street approach.
- Speed limit on main street.
- Presence of on-street parking on main street approach.
- Type of traffic control on approach of interest (signal or no signal).



BICYCLE LEVEL-OF-SERVICE

Interrupted flow:

- LOS reported separately for each mode
  - Purpose, length, and expectation differs
- Travel speed
- Intersection delay
- Bicyclist perception



BICYCLE LEVEL-OF-SERVICE

Factors in bicycle LOS score:
Interrupted flow

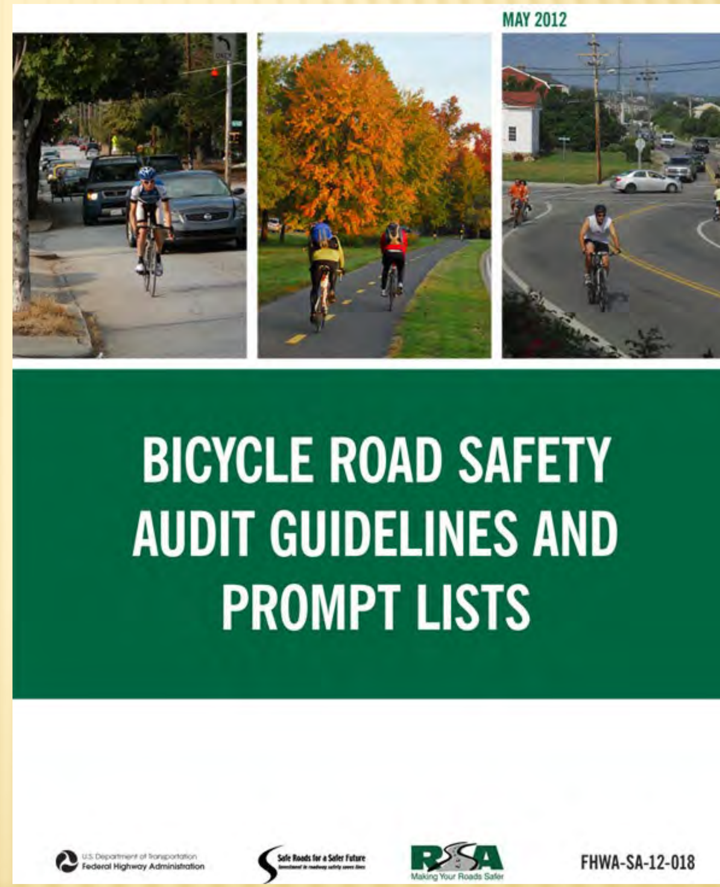
- Motorized vehicle volume
- % heavy vehicles
- % occupied parking
- # lanes
- Outside lane width
- Median
- Curb
- Access
- Pavement condition
- Motorized vehicle speed

LEVELS OF TRAFFIC STRESS (LTS)

Levels of Traffic Stress			
LTS 1	LTS 2	LTS 3	LTS 4
• Physically separated from traffic or low-volume, mixed-flow traffic at 25 mph or less • Bike lanes 6 ft wide or more • Intersections easy to approach and cross • Comfortable for children	• Bike lanes 5.5 ft wide or less, next to 30 mph auto traffic • Unsignalized crossings of up to 5 lanes at 30 mph • Comfortable for most adults • Typical of bicycle facilities in Netherlands	• Bicycle lanes next to 35 mph auto traffic, or mixed-flow traffic at 30 mph or less • Comfortable for most current U.S. riders • Typical of bicycle facilities in U.S.	• No dedicated bicycle facilities • Traffic speeds 40 mph or more • Comfortable for “strong and fearless” riders (vehicular cyclists)

ROAD SAFETY AUDIT

- Formal safety examination conducted by an independent, experienced, multidisciplinary team
- RSA Prompt List
- Bikeability checklist



RSA PROMPT LIST

D.8: Are the intersection/transition and paths leading to the transition adequately lit (see C.8)?

D.9: Is the visibility of cyclists as they make the transition from one facility or roadway geometry to another adequate from the perspective of all road users?

The transition, whether along a roadway or at an intersection, should allow drivers to see cyclists and understand their path and intent, and vice versa. The following should be investigated:

- Obstructions caused by roadside features (e.g., fences and vegetation).
- Adequacy of warning signs.
- Location of the transition with respect to roadway geometry (e.g., shoulder drop and turn lanes) (see also A.9 and C.9).

The picture to the left depicts a bike lane that hooks right through a major intersection and transitions to a protected bikeway. Chevrons on the pavement help guide cyclists and show motorists the path provided for cyclists through the intersection (note that the chevron pavement markings do not conform to the MUTCD).

D.10 and D.11: Are signs and markings at transition areas appropriate?

Transitions and termini should be appropriately signed and marked to warn cyclists of conditions ahead, particularly at locations at which cyclists do not expect transitions or termini. Likewise, motorized vehicles should have adequate warning when off-road bicycle facilities transition to on-road facilities. The intended paths of all road users should also be appropriately signed and marked at the point of transition. Additional attention may be given to locations with high volumes of unfamiliar users or tourists.

BIKEABILITY CHECKLIST

Go for a ride and use this checklist to rate your neighborhood's bikeability.

How bikeable is your community?

Location of bike ride (be specific):

Rating Scale: 1 awful — 2 many problems — 3 some problems — 4 good — 5 very good — 6 excellent

1. Did you have a place to bicycle safely?

a) On the road, sharing the road with motor vehicles?

- ☐ Yes
- ☐ Some problems (please note locations):
  - ☐ No space for bicyclists to ride
  - ☐ Bicycle lane or paved shoulder disappeared
  - ☐ Heavy and/or fast-moving traffic
  - ☐ Too many trucks or buses
  - ☐ No space for bicyclists on bridges or in tunnels
  - ☐ Poorly lighted roadways

  Other problems: ______________________

  ____

b) On an off-road path or trail, where motor vehicles were not allowed?

- ☐ Yes
- ☐ Some problems:
  - ☐ Path ended abruptly
  - ☐ Path didn't go where I wanted to go
  - ☐ Path intersected with roads that were difficult to cross
  - ☐ Path was crowded
  - ☐ Path was unsafe because of sharp turns or dangerous downhills
  - ☐ Path was uncomfortable because of too many hills
  - ☐ Path was poorly lighted

  Other problems: ______________________

2. How was the surface that you rode on?

- ☐ Good
- ☐ Some problems, the road or path had:
  - ☐ Potholes
  - ☐ Cracked or broken pavement
  - ☐ Debris (e.g. broken glass, sand, gravel, etc.)
  - ☐ Dangerous drain grates, utility covers, or metal plates
  - ☐ Uneven surface or gaps
  - ☐ Slippery surfaces when wet (e.g. bridge decks, construction plates, road markings)
  - ☐ Bumpy or angled railroad tracks
  - ☐ Rumble strips

  Other problems: ______________________

  ____

Overall Surface Rating: (circle one)
1 2 3 4 5 6

3. How were the intersections you rode through?

- ☐ Good
- ☐ Some problems:
  - ☐ Had to wait too long to cross intersection
  - ☐ Couldn't see crossing traffic
  - ☐ Signal didn't give me enough time to cross the road
  - ☐ Signal didn't change for a bicycle
  - ☐ Unsure where or how to ride through intersection

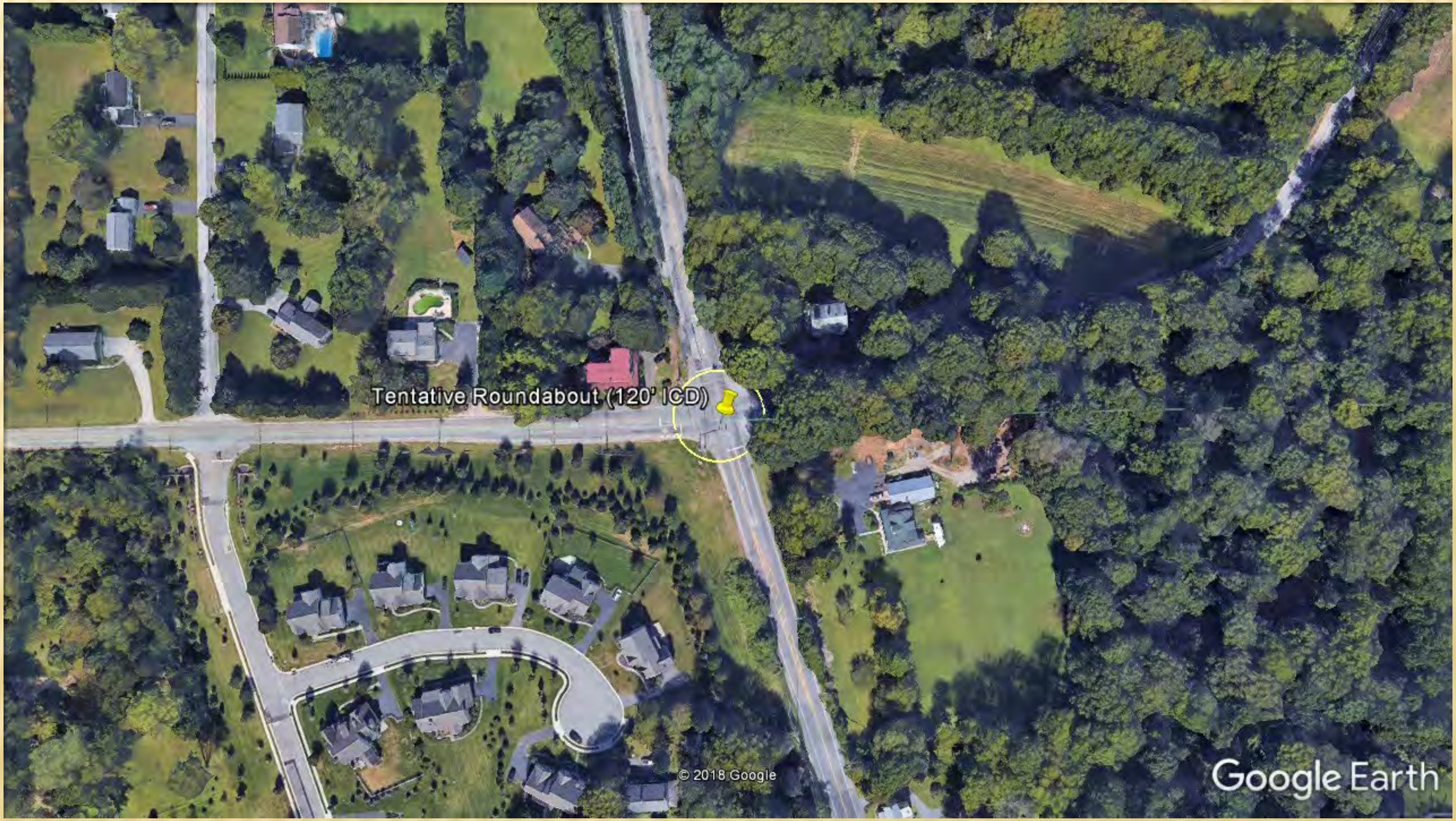
  Other problems: ______________________

EXAMPLE (BACKGROUND)

- Existing signalized intersection
  - Peak hour delays are a concern
  - Speeds are a concern, especially off peak
  - Higher crash location
  - Several injuries and 1 fatality in the past
  - Additional future delay and safety impacts expected with nearby development projects
  - A roundabout is the preferred alternative
  - However, ROW and utility impacts are a concern

The project team has requested analysis of a roundabout.

EXAMPLE (LOCATION)



Source: Google Earth Pro
Location: Southeastern Pennsylvania

EXAMPLE (DATA IN HAND)

- ✓ Existing daily traffic counts (tube counters)
- ✓ Existing peak hour counts (AM, MID, PM, SAT)
- ✓ Projected peak hour counts (AM, MID, PM, SAT)
- ✓ Little to no trucks or pedestrians
- ✓ Existing crash data (fatal/injuries and PDO)
- ✓ Some developer traffic impact studies
- ✓ HCM2010-based peak hour capacity analysis
- ✓ HSM predicted crashes
- ✓ HSM crash modification factors

EXAMPLE (TRADITIONAL ANALYSIS)

Year 2018 (Opening Year) HCM 6th Edition Analysis Overall Intersection Results	Existing Signalized Intersection w/ Turn Lanes (Semi-Actuated, Isolated)	Proposed Roundabout (1-lane entries, 1 circulating lane, ~120' ICD)
AM Peak Hour (0700-0800) Average Control Delay in Seconds/Vehicle (LOS)	32.1 (C)	32.4 (D)
MID Peak Hour (1200-1300) Average Control Delay in Seconds/Vehicle (LOS)	19.9 (B)	16.4 (C)
PM Peak Hour (1700-1800) Average Control Delay in Seconds/Vehicle (LOS)	46.3 (D)	51.9 (F)

Source: Dave Petrucci FHWA-RC-SDTST

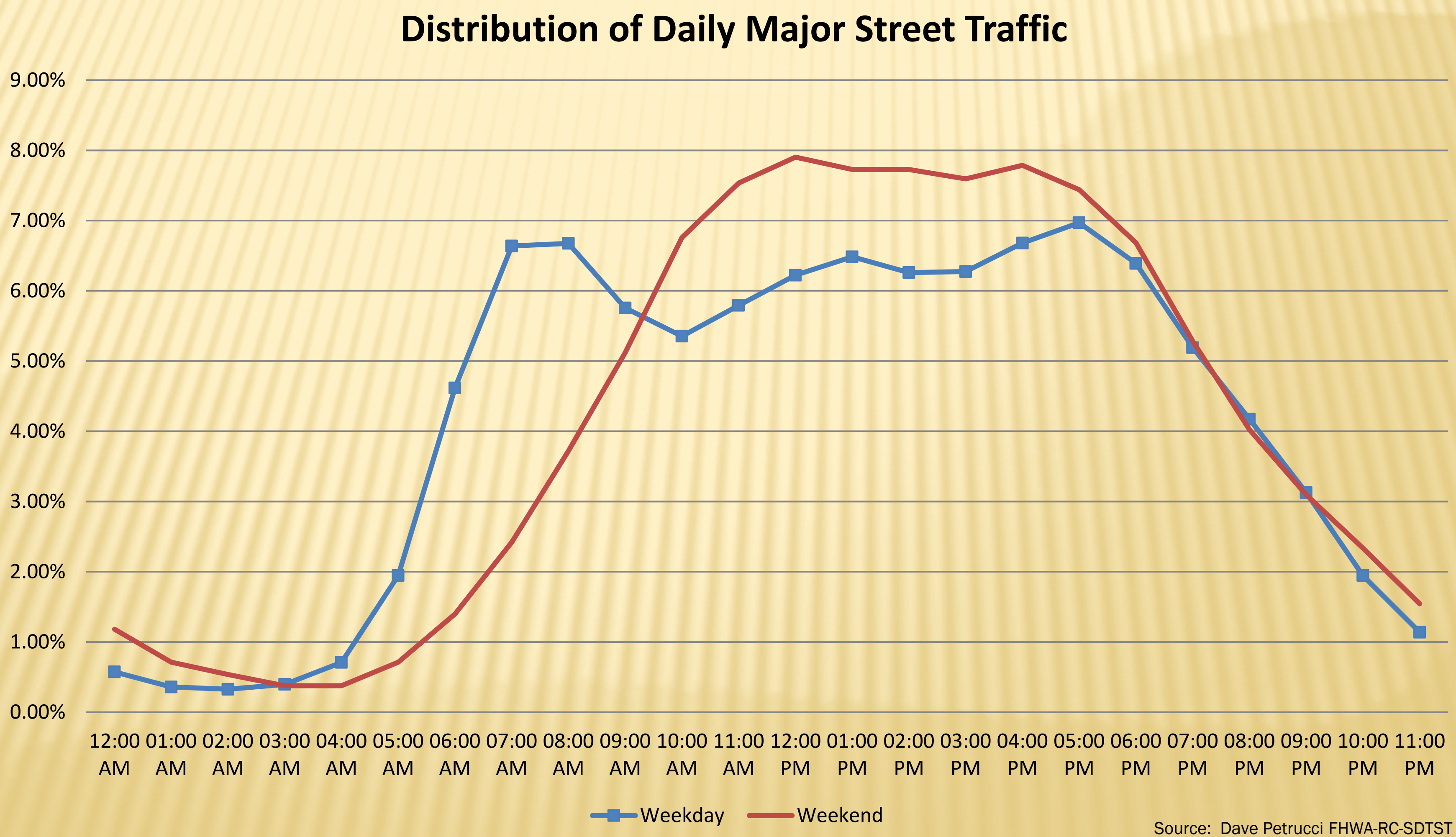
EXAMPLE (TRADITIONAL ANALYSIS)

- The project traffic study provides peak hour HCM analysis and overall intersection delay savings for opening and design years.
- The roundabout option has slightly more peak hour delay than the no build option (signal)
- We can consider more than just peak hour delay and leverage daily traffic estimates

EXAMPLE (ASSUMPTIONS)

- Proportional relationships between traffic volumes and delay values
- No seasonal variations in traffic demand
- To convert peak hour delay savings to annual vehicle-hours assume:
  - 39 representative weeks of the year
  - 12 summer weeks and 1 holiday week are excluded
  - 3 representative weekdays per week (T, W, THURS)
  - 1 representative weekend day per week (Saturday)
- Derive vehicle-hours of delay
- Extrapolate peak hour results for the entire day

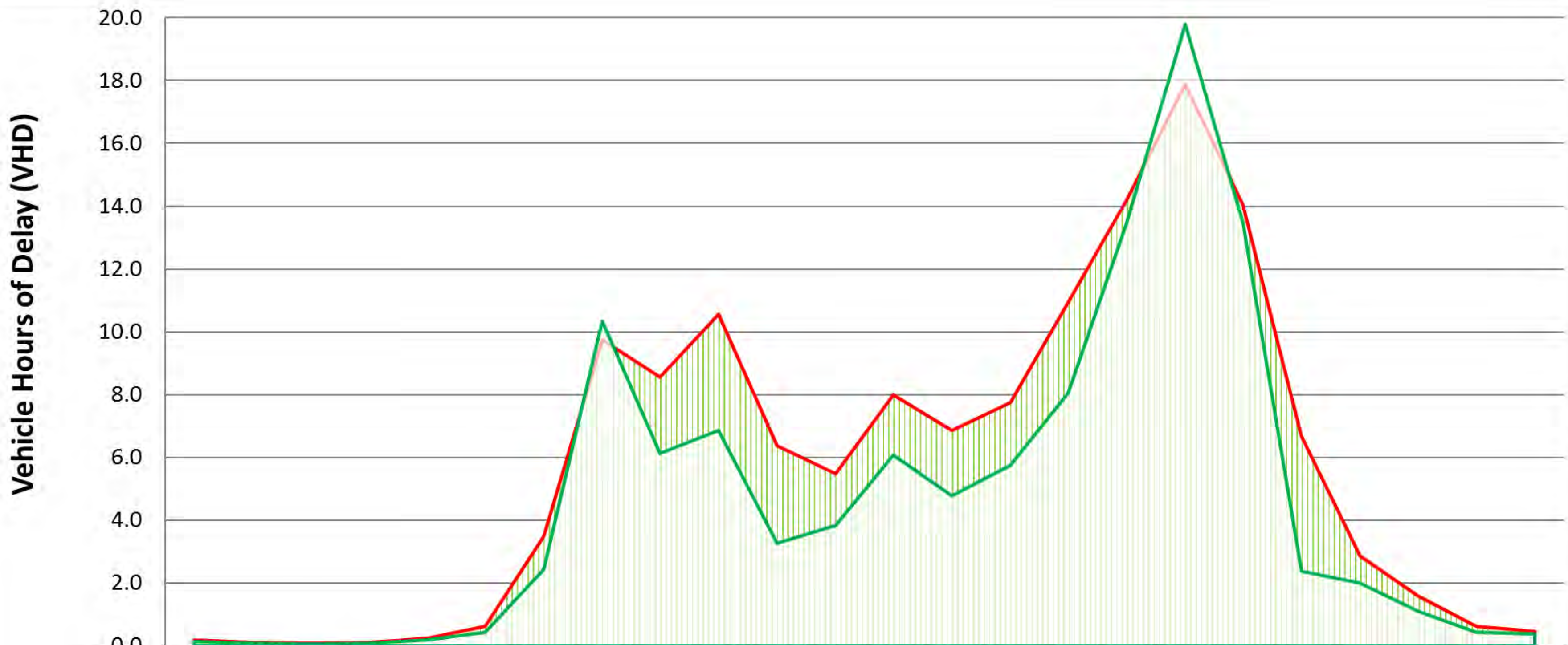
EXAMPLE (DAILY TRAFFIC)



Source: Dave Petrucci FHWA-RC-SDTST

EXAMPLE (DAILY DELAY COMPARISON)

- Vehicle-hours of delay estimated (HCM)

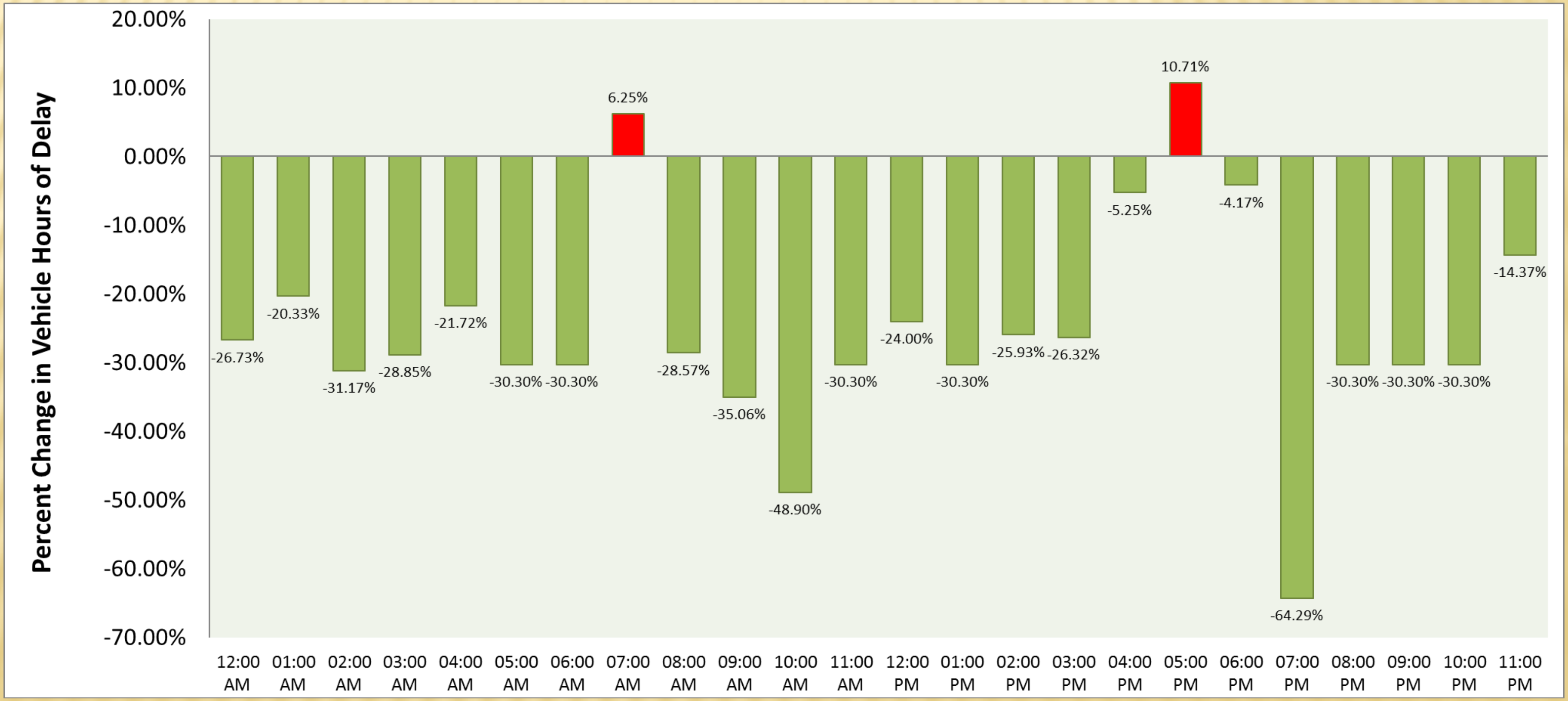


	12:00 AM	01:00 AM	02:00 AM	03:00 AM	04:00 AM	05:00 AM	06:00 AM	07:00 AM	08:00 AM	09:00 AM	10:00 AM	11:00 AM	12:00 PM	01:00 PM	02:00 PM	03:00 PM	04:00 PM	05:00 PM	06:00 PM	07:00 PM	08:00 PM	09:00 PM	10:00 PM	11:00 PM
Existing	0.2	0.1	0.1	0.1	0.2	0.6	3.5	9.7	8.6	10.6	6.4	5.5	8.0	6.9	7.7	10.9	14.2	17.9	14.1	6.7	2.8	1.6	0.6	0.4
Roundabout	0.1	0.1	0.1	0.1	0.2	0.4	2.4	10.3	6.1	6.9	3.3	3.8	6.1	4.8	5.7	8.1	13.5	19.8	13.5	2.4	2.0	1.1	0.4	0.4

Source: Dave Petrucci FHWA-RC-SDTST

EXAMPLE (DAILY DELAY COMPARISON)

- What if we just used peak hour HCM analysis?



Source: Dave Petrucci FHWA-RC-SDTST

EXAMPLE (SAFETY ANALYSIS)

- Safety performance (using HSM SPF's & CMF's)

Crash Frequency at Intersection									
Year	**NO BUILD**			**BUILD**			**Δ**		
	Total	FI	PDO	**Total**	FI	PDO	**Total**	FI	PDO
2019	10.7	1.6	9.1	**6.0**	0.3	5.7	**4.7**	1.3	3.4
2020	10.9	1.6	9.3	**6.1**	0.3	5.8	**4.8**	1.3	3.5
2021	11.1	1.7	9.4	**6.2**	0.3	5.9	**4.9**	1.4	3.5
2022	11.3	1.7	9.6	**6.3**	0.3	6.0	**5.0**	1.4	3.6
2023	11.5	1.7	9.8	**6.4**	0.3	6.1	**5.1**	1.4	3.7
2024	11.7	1.8	9.9	**6.6**	0.3	6.3	**5.1**	1.5	3.6
2025	11.9	1.8	10.1	**6.7**	0.3	6.4	**5.2**	1.5	3.7
2026	12.1	1.8	10.3	**6.8**	0.3	6.5	**5.3**	1.5	3.8
2027	12.3	1.8	10.5	**6.9**	0.3	6.6	**5.4**	1.5	3.9
2028	12.5	1.9	10.6	**7.0**	0.3	6.7	**5.5**	1.6	3.9

Source: Dave Petrucci FHWA-RC-SDTST

EXAMPLE (ECONOMIC ANALYSIS)

- Monetization of Results

		Project Year			Project Costs		7.00%	Safety	Operations
Year	Status	Years in Service	Major AADT	Minor AADT	Capital	Operating	NPV Costs	NPV Benefits	NPV Benefits
2015	Planning	-3	19670	5456	$50,000		$61,252		
2016	Design	-2	20063	5565	$150,000		$171,735		
2017	ROW	-1	20464	5676	$250,000		$267,500		
2018	Construction	0	20873	5790	$850,000	$10,000	$860,000		
2019	Maintenance	1	21290	5906		$10,000	$9,346	$292,896	$110,481
2020	Maintenance	2	21716	6024		$10,000	$8,734	$295,032	$114,791
2021	Maintenance	3	22150	6144		$10,000	$8,163	$297,037	$118,065
2022	Maintenance	4	22593	6267		$10,000	$7,629	$298,913	$120,419
2023	Maintenance	5	23045	6392		$10,000	$7,130	$300,666	$121,960
2024	Maintenance	6	23506	6520		$10,000	$6,663	$301,430	$122,783
2025	Maintenance	7	23976	6650		$10,000	$6,227	$302,957	$122,977
2026	Maintenance	8	24456	6783		$10,000	$5,820	$304,369	$122,621
2027	Maintenance	9	24945	6919		$10,000	$5,439	$305,669	$121,784
2028	Maintenance	10	25444	7057		$10,000	$5,083	$306,861	$120,532
2029	End of Life	11	25953	7198			$0		
2030	End of Life	12	26472	7342			$0		
							$1,430,723	$3,005,829	$1,196,414
Source: Dave Petrucci FHWA-RC-SDTST								2.94	BCR

NCHRP Report 948 – Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges

Applying the '20 Flag' Assessment Method from NCHRP 07-25

Bastian Schroeder
Senior Principal, Kittelson

AASHTO TCGD
November 10,2021

KITTELSON & ASSOCIATES

Guiding Principles

1

Integrate Multimodal Facilities in the Design Process, as opposed to '*accommodating*' pedestrians and bicyclists at later stages

2

Allow **comparison** of alternative intersections and interchanges (A.I.I.) with 'conventional' designs

3

Focus on **design elements** of the intersection, rather than intersection form

4

Follow a **performance-based** design process

Design Flag Assessment Method – 20 Questions for Pedestrian and Bicyclist Safety

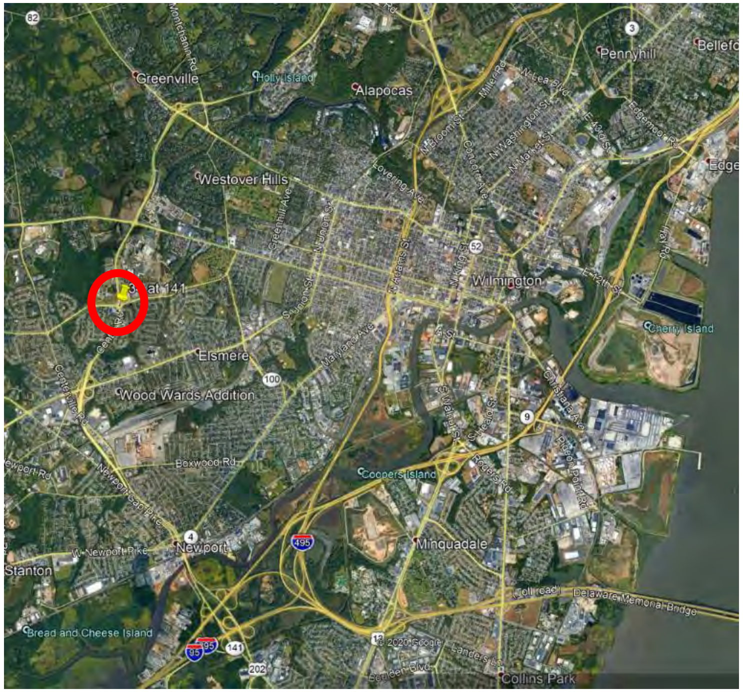
Motor Vehicle Right Turns	Uncomfortable/ Tight Walking Environment	Nonintuitive Motor Vehicle Movements	Crossing Yield- or Uncontrolled Vehicle Paths
Indirect Paths	Executing Unusual Movements	Multilane Crossings	Long Red Times
Undefined Crossing at Intersections	Motor Vehicle Left Turns	Intersecting Driveways and Side Streets	Sight Distance for Gap Acceptance Movements
Grade Change	Riding in Mixed Traffic	Bicycle Clearance Times	Lane Change Across Motor Vehicle Lane(s)
Channelized Lanes	Turning Motorists Crossing Bicycle Paths	Riding Between Travel Lanes, Lane Additions, or Lane Merges	Off-tracking Trucks in Multilane Curves

Yellow vs. Red Flags

Yellow Flags, for design elements negatively affecting user comfort (in other words, increasing user stress) or the quality of the walking or cycling experience.

Red Flags, for design elements that are directly related to a safety concern for pedestrians or bicyclists.

Case Study Application:
Faulkland Rd (34) at Centre Rd. (141), Wilmington, DE



KITTELSON & ASSOCIATES

Results: Existing Conditions

- **Motor Vehicle Right Turns**
- Tight Walking Environment
- **Crossing Yield Control Path**
- **Multilane Crossing**
- Long Red Times
- **Intersecting Driveways**
- **Sight Distance**
- **Riding in Mixed Traffic**
- **Bicycle Clearance Times**
- **Lane Change Across Vehicle Lanes**
- **Channelized Lanes**
- Motorist Crossing Bike Path
- Riding Between Travel Lanes

Results: Existing Conditions

- **Motor Vehicle Right Turns**
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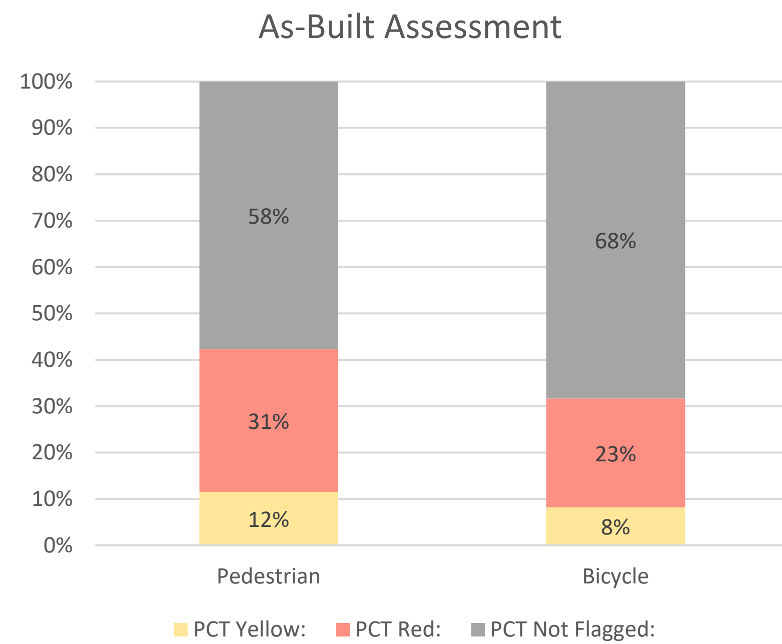

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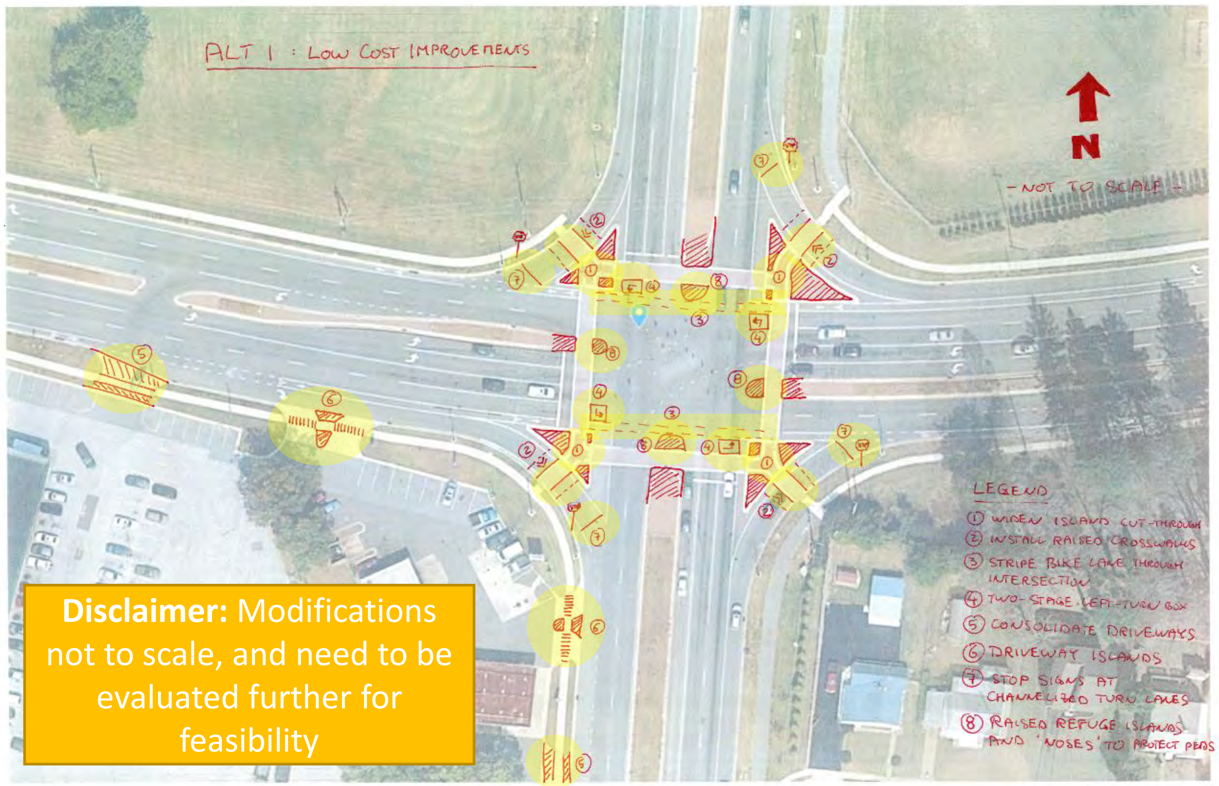
Assessment: Alt. 1 – Low Cost Strategies



Disclaimer: Modifications not to scale, and need to be evaluated further for feasibility

1. Widen Island Cut-Throughs
2. Install Raised Crosswalks
3. Stripe Bike-Lane Through Intersection
4. Add Two-Stage Left-Turns
5. Consolidate Driveways
6. Build Driveway Islands
7. Install Stop Signs at Channelized Turn Lane Exits
8. Raised Refuge Islands and 'noses' to protect pedestrians

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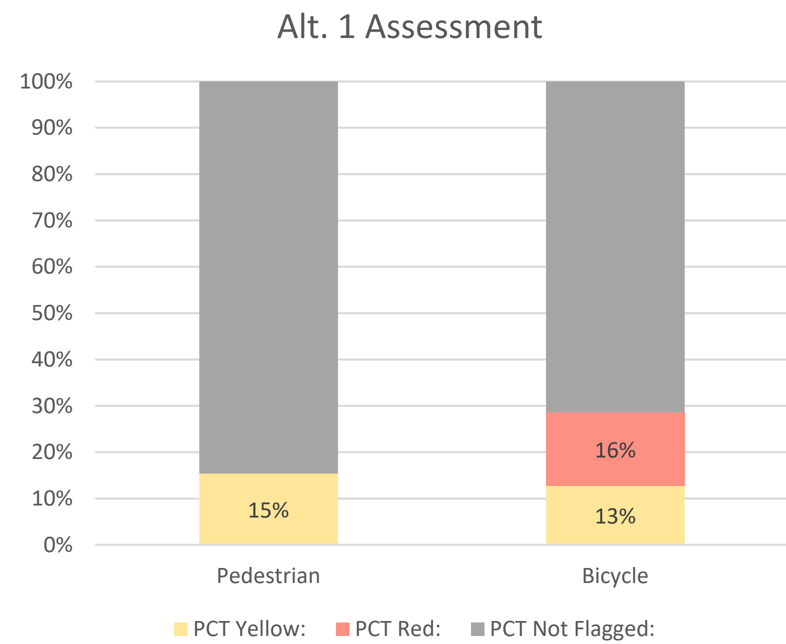
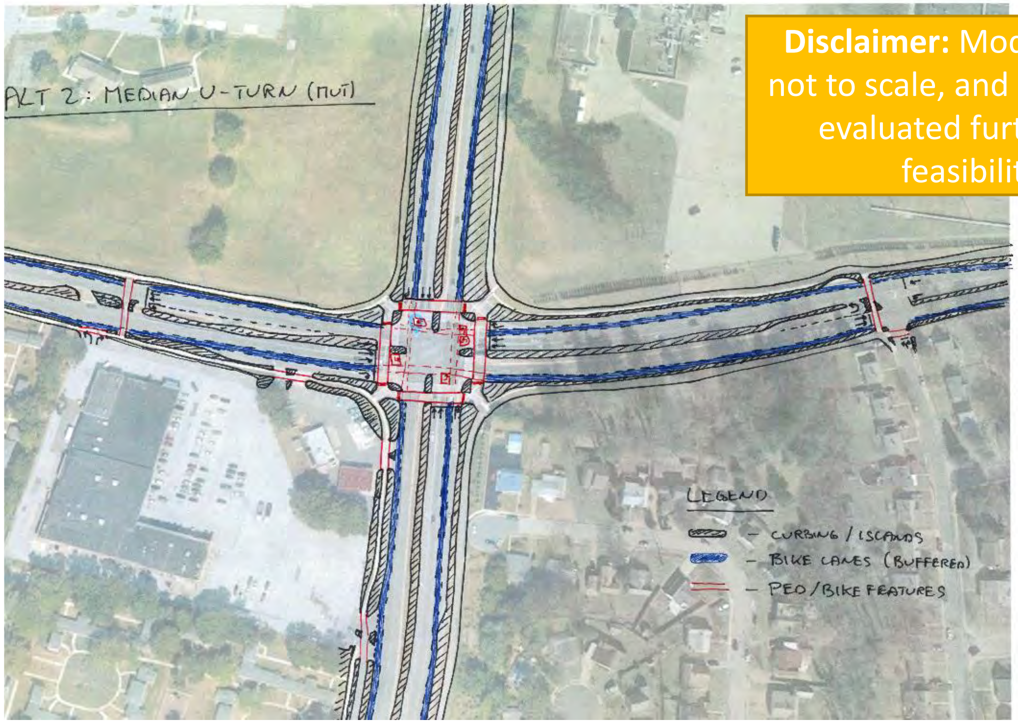
Results: Alt. 1 – Low Cost Strategies

- ~~Motor Vehicle Right Turns~~
- ~~Tight Walking Environment~~
- **Crossing Yield Control Path**
- Multilane Crossing*
- Long Red Times
- Intersecting Driveways*
- ~~Sight Distance~~
- **Riding in Mixed Traffic**
- **Bicycle Clearance Times**
- ~~Lane Change Across Vehicle Lanes~~
- **Channelized Lanes***
- Motorist Crossing Bike Path
- Riding Between Travel Lanes

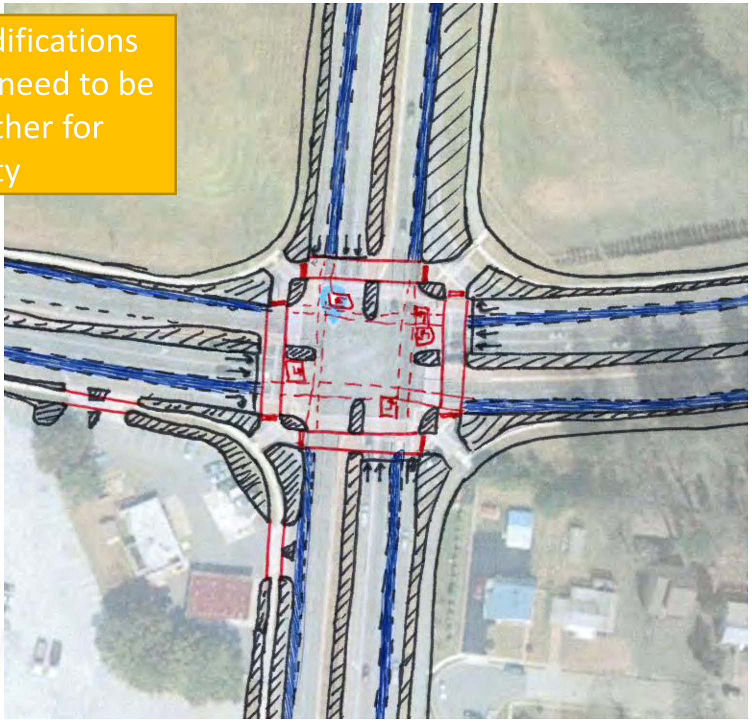
*Mitigated but not eliminated



Assessment: Alt. 2 – Median U-Turn (MUT)



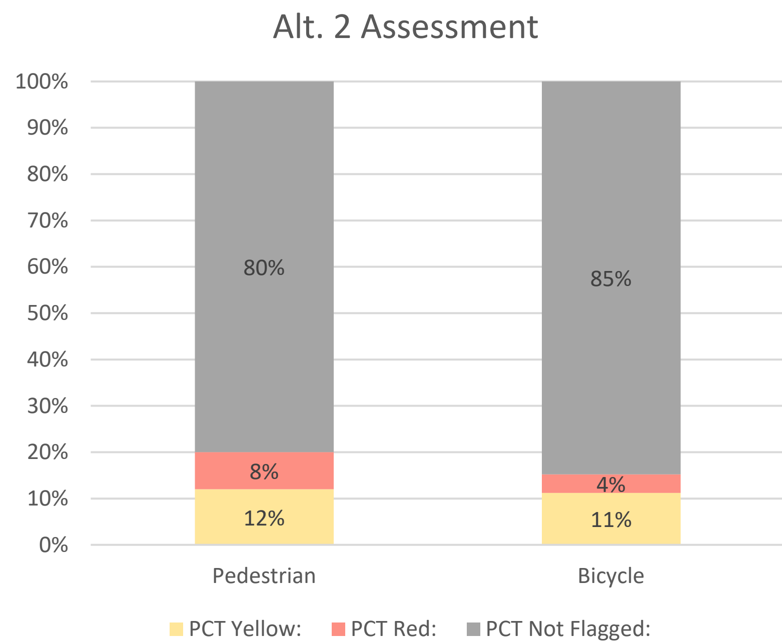
Disclaimer: Modifications not to scale, and need to be evaluated further for feasibility



Results: Alt. 2 – Median U-Turn (MUT)

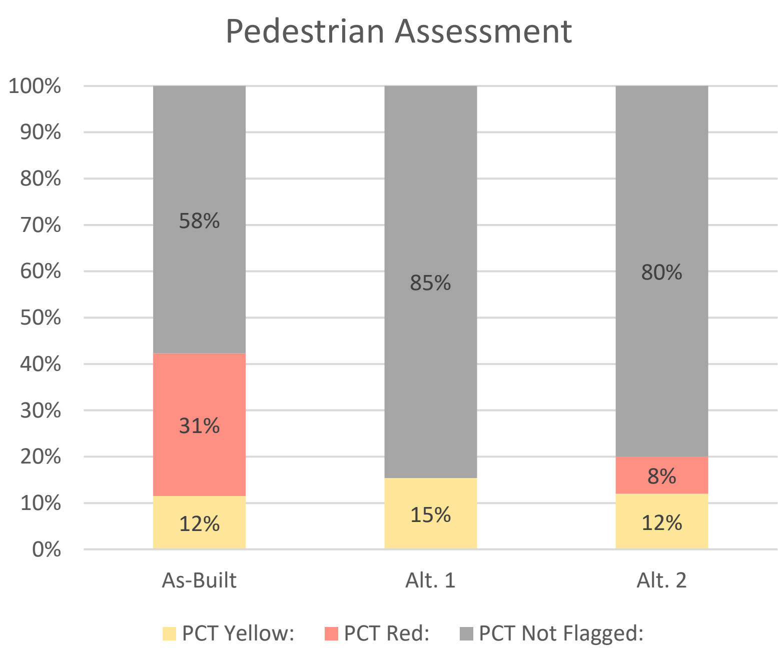
- **Motor Vehicle Right Turns**
- ~~Tight Walking Environment~~
- ~~Crossing Yield Control Path~~
- Multilane Crossing*
- **Long Red Times***
- Intersecting Driveways*
- ~~Sight Distance~~
- ~~Riding in Mixed Traffic~~
- ~~Bicycle Clearance Times~~
- ~~Lane Change Across Vehicle Lanes~~
- ~~Channelized Lanes~~
- Motorist Crossing Bike Path
- Riding Between Travel Lanes

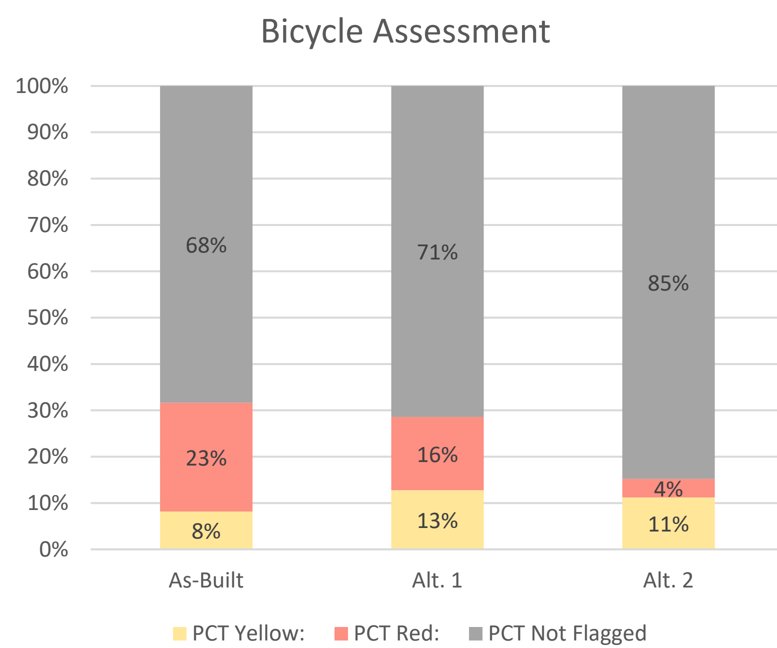
*Mitigated but not eliminated



KITTELSON & ASSOCIATES

Results


Pedestrian Assessment
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
58%
31%
12%
85%
15%
80%
8%
12%
As-Built
Alt. 1
Alt. 2
PCT Yellow:
PCT Red:
PCT Not Flagged:


Bicycle Assessment
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
68%
23%
8%
71%
16%
13%
85%
4%
11%
As-Built
Alt. 1
Alt. 2
PCT Yellow:
PCT Red:
PCT Not Flagged