PEDESTRIAN & BICYCLIST SAFETY COUNTERMEASURES FOR FIRST/LAST MILE

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DEPARTMENT OF TRANSPORTATION
UNITED STATES OF AMERICA

TRAFFIC OPERATIONS

Caltrans

FEHR & PEERS

PRESENTATION OUTLINE

SECTION 1: General Considerations for First/Last Mile Transit Accessibility

SECTION 2: Pedestrian Facilities

SECTION 3: Bicycle Facilities

SECTION 4: Uncontrolled Crossings

SECTION 5: Bike/Ped Accommodations at Intersections

SECTION 6: Transit Facilities

SECTION 7: Bus/Bike Interface

SECTION 8: Bike/Ped Accommodations at Interchanges

SECTION 9: Questions and Sources for Guidance

GENERAL CONSIDERATIONS FOR FIRST/LAST MILE TRANSIT ACCESSIBILITY

Section 1

THE GOAL OF TRANSIT

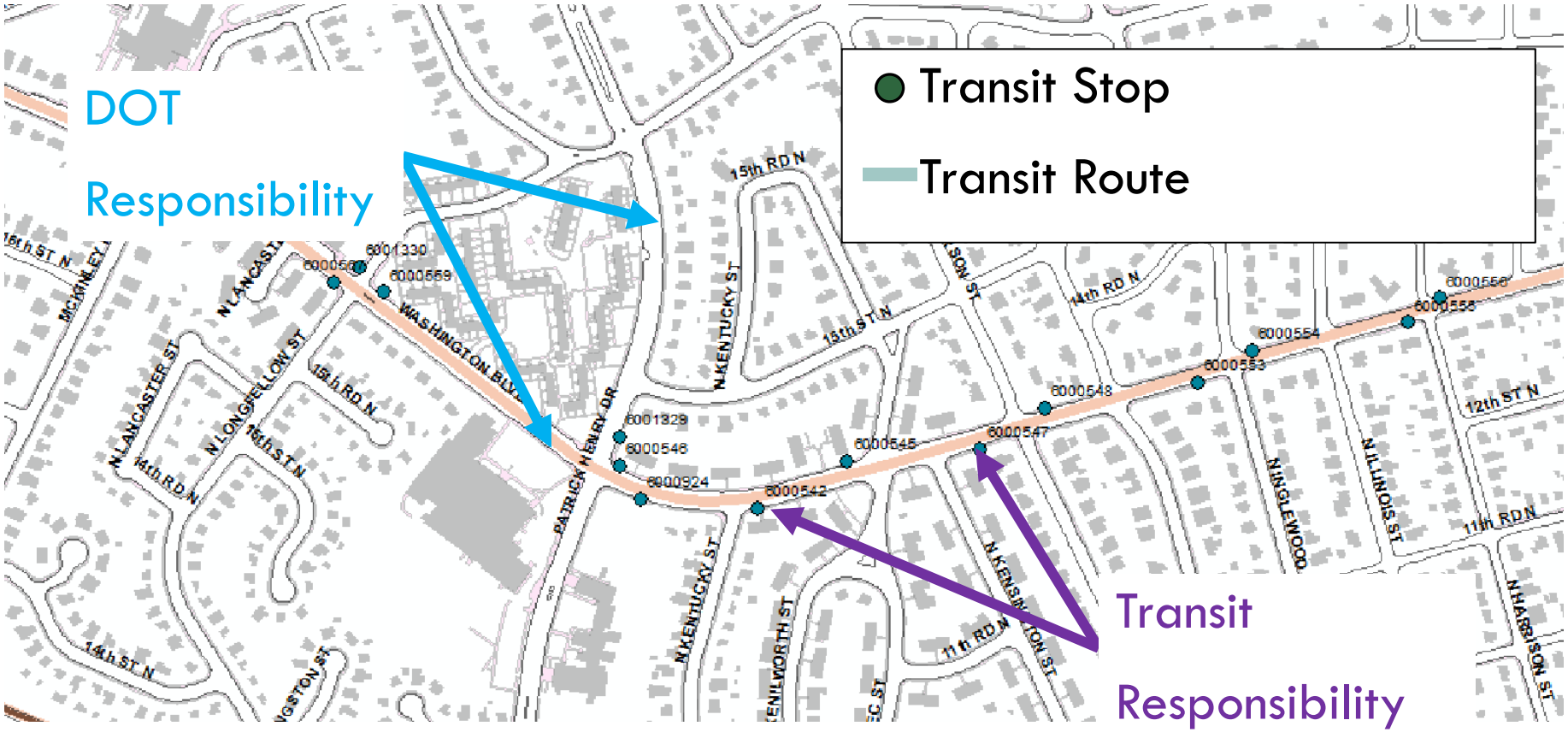
The primary goal of transit is to carry passengers between residences, employment, and other destinations in a safe, efficient, and reliable manner

The physical safety of ALL passengers is vital to the success of any transit system- not only to retain riders, but to encourage new riders

. . . THERE ARE NUMEROUS COMPETING NEEDS

- Increases in ridership
- Crashes
- Amenities
- Conditions
- Vehicle needs
- Stop characteristics
- Capacity
- Security concerns
- Real time information
- Customer information
- Roadwork/Construction
- Transit plans
- Enforcement
- Private development
- Driver needs
- Special needs
- Funding

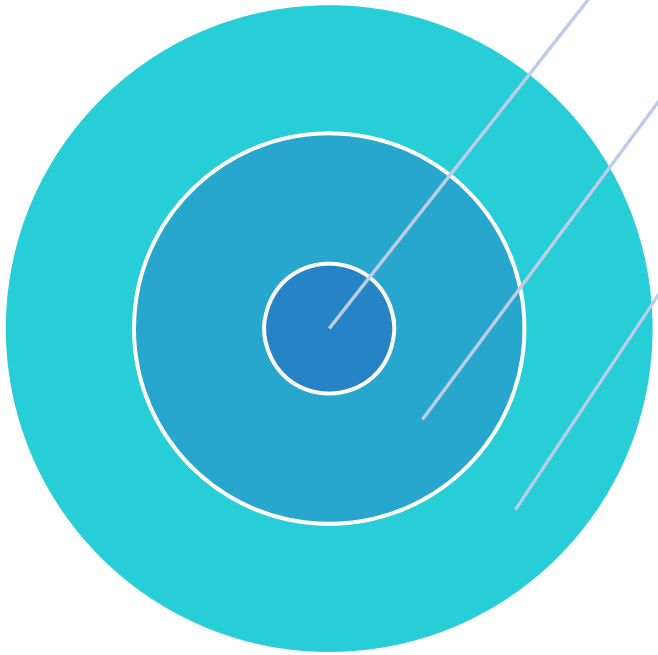
AGENCY CONSIDERATIONS: TRANSIT VS. DOT RESPONSIBILITY



HIGH-USE LOCATIONS
KEY GENERATORS & TRANSFERS

ACCESS TO TRANSIT

Access to transit exists on multiple levels:

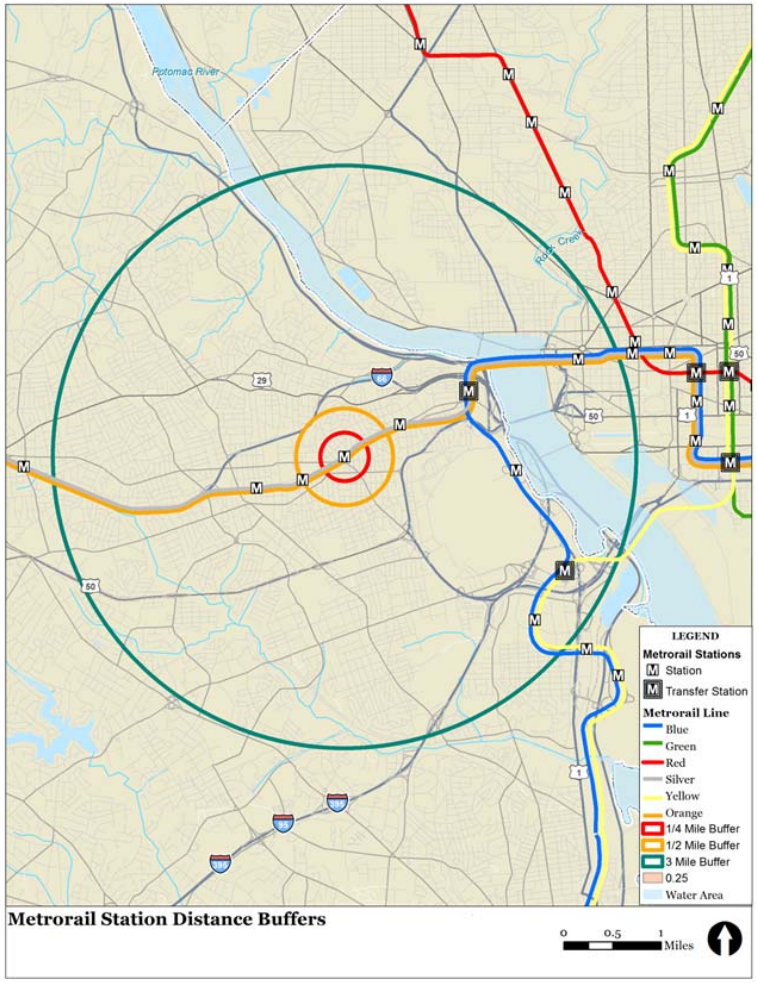


Access at transit stop

Access to transit stop

Connections to transit routes

CATCHMENT AREA



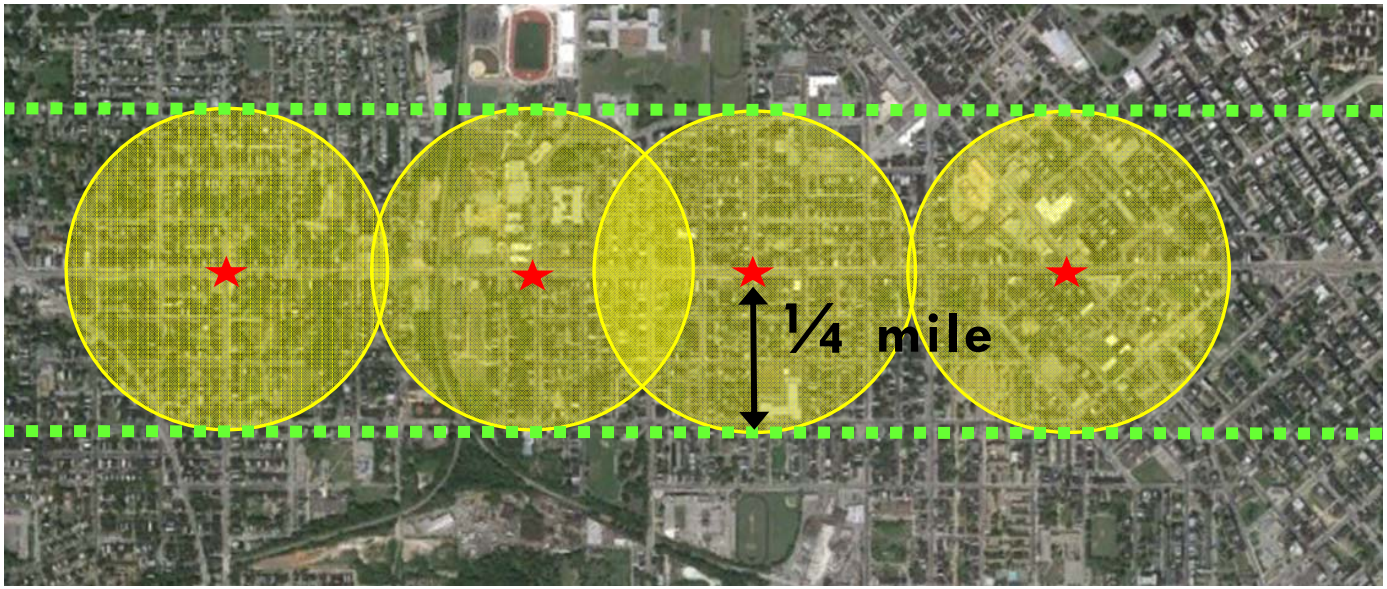
The catchment area is defined as the area served by transit

Transit access considers elements within catchment area

In general, people are willing to:

- Walk up to ¼ Mile to access Local Bus transit
- Walk up to ½ Mile to access BRT or Rail transit
- Bike between 1-3 Miles to access Rail transit
- Drive 15 miles

CATCHMENT AREA



- Bus Stop
- Bus Stop Catchment Area
- Corridor Catchment Area

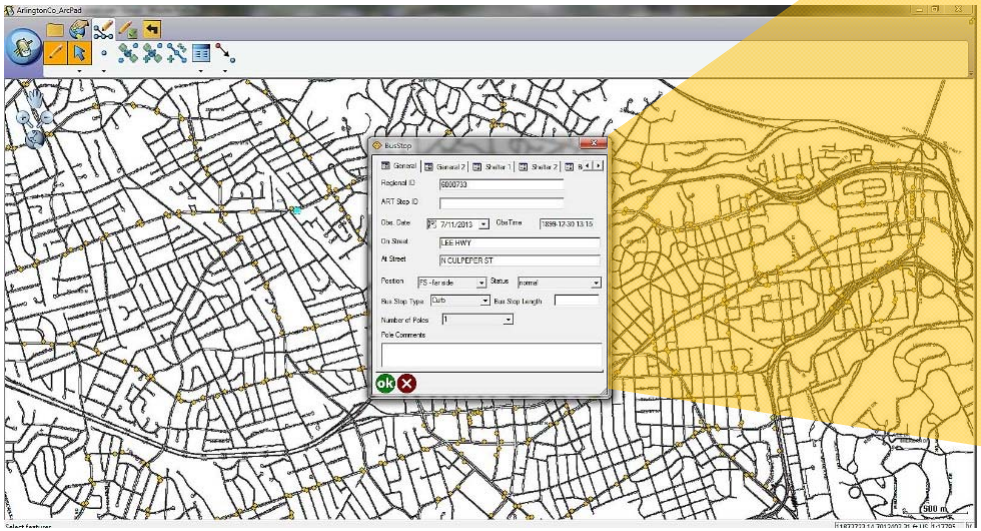
INFRASTRUCTURE NEEDS: TRANSIT STOP INVENTORY

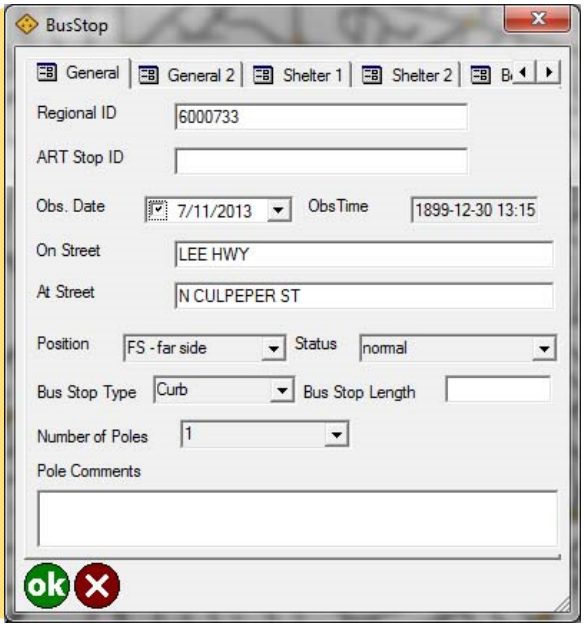
Tool to identify needs at transit stops and transit corridors

Immediate transit stop characteristics inventoried and evaluated

Includes surrounding ped/bike connections

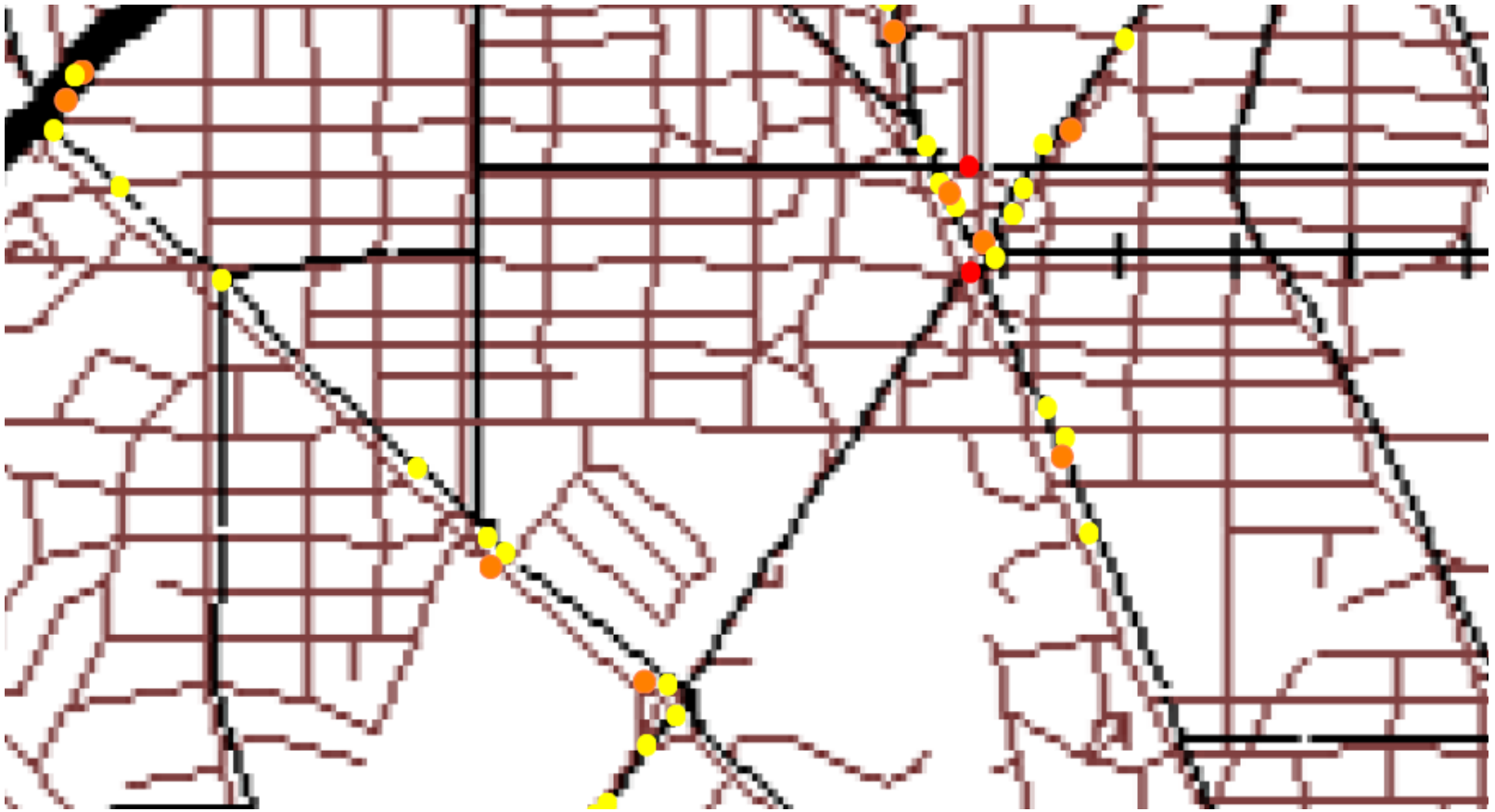
Ped/bike facilities at the stop





INFRASTRUCTURE NEEDS: ADA COMPLIANCE

PEDESTRIAN CRASHES



COMBINE ALL ELEMENTS

- Transit ridership
- Transit stop inventory (ADA compliance and other design elements)
- Crashes

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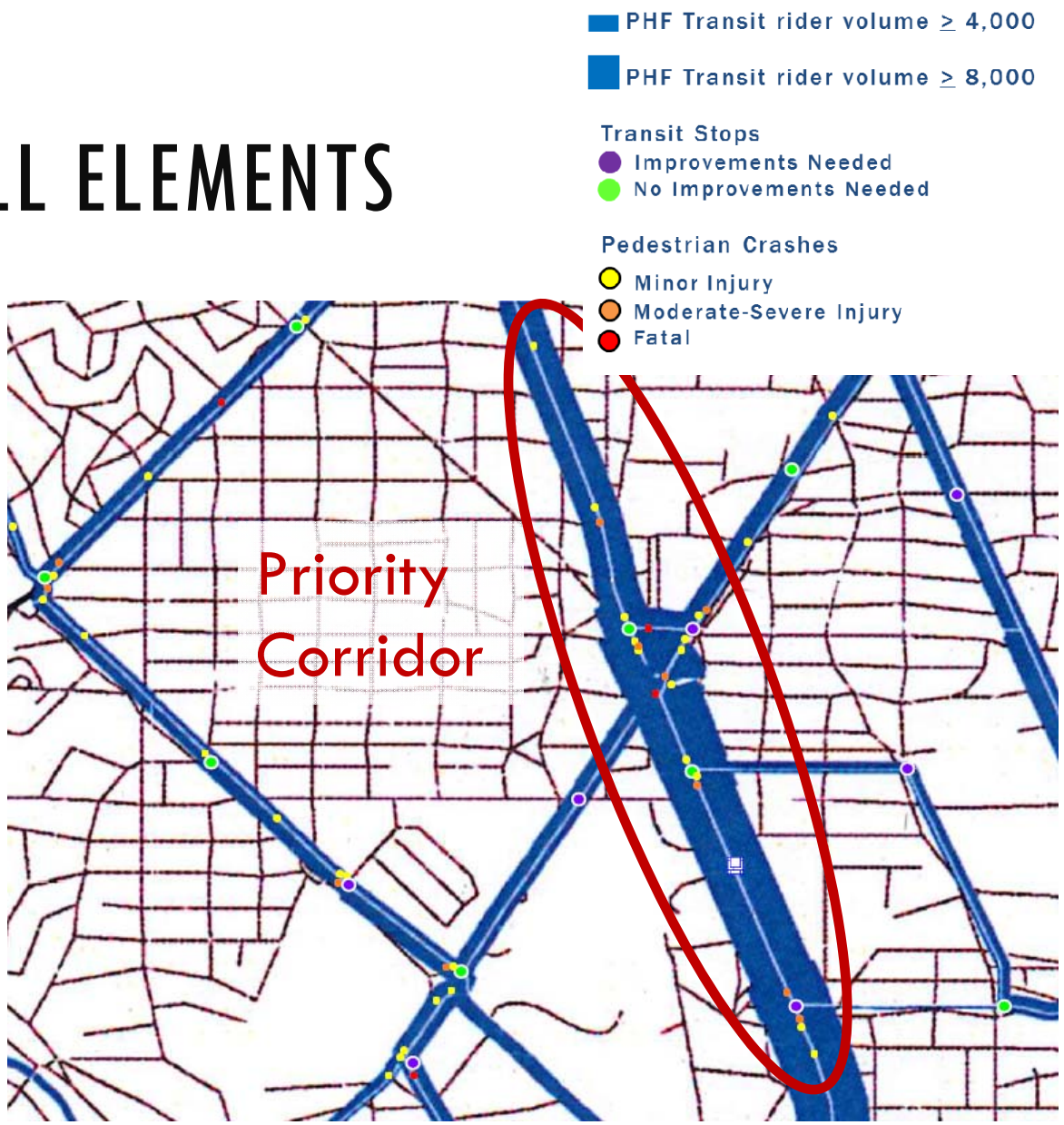

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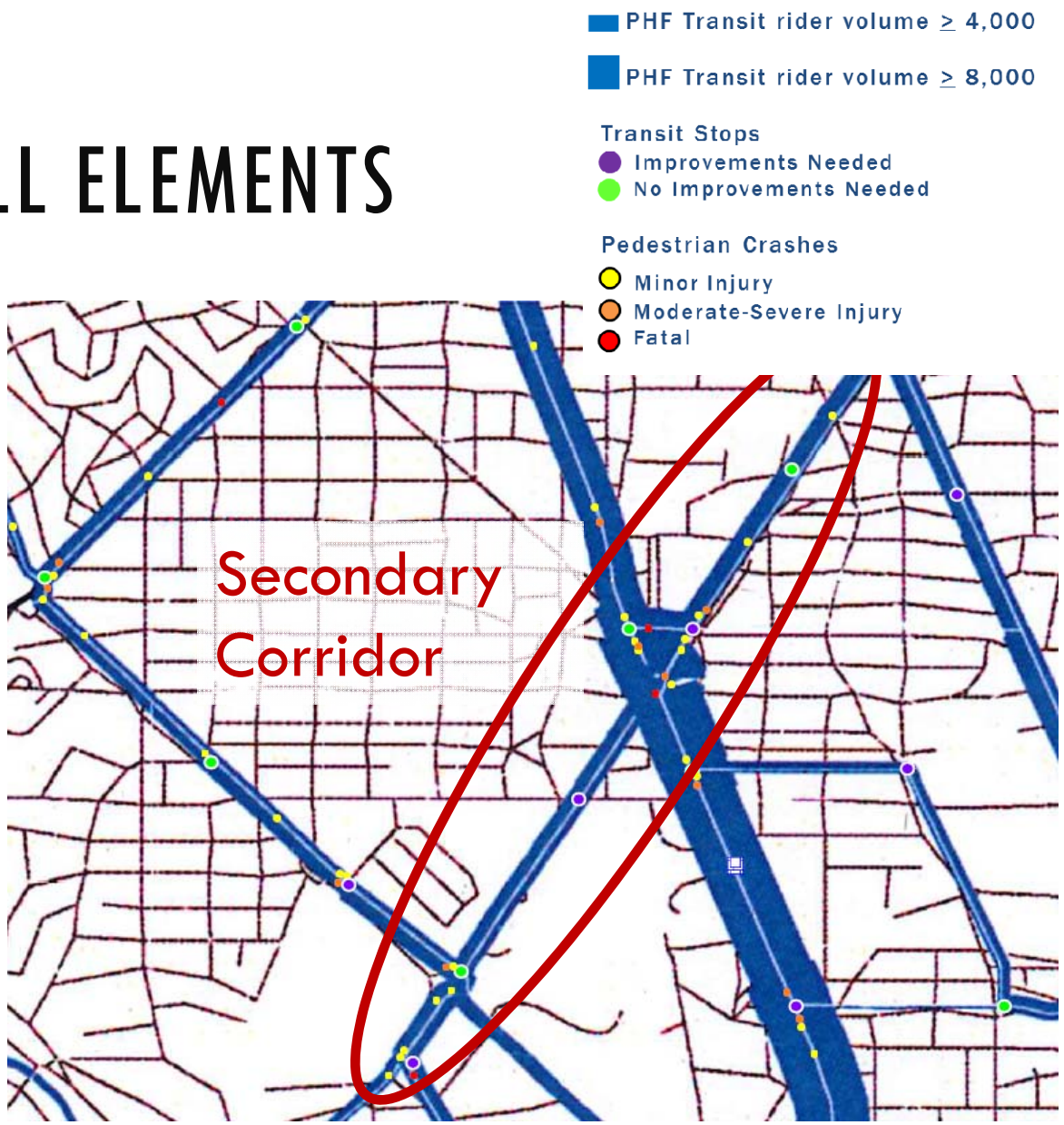

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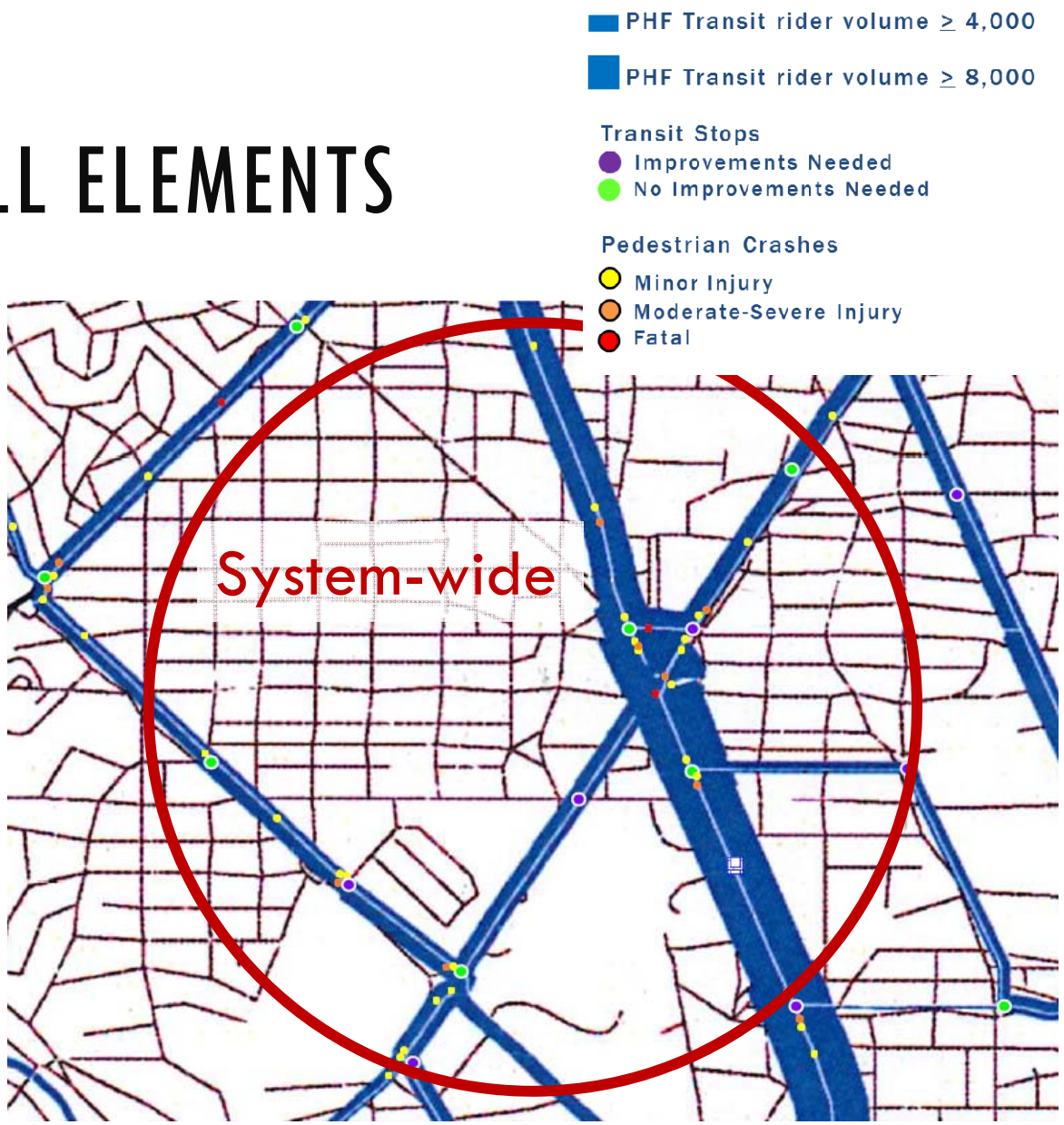
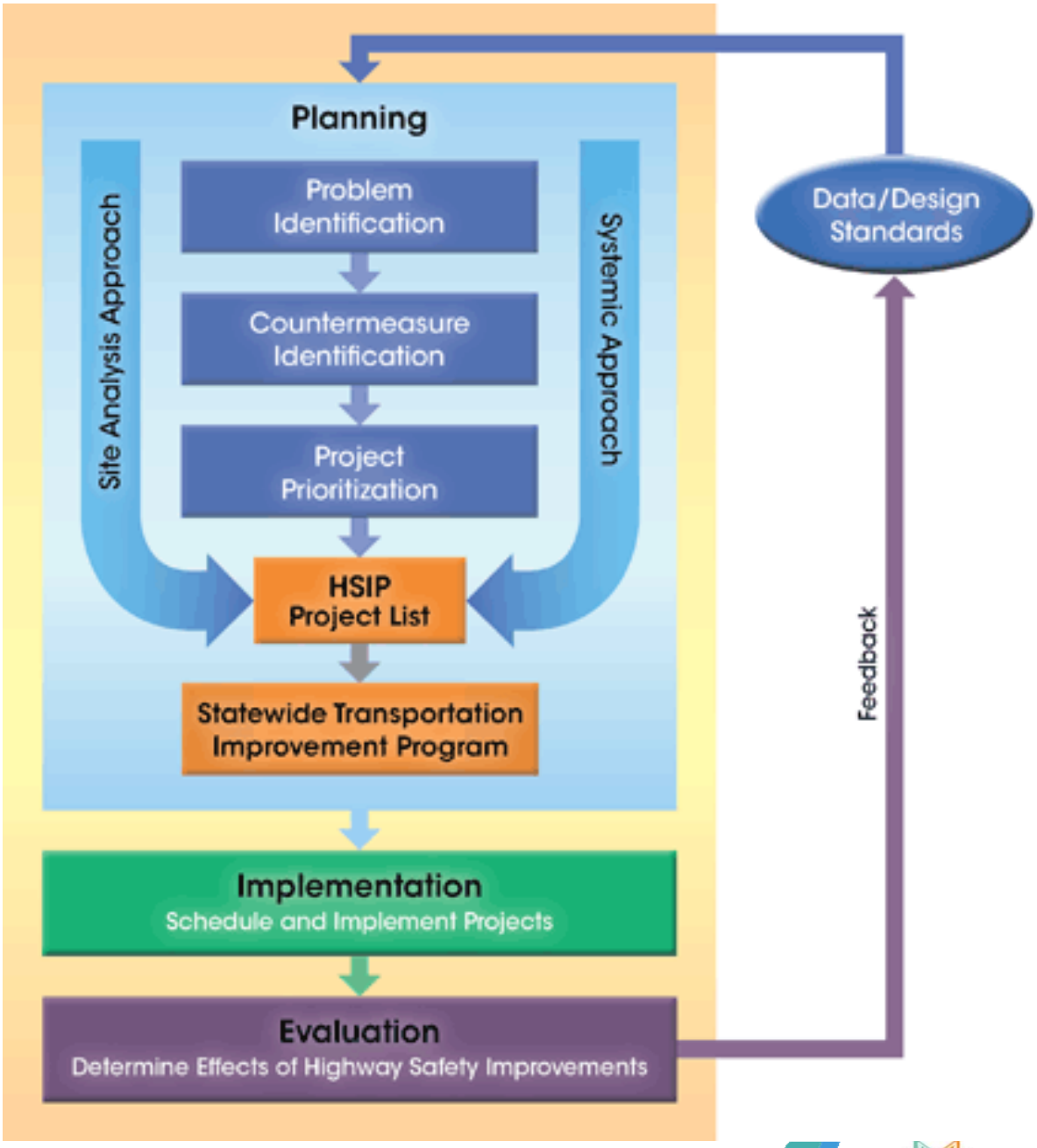


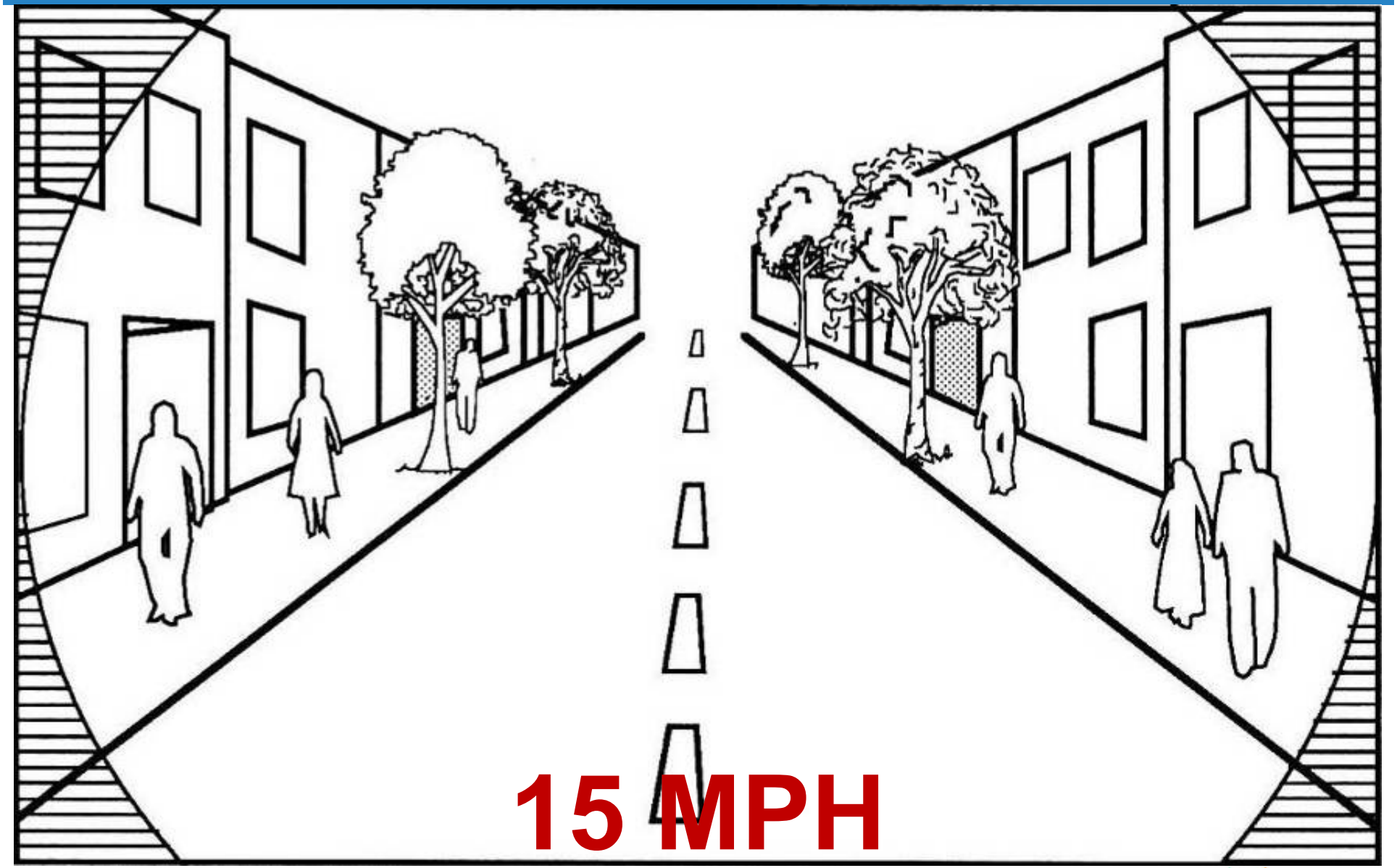
SAFETY ANALYSIS



KEY SAFETY FACTORS

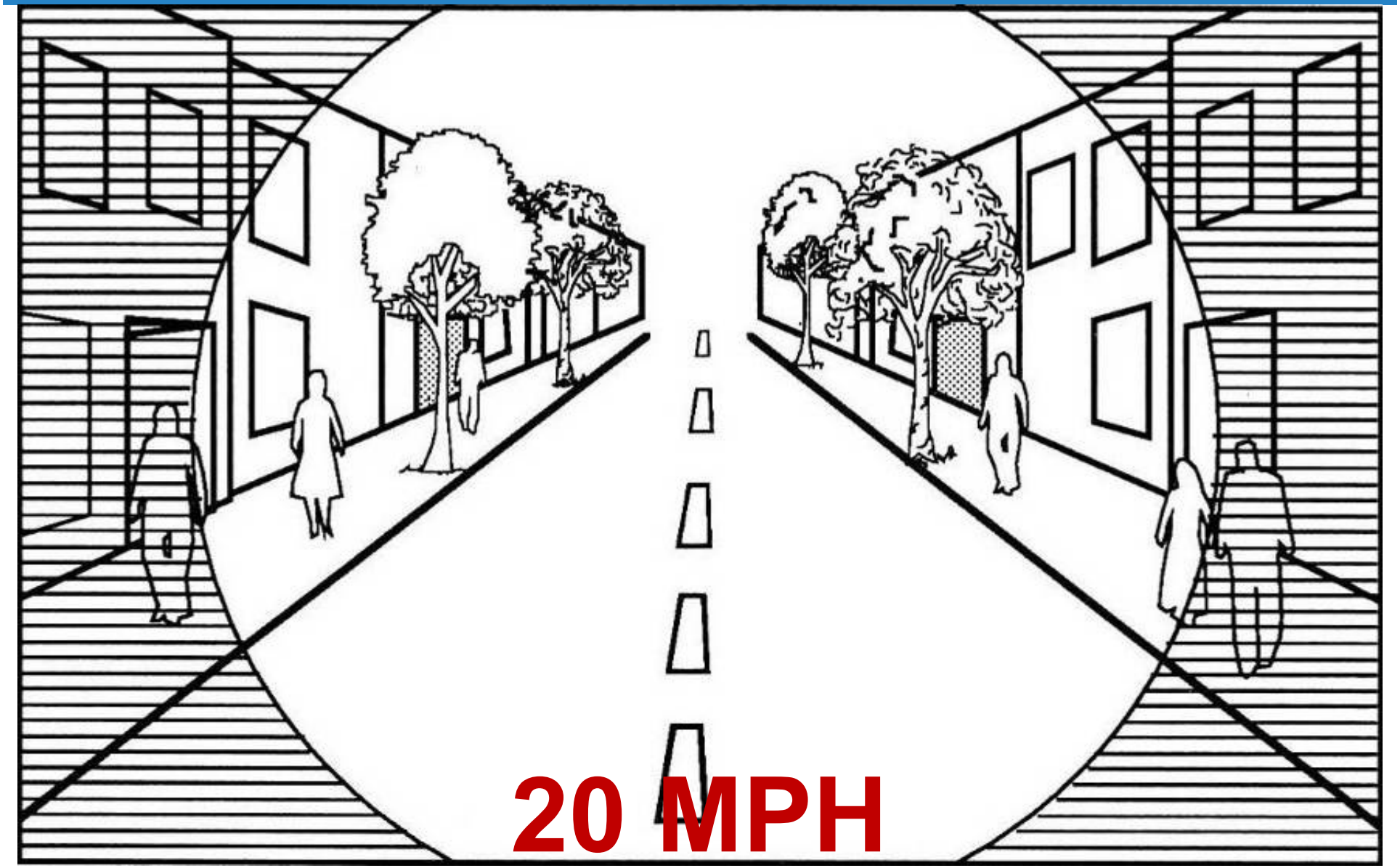
- Speed
- Number of lanes
- Visibility
- Traffic volume & composition
- Conflict points
- Proximity
- Connectivity

SPEED MATTERS



Source: FHWA

SPEED MATTERS



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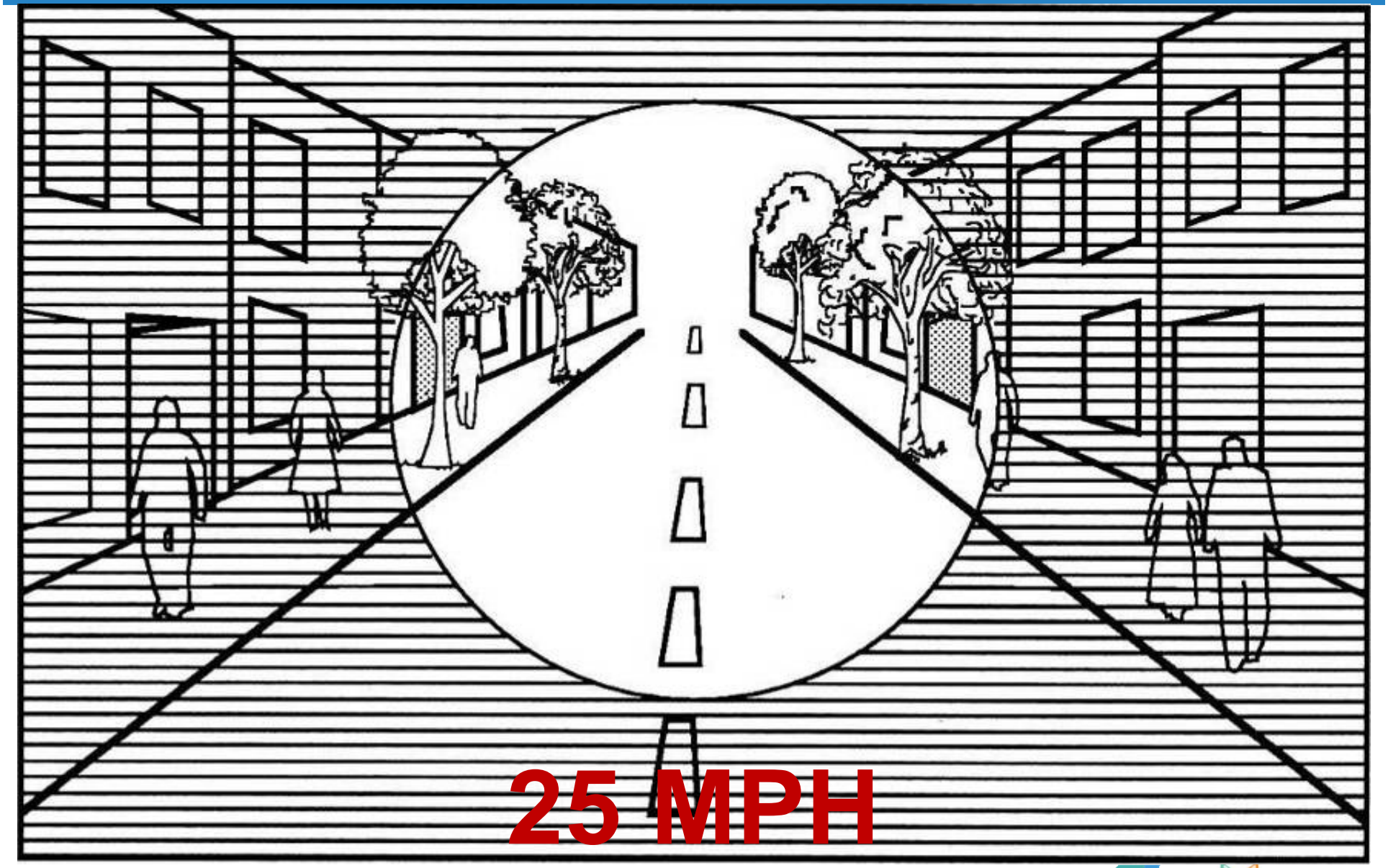

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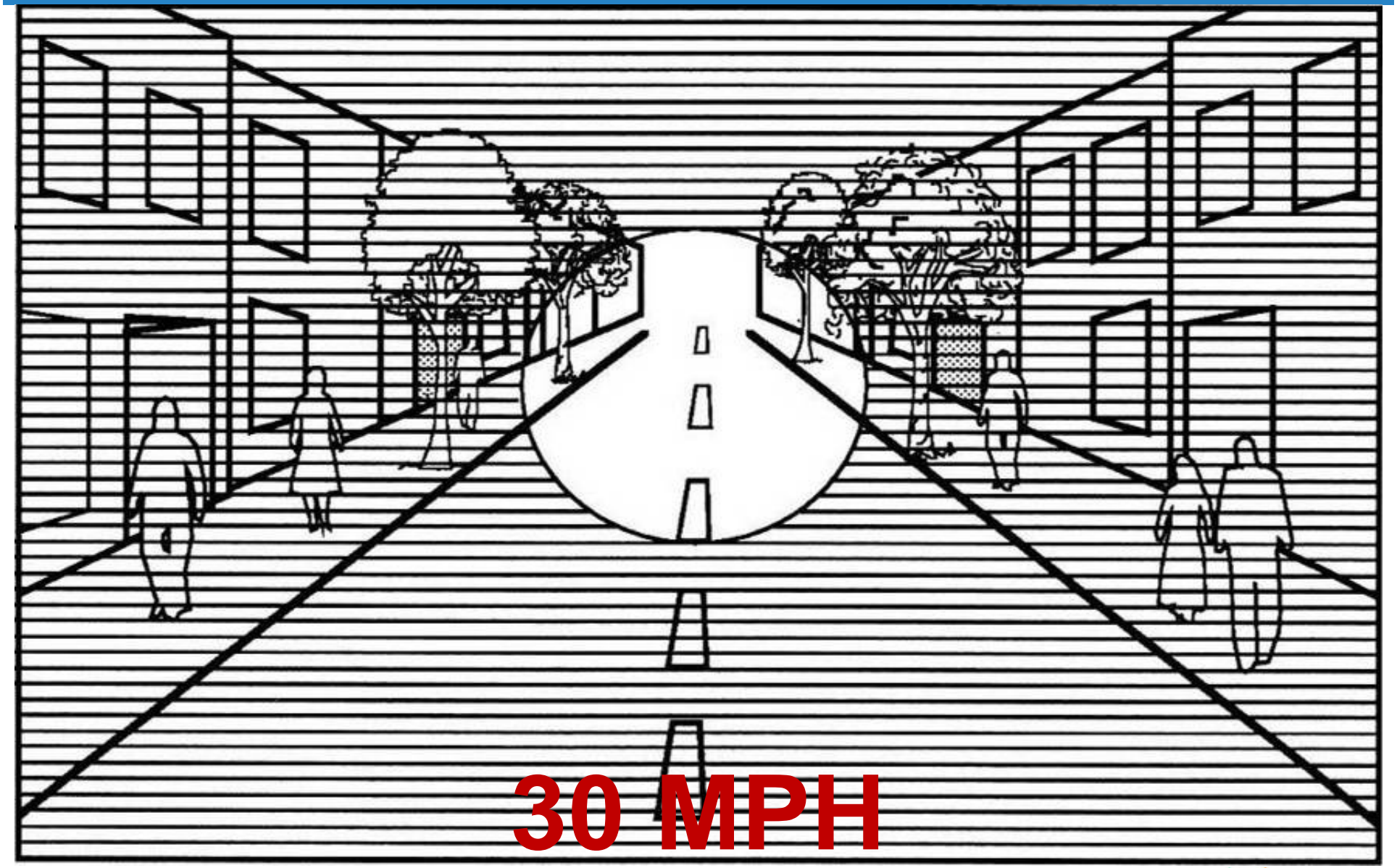


Source: FHWA

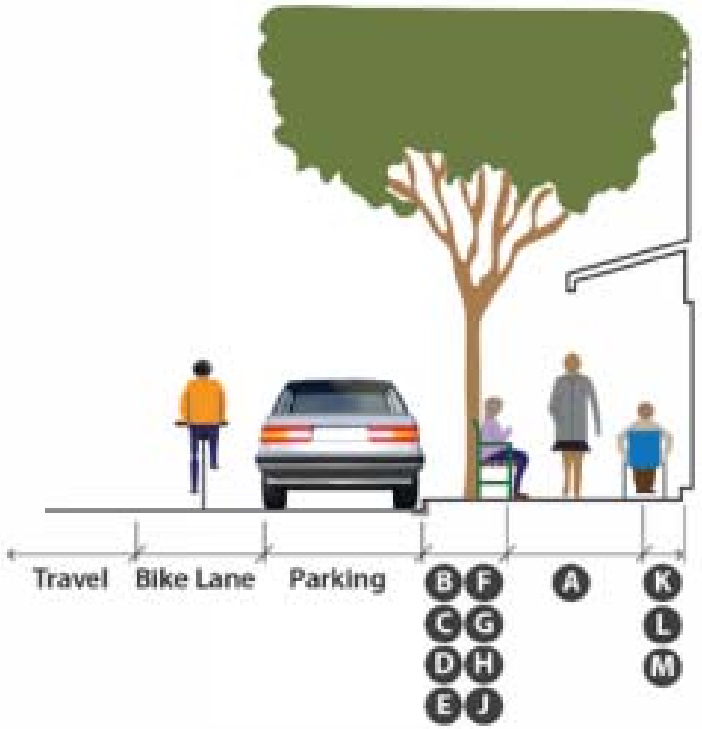
PEDESTRIAN FACILITIES: SIDEWALKS AND ADA

Section 2

SIDEWALKS AND CURBSIDES

Source: NACTO

SIDEWALK ZONE SYSTEM



		Range (feet)
A	Minimum Pedestrian Clear Area	4'-0"
	Clearance from Face of Curb (pick the largest)	
B	Parallel Parking (Car Door Clearance)	1'-6" to 2'-0"
C	Curbside Bus Stop	2'-0"
D	Light Poles	2'-6" to 3'-6"
E	Street Furniture Zone	3'-0" to 5'-6"
F	Traffic Signal Poles and Boxes	3'-0" to 4'-0"
G	Planter Box	3'-0" to 4'-6"
H	Bus Bench	3'-0" to 5'-0"
J	Bus Shelter	5'-0" to 8'-0"
	Clearance from Back of Sidewalk (pick the largest)	
K	Pedestrian Clearance from Building (zero setback)	1'-6"
L	Window Shopping Zone	3'-0"
M	Street Furniture Zone	3'-0" to 5'-6"

ADA CONSIDERATIONS

ADA addresses the needs of people with a variety of disabilities

Some disabilities are obvious

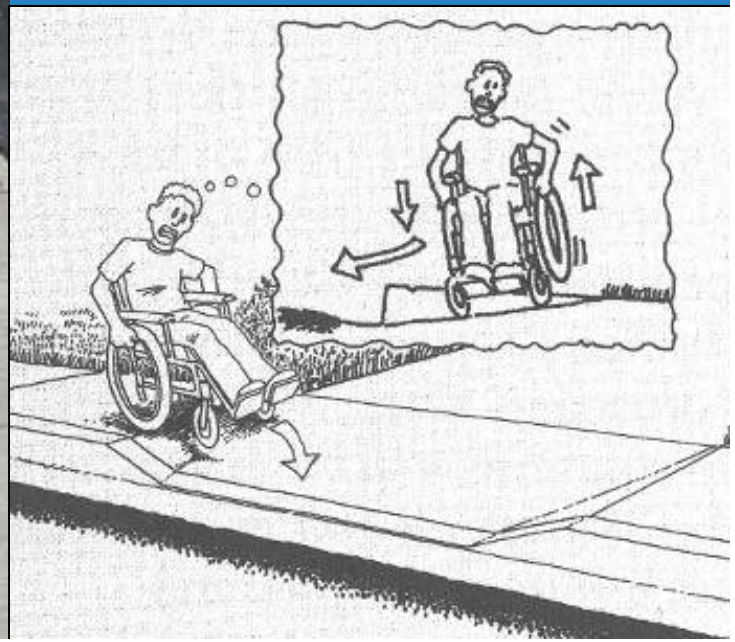
ADA CONSIDERATIONS

ADA addresses the needs of people with a variety of disabilities

*Some disabilities are **less** obvious*

MOST CRITICAL ENVIRONMENT WITH EXCESSIVE CROSS SLOPE:

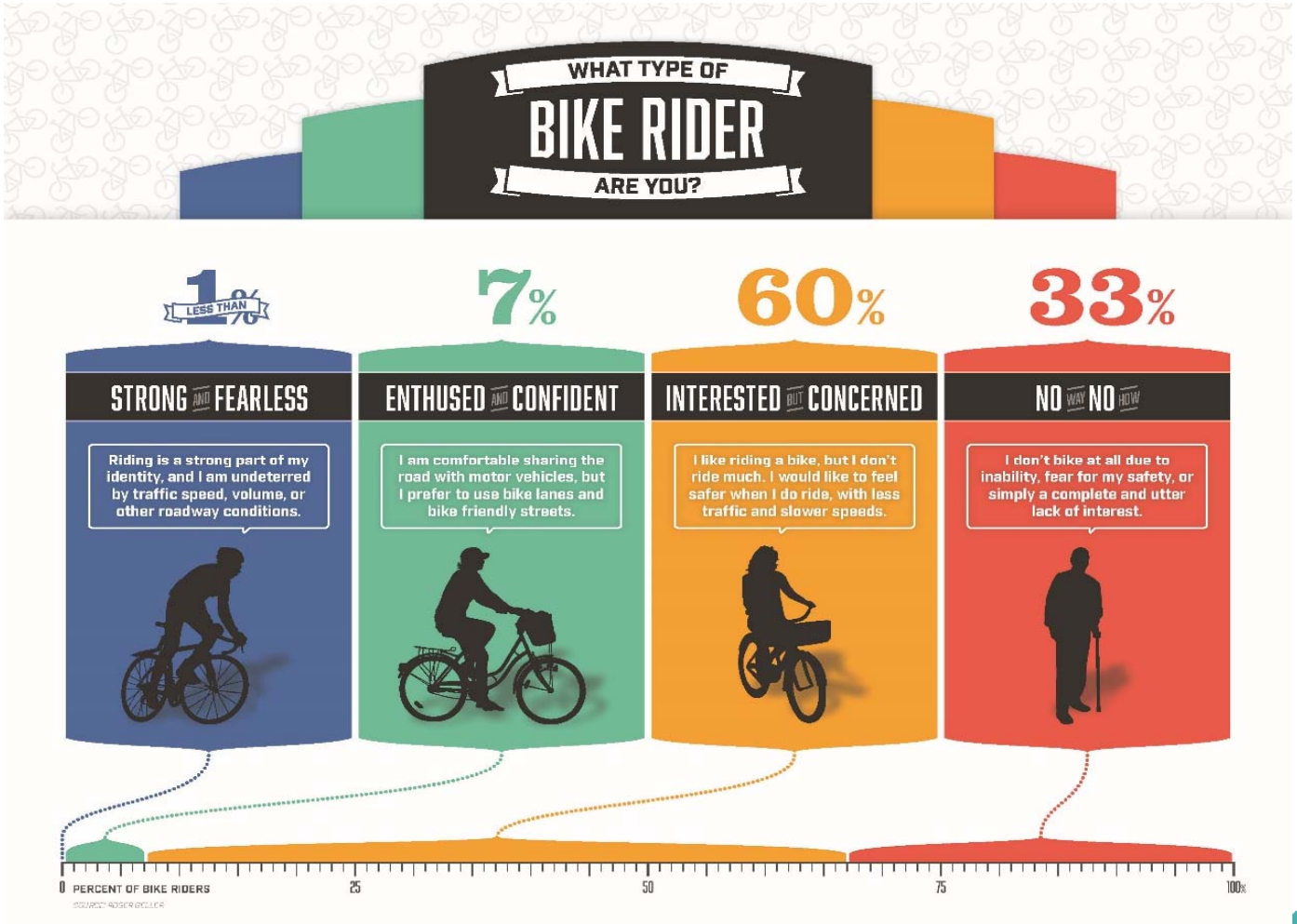
DRIVEWAYS



BICYCLE FACILITIES: CORRIDOR TREATMENTS

Section 3

TYPES OF BICYCLISTS



LEVEL OF TRAFFIC STRESS

BICYCLE INFRASTRUCTURE

Why build bicycle infrastructure?

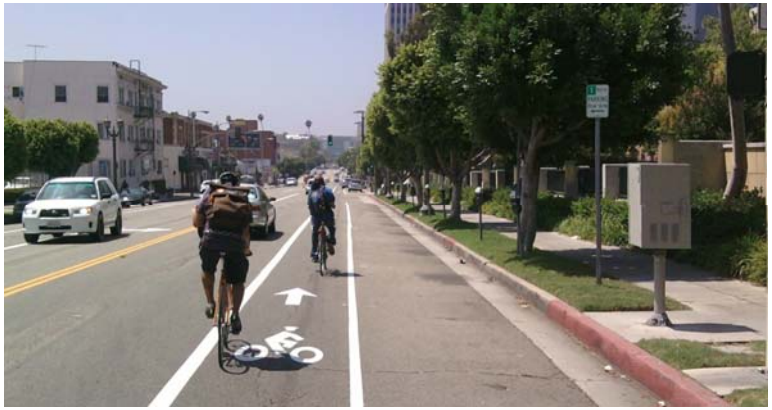
- Safety
- Comfort
- Access and network connections
- Link to other investments to provide choices
- Build infrastructure that people want to use

CicLAvia – 12/20/2014
Source: Fehr & Peers

BICYCLE INFRASTRUCTURE

Class I: Bike Path

Class II: Bike Lane



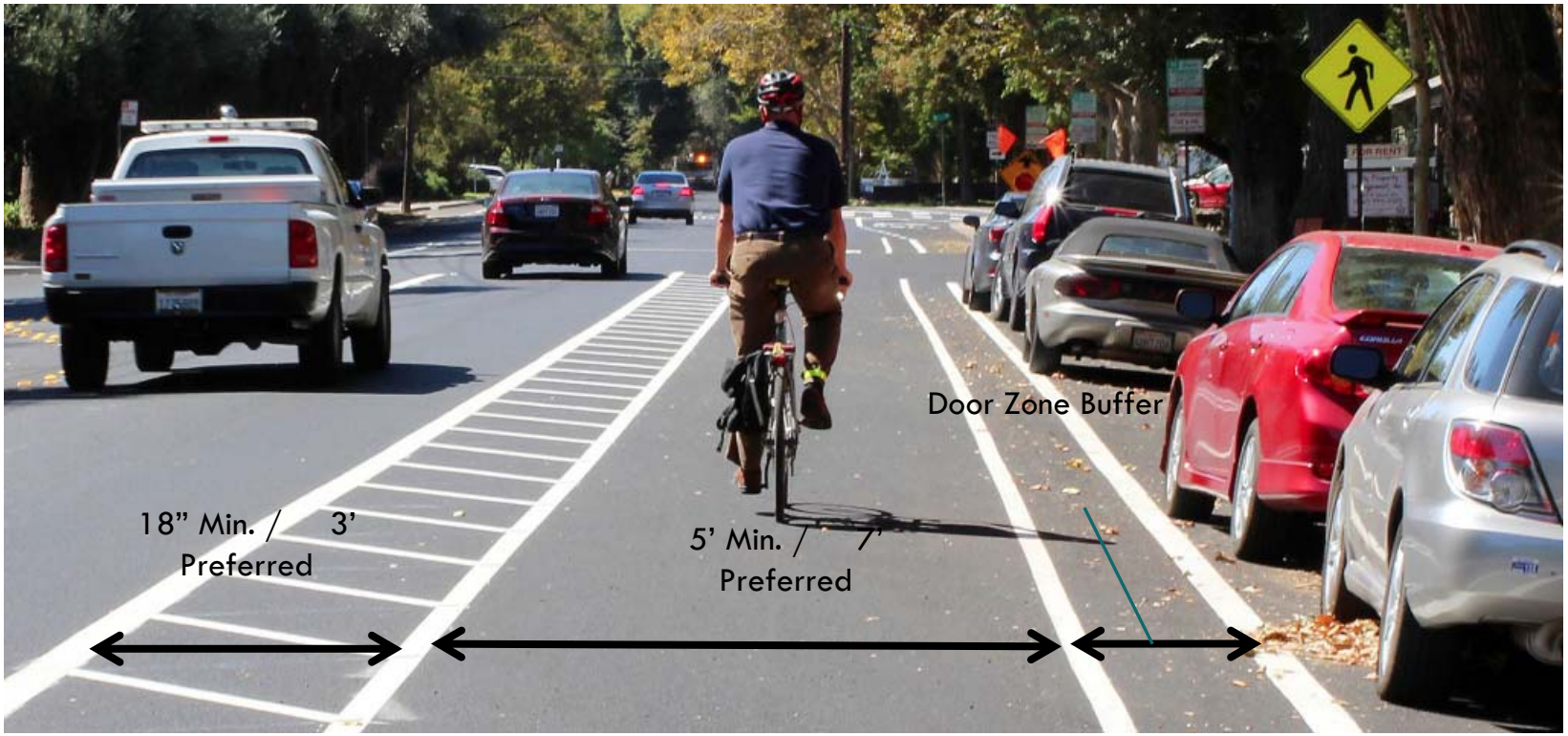
Class III: Bike Route

Class IV: Separated Bike Lane

Sources: Fehr & Peers, Metro & LA EcoVillage

BUFFERED BIKE LANES (CLASS II)

- Higher travel speeds
- More truck traffic
- Extra lanes or lane width
- Transit stop conflicts



GREEN COLORED BIKE LANES (CLASS II)

- Approved for use in CA based on FHWA Interim Approval (CA MUTCD IA-14)
- Guidance in FHWA Interim Approval Memo
- Caltrans example at Alpine Rd/I-280 (District 4)

Downtown Los Angeles
Source: Metro

BICYCLE INFRASTRUCTURE

Conflict Area Markings

Source: Fehr & Peers

Source: NACTO

BIKE BOULEVARDS (CLASS III)

Collection of treatments

- Wayfinding
- Traffic calming
- Volume management
- Crossing treatments
- Green infrastructure
- Traffic control adjustments
- Route planning

Source: DavidBaker+Partners.com

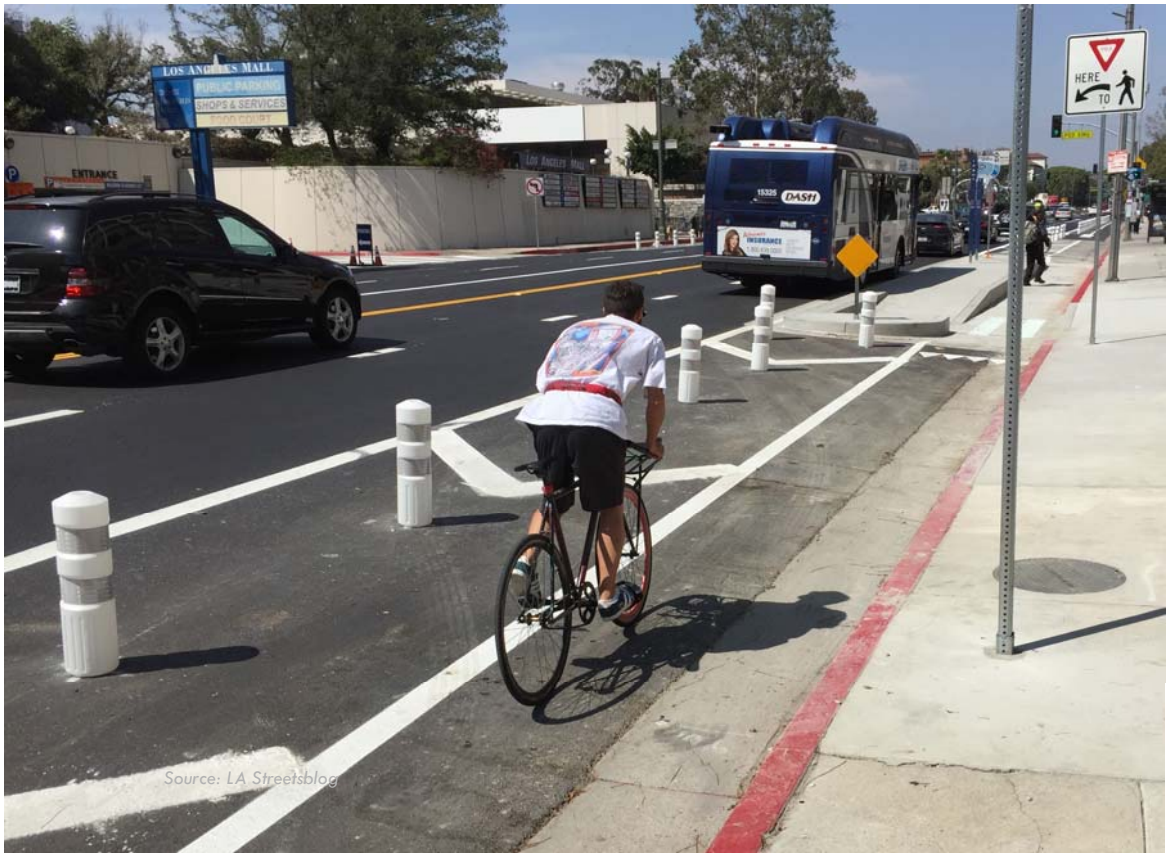
CLASS IV: SEPARATED BIKE LANES/ CYCLE TRACKS

On-street facilities that provide physical protection from moving traffic

Comprised of buffer space and bike lane

Protection is provided through:

- Tubular markers
- Movable planters
- Raised curb
- Floating parking
- Landscaping buffer
- Elevated bicycle facility



2017 NACTO GUIDANCE

Contextual Guidance for Selecting All Ages & Abilities Bikeways

Roadway Context				All Ages & Abilities Bicycle Facility
Target Motor Vehicle Speed*	Target Max. Motor Vehicle Volume (ADT)	Motor Vehicle Lanes	Key Operational Considerations	
Any		*Any*	*Any of the following:* high curbside activity, frequent buses, motor vehicle congestion, or turning conflicts‡	**Protected Bicycle Lane**
< 10 mph	Less relevant	No centerline, or single lane one-way	Pedestrians share the roadway	**Shared Street**
≤ 20 mph	≤ 1,000 – 2,000		< 50 motor vehicles per hour in the peak direction at peak hour	**Bicycle Boulevard**
	≤ 500 – 1,500			
≤ 25 mph	≤ 1,500 – 3,000	Single lane each direction, or single lane one-way	Low curbside activity, or low congestion pressure	**Conventional or Buffered Bicycle Lane, or Protected Bicycle Lane**
	≤ 3,000 – 6,000			**Buffered or Protected Bicycle Lane**
	Greater than 6,000			**Protected Bicycle Lane**
	Any	Multiple lanes per direction		
Greater than 26 mph†	≤ 6,000	Single lane each direction	Low curbside activity, or low congestion pressure	**Protected Bicycle Lane, or Reduce Speed**
		Multiple lanes per direction		**Protected Bicycle Lane, or Reduce to Single Lane & Reduce Speed**
	Greater than 6,000	*Any*	*Any*	**Protected Bicycle Lane, or Bicycle Path**
High-speed limited access roadways, natural corridors, or geographic edge conditions with limited conflicts		*Any*	High pedestrian volume	**Bike Path with Separate Walkway or Protected Bicycle Lane**
			Low pedestrian volume	**Shared-Use Path or Protected Bicycle Lane**

*While posted or 85th percentile motor vehicle speed are commonly used design speed targets, 95th percentile speed captures high-end speeding, which causes greater stress to bicyclists and more frequent passing events. Setting target speed based on this threshold results in a higher level of bicycling comfort for the full range of riders.

†Setting 25 mph as a motor vehicle speed threshold for providing protected bikeways is consistent with many cities' traffic safety and Vision Zero policies. However, some cities use a 30 mph posted speed as a threshold for protected bikeways, consistent with providing Level of Traffic Stress level 2 (LTS 2) that can effectively reduce stress and accommodate more types of riders.[18]

‡Operational factors that lead to bikeway conflicts are reasons to provide protected bike lanes regardless of motor vehicle speed and volume.

UNCONTROLLED CROSSINGS

Section 4

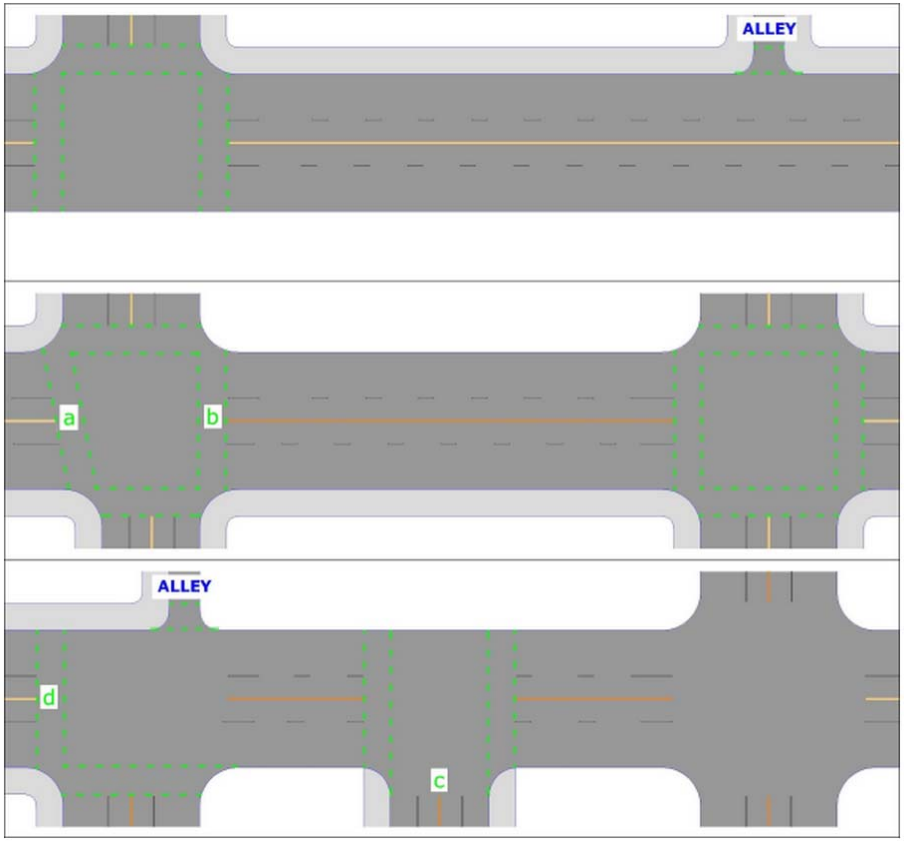
THE CVC DEFINITION

What is an Unmarked Crosswalk?

California Vehicle Code §275
"Crosswalk" is either:

a) That portion of a roadway included within the prolongation or connection of the boundary lines of sidewalks at intersections where the intersecting roadways meet at approximately right angles, except the prolongation of such lines from an alley across a street.

b) Any portion of a roadway distinctly indicated for pedestrian crossing by lines or other markings on the surface.



MARKED CROSSWALK PURPOSE

Provide guidance for pedestrians
Help alert drivers to pedestrian crossing
Establish legal mid-block crossing

Decorative Crosswalk

Mid-Block Crossing

TO MARK OR NOT TO MARK

Herms, Bruce. (1972) Pedestrian crosswalk study: accidents in painted and unpainted crosswalks. Transportation Research Record, 406.

- "The San Diego study"
- Marked crosswalks vs. unmarked crosswalks
- Increased incidence of pedestrian collisions in marked crosswalks
- Did not differentiate between:
  - Number of lanes
  - Traffic volume
  - Speed limit

TO MARK OR NOT TO MARK

Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations (2002)

- "The Zegeer study"
- Marked vs. unmarked
- Two-lane roads - no difference in pedestrian crash rate
- Multilane roads - marked crosswalk, without other measures, associated with higher crash rate on roadways with higher ADT and speed

MULTIPLE THREAT CRASH

DECISION MAKING AND DESIGN

Zegeer Study Key Findings

Table 1. Recommendations for installing marked crosswalks and other needed pedestrian improvements at uncontrolled locations.*

Roadway Type (Number of Travel Lanes and Median Type)	Vehicle ADT ≤ 9,000			Vehicle ADT >9000 to 12,000			Vehicle ADT >12,000 - 15,000			Vehicle ADT > 15,000		
	Speed Limit**											
	≤ 30 mi/h	35 mi/h	40 mi/h	≤ 30 mi/h	35 mi/h	40 mi/h	≤ 30 mi/h	35 mi/h	40 mi/h	≤ 30 mi/h	35 mi/h	40 mi/h
2 Lanes	C	C	P	C	C	P	C	C	N	C	P	N
3 Lanes	C	C	P	C	P	P	P	P	N	P	N	N
Multi-Lane (4 or More Lanes) With Raised Median***	C	C	P	C	P	N	P	P	N	N	N	N
Multi-Lane (4 or More Lanes) Without Raised Median	C	P	N	P	P	N	N	N	N	N	N	N

Key:

C = Candidate sites for marked crosswalks;

P = Possible increase in pedestrian crashes may occur if crosswalks are marked without other pedestrian enhancements;

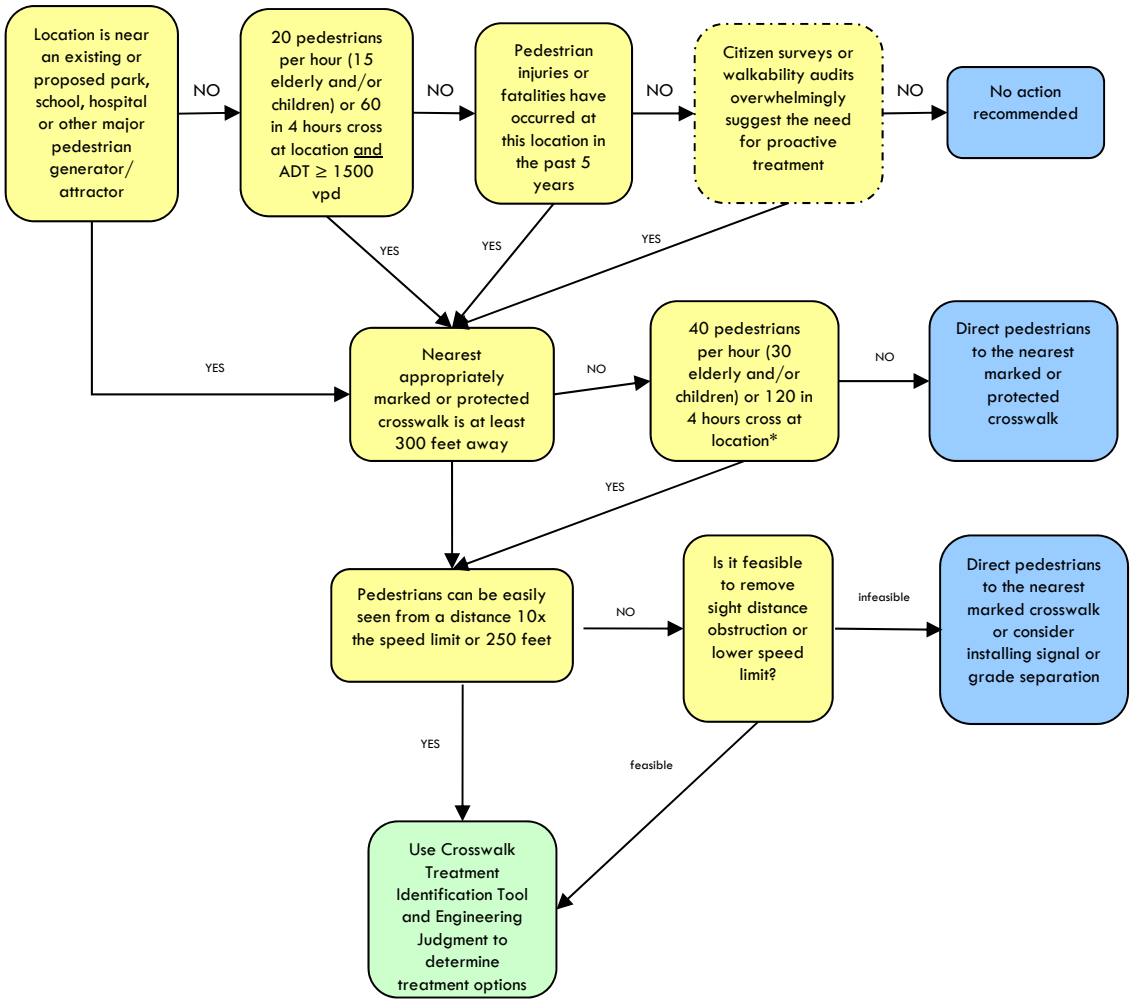
N = Marked crosswalks alone are insufficient.

DECISION MAKING AND DESIGN

> Regardless of **whether** marked crosswalks are used, there remains the fundamental obligation to get pedestrians safely across the street.

FHWA Safety Effects of Marked v. Unmarked Crosswalks

DEMAND CONSIDERATIONS



2018 FHWA GUIDANCE

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

Roadway Configuration	Speed Limit								
	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph
	Vehicle AADT <9,000			Vehicle AADT 9,000–15,000			Vehicle AADT >15,000		
2 lanes*	❶ 2 3 4 5 6	❶ ❸ 5 6 7	❶ ❸ 5 6 ❼	❶ 3 4 5 6	❶ ❸ 5 6 7	❶ ❸ 5 6 ❼	❶ 3 4 5 6 7	❶ ❸ 5 6 7	❶ ❸ 5 6 ❼
3 lanes with raised median*	❶ 2 3 4 5	❶ ❸ 5 7	❶ ❸ 5 ❼	❶ 3 4 5 7	❶ ❸ 5 ❼	❶ ❸ 5 ❼	❶ ❸ 4 5 7	❶ ❸ 5 ❼	❶ ❸ 5 ❼
3 lanes w/o raised median†	❶ 2 3 4 5 6 7	❶ ❸ 5 6 7	❶ ❸ 5 6 ❼	❶ 3 4 5 6 7	❶ ❸ 5 6 ❼	❶ ❸ 5 6 ❼	❶ ❸ 4 5 6 7	❶ ❸ 5 6 ❼	❶ ❸ 5 6 ❼
4+ lanes with raised median‡	❶ ❸ 5	❶ ❸ 5 7	❶ ❸ 5 ❼	❶ ❸ 5 7	❶ ❸ 5 ❼	❶ ❸ 5 ❼	❶ ❸ 5 ❼	❶ ❸ 5 ❼	❶ ❸ 5 ❼
4+ lanes w/o raised median‡	❶ ❸ 5 6 7 8	❶ ❸ 5 ❻ 7 8	❶ ❸ 5 ❻ ❼ 8	❶ ❸ 5 ❻ 7 8	❶ ❸ 5 ❻ ❼ 8	❶ ❸ 5 ❻ ❼ 8	❶ ❸ 5 ❻ ❼ 8	❶ ❸ 5 ❻ ❼ 8	❶ ❸ 5 ❻ ❼ 8

*One lane in each direction †One lane in each direction with two-way left-turn lane ‡Two or more lanes in each direction

Given the set of conditions in a cell,

❶ 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 the countermeasure is a candidate treatment at a marked uncontrolled crossing location.

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 restriction on crosswalk approach, adequate nighttime lighting levels
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 Pedestrian Hybrid Beacon
8 Road Diet

This table was developed using information from: Zegeer, C. V., Stewart, J. R., Huang, H. H., Lagerwey, P. A., Feaganes, J., & Campbell, B. J. (2005), Safety effects of marked versus unmarked crosswalks at uncontrolled locations: Final report and recommended guidelines (No. FHWA-HRT-04-100); Manual on Uniform Traffic Control Devices, 2009 Edition, Chapter 4F. Pedestrian Hybrid Beacons; the Crash Modification Factors (CMF) Clearinghouse website (http://www.cmfclearinghouse.org/); and the Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE) website (http://www.pedbikesafe.org/PEDSAFE/).

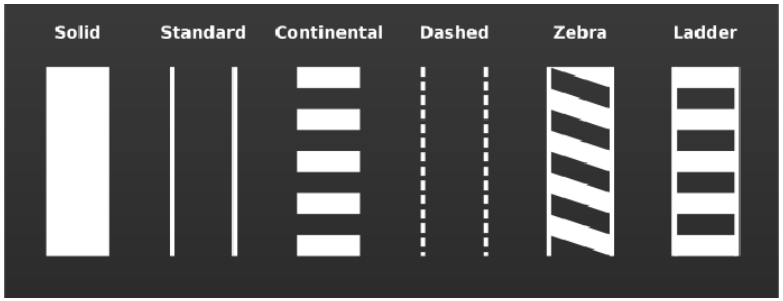
SIGNING AND STRIPING

- 6’ minimum width, 10’ recommended
- Should be straight
- High-visibility (continental, ladder) recommended at uncontrolled and mid-block locations
- W11-2 sign with W16-7P (two per approach, especially on multilane approaches)
- Advanced yield/stop lines at uncontrolled multi-lane approaches (20-50 feet)
- R1-5 signs are required when advanced yield/stop lines are used on multilane approaches

W11-2

W16-7P

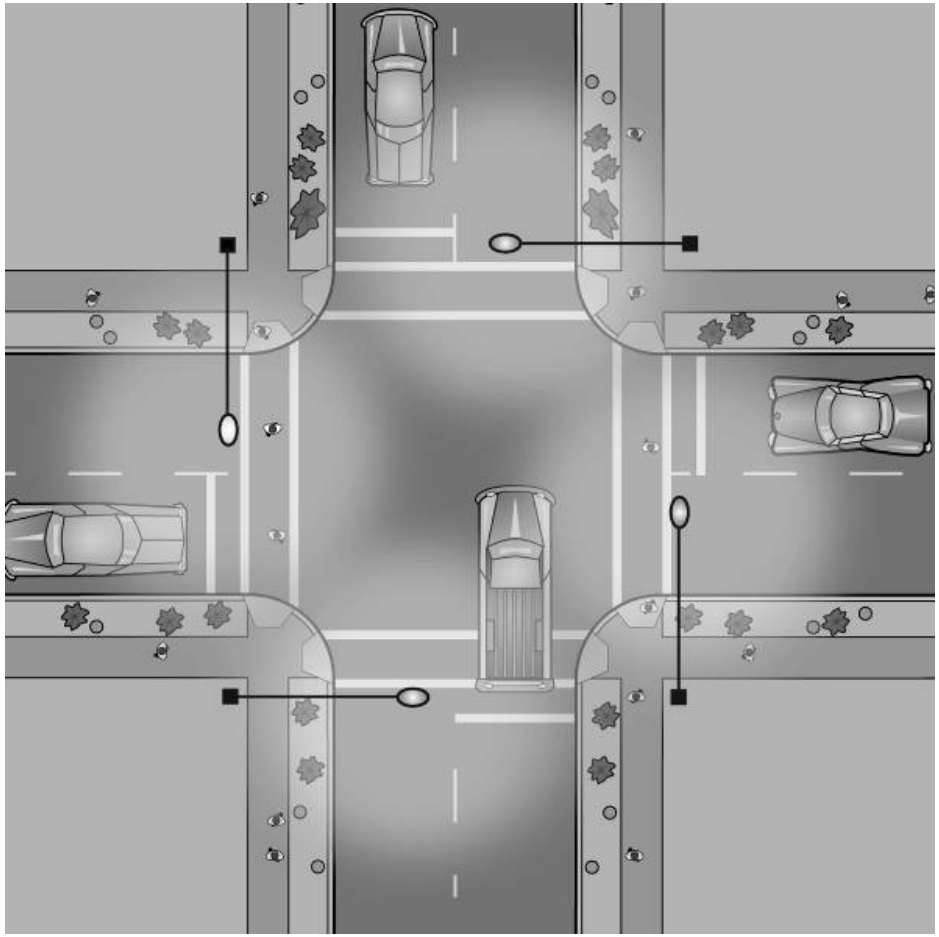
Example crosswalk markings



ILLUMINATION: ESSENTIAL FOR ANY CROSSING

Marked crosswalk?

- Light it



Over 70% of pedestrian fatalities occur during darkness in California

RAISED CROSSWALKS

Figure 6. Raised crosswalk and overhead flasher, Towerview Drive, Durham, North Carolina.

- FHWA Study "*The Effects of Traffic Calming Measures on Pedestrian and Motorist Behavior*" -2001
- Increase pedestrian visibility & likelihood the driver yields to pedestrians especially when combined with an overhead flashing light
- Most appropriate on low speed local or neighborhood streets
- Should not be used on emergency routes, bus routes, or high speed streets
- Drainage of storm water runoff and snow plowing considerations may also be a concern with raised crosswalks

ADVANCE YIELD LINE

IN-STREET PEDESTRIAN CROSSING SIGN

2009 MUTCD Section 2B.12 and Figure 2B-2

CURB EXTENSIONS

- Increases pedestrian visibility
- Allows pedestrians to better observe approaching motorists
- Decreases crossing distance
- Reduces pedestrian exposure to traffic
- Improves opportunity for directional curb ramps
- Can reduce speeds by visually narrowing the street
- Slows turning vehicles
- Can improve signal timing/may reduce cycle length

MEDIAN ISLANDS

- 6’ minimum width for refuge, 8’ or larger recommended to accommodate bicyclists, higher pedestrian volumes
- Consider fire department requirements
  - Often 20’ clear to pass stopped vehicles
  - Wider for hook & ladder trucks
- 5’ minimum opening for ADA, width of crosswalk recommended
- At roadway grade, with detectable surface
- Place signs, beacons both right-side and in median

Median does not provide refuge

Median refuge island

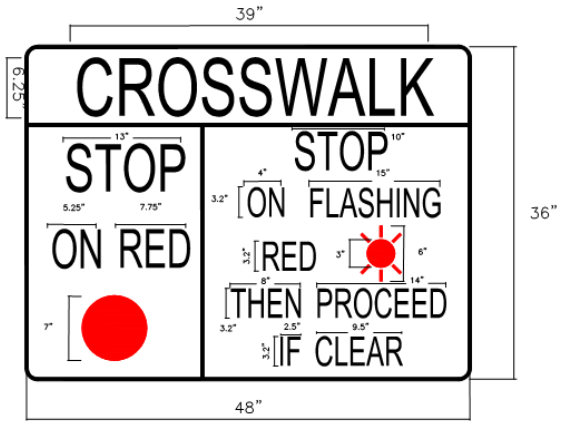
RECTANGULAR RAPID FLASHING BEACON (RRFB)

- RRFBs
  - FHWA issued Interim Approval (IA-11) in July 2008; was recently terminated
  - Caltrans has recently requested blanket approval regarding IA-21 from FHWA

PEDESTRIAN HYBRID BEACONS

- Similar in design and cost to pedestrian signal
- Pedestrian head shall rest with upraised hand

Standard R10-23 sign



Modified R10-23 sign

PEDESTRIAN HYBRID BEACONS

1

Blank for drivers

2

Flashing yellow

3

Steady yellow

4

Steady red

5

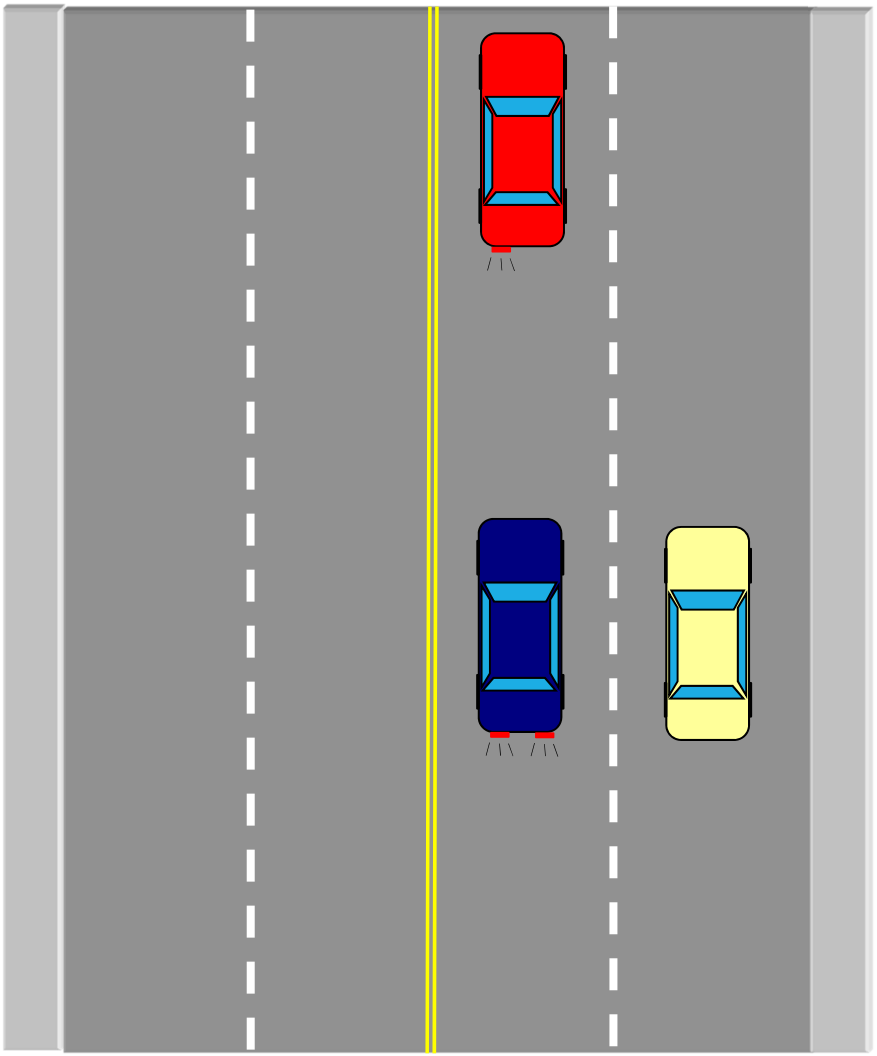
Wig-Wag

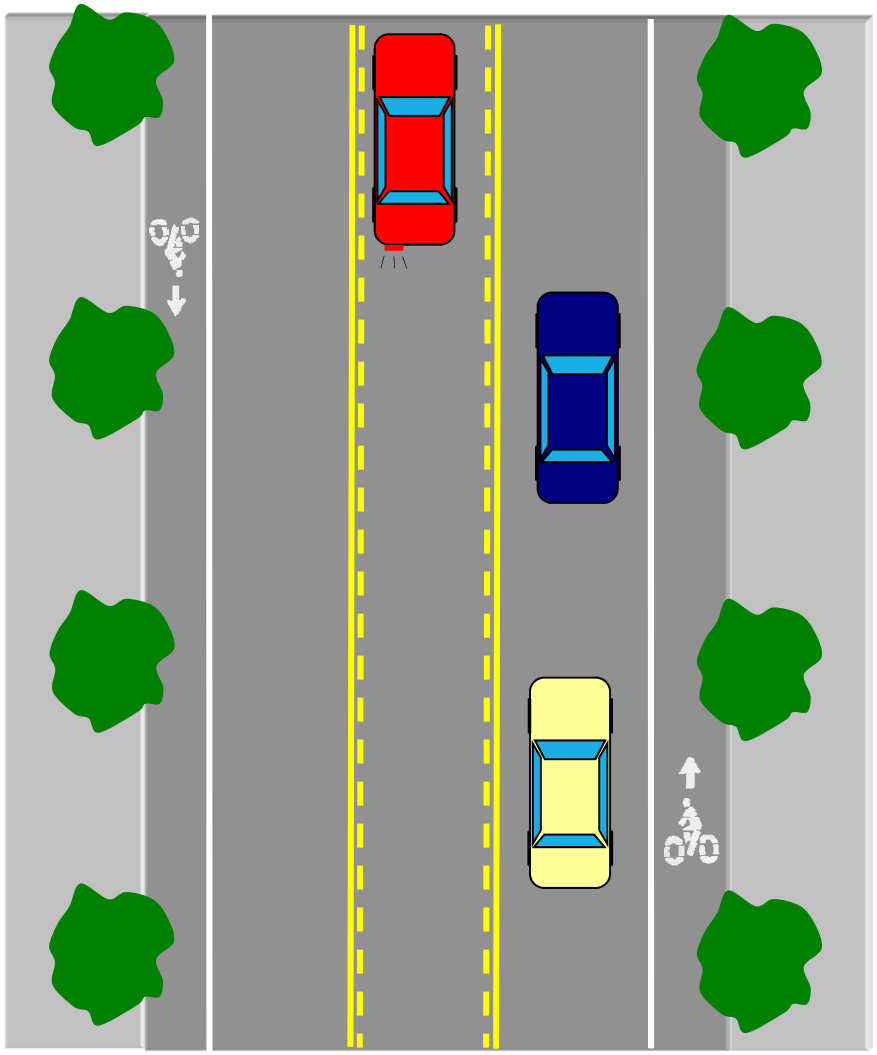
Return to **1**

"CLASSIC ROAD DIET"

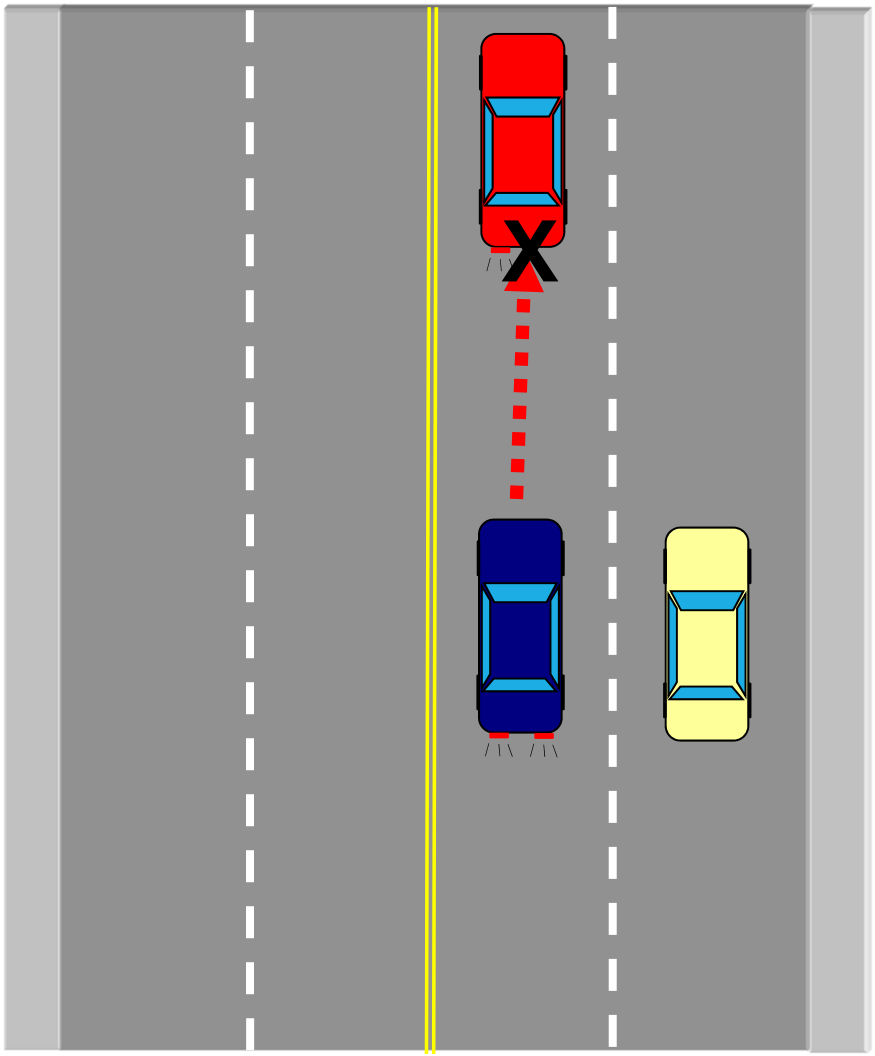
4 to 3 Lanes | San Antonio, TX

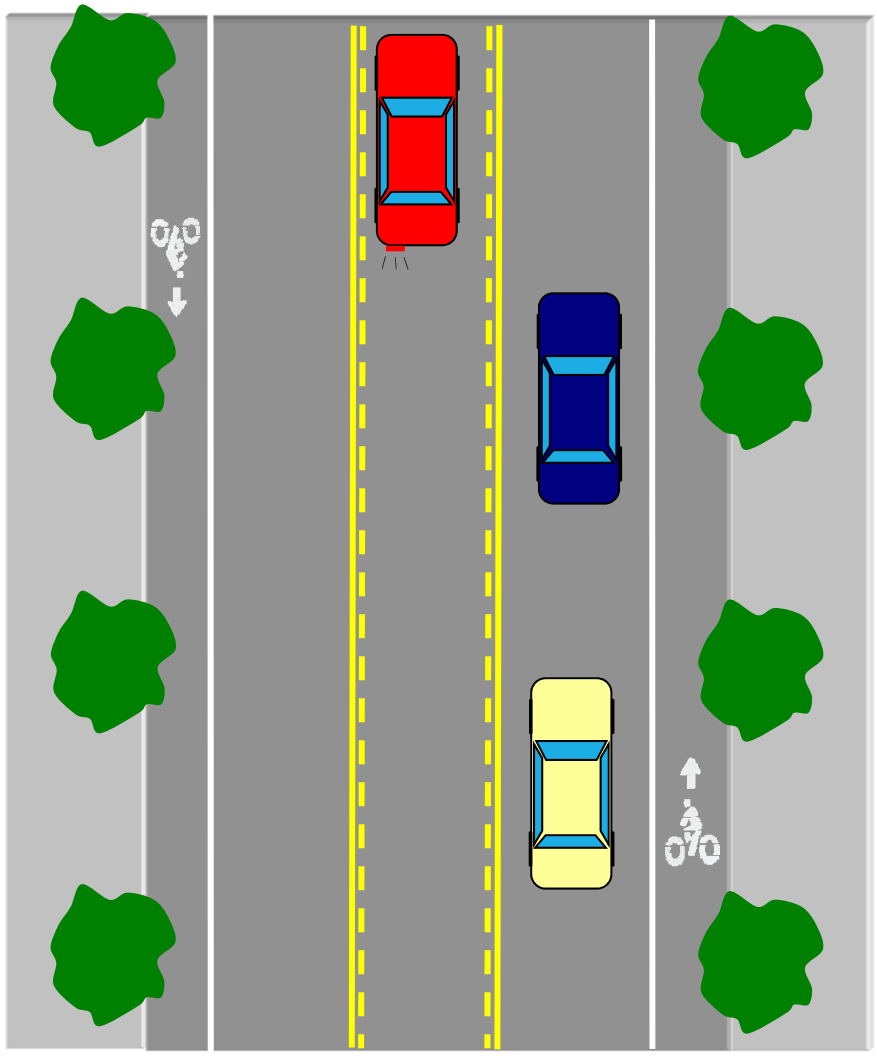
3 CRASH TYPES CAN BE REDUCED BY GOING FROM 4 TO 3 LANES:
WHICH ONES?



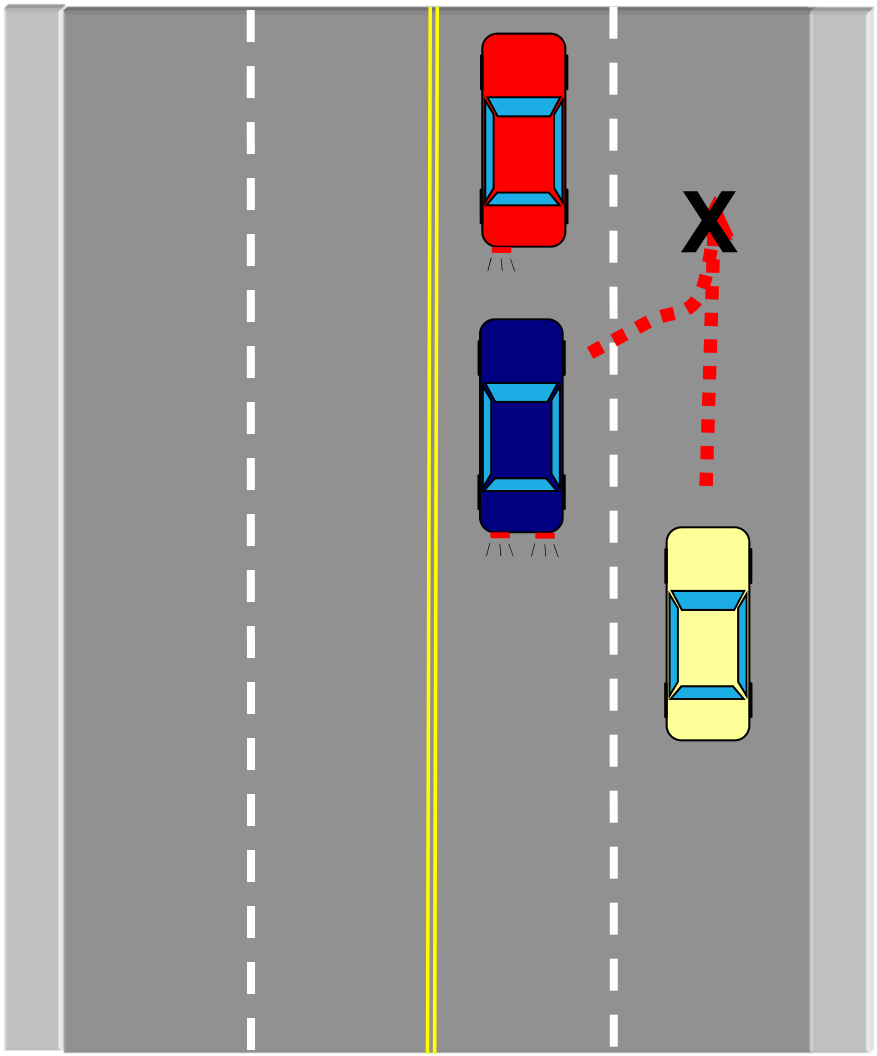


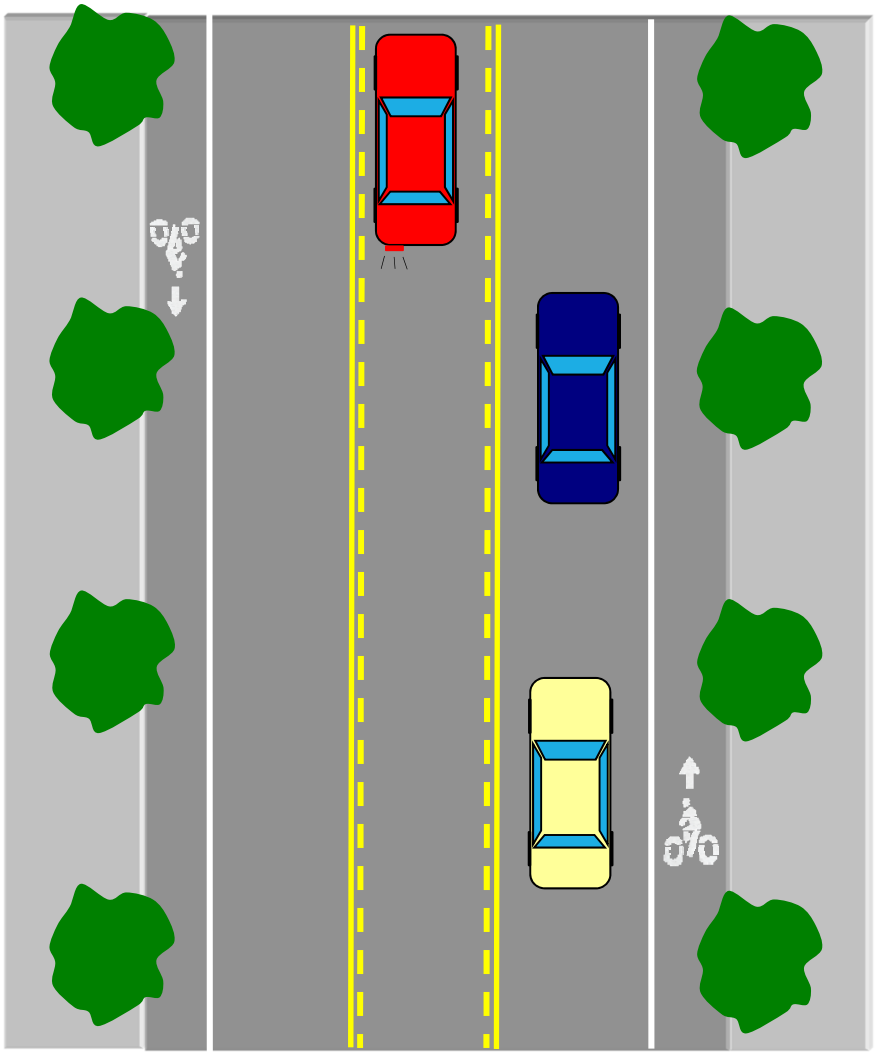
3 CRASH TYPES CAN BE REDUCED BY GOING FROM 4 TO 3 LANES:
1) REAR ENDERS





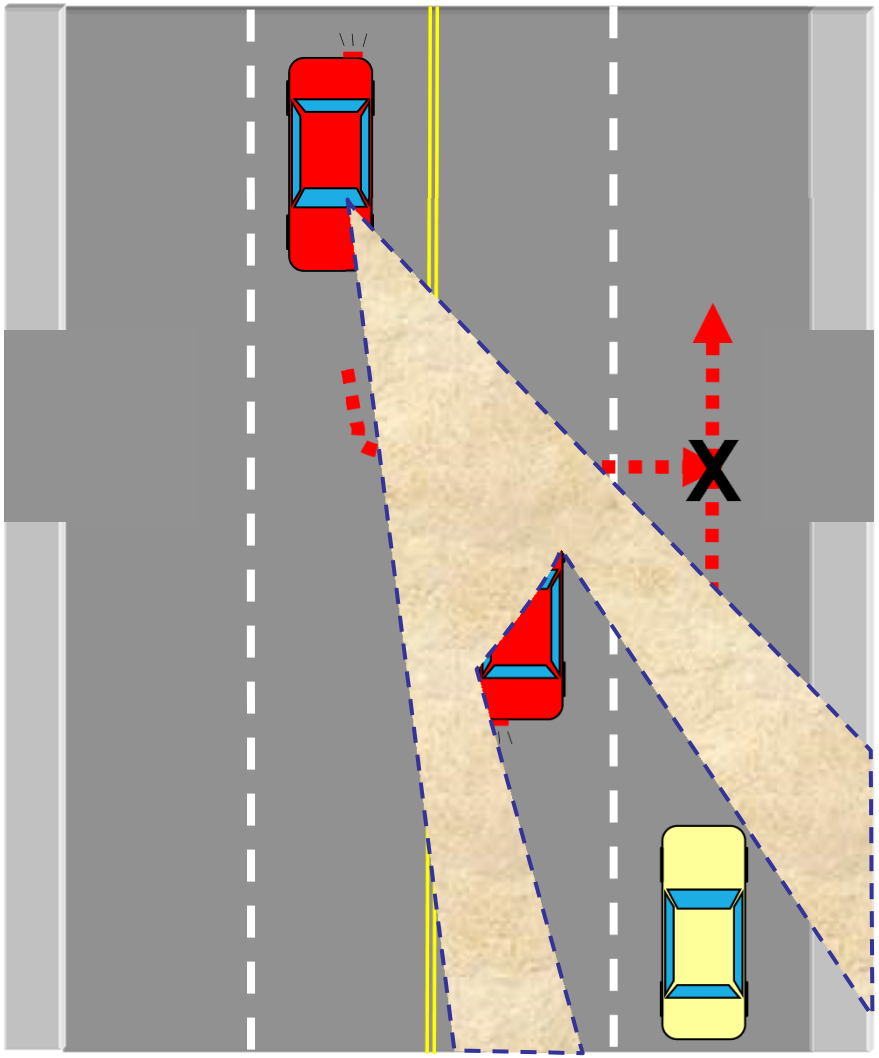
3 CRASH TYPES CAN BE REDUCED BY GOING FROM 4 TO 3 LANES:
2) SIDE SWIPES

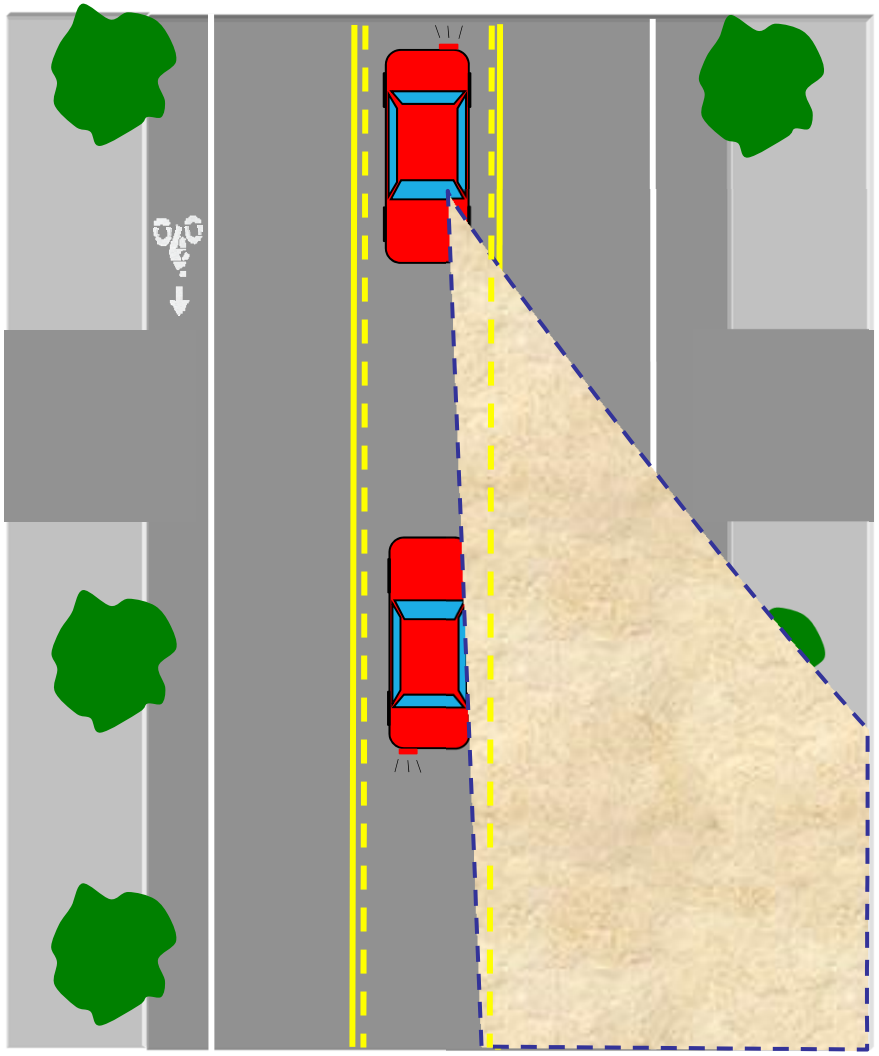




3 CRASH TYPES CAN BE REDUCED BY GOING FROM 4 TO 3 LANES:

3) LEFT TURN/BROADSIDE





PEDESTRIAN SIGNALS

- Cannot be used at intersection
- Same standards as full traffic signal

TREATMENT SELECTION TOOLS

XWalk+

Location
User
Date : 6-15-2015

Type: Uncontrolled Intersection

Input Parameters	Value	Intersection Characteristics	Yes	No
Speed Limit	35	Frequent at-grade transit?	●	○
Peak Hour Pedestrian Vol	78	Bicycle lanes?	●	○
Major Road Peak Hour Volume Total	450	Heavy bicycle traffic?	●	○
Major Road Peak Hour Vol Dir 1	150	Major/minor road intersection?	●	○
Major Road Peak Hour Vol Dir 2	300	Midblock/off-set intersection?	○	●
Avg Pedestrian Walking Speed	3	Heavy truck traffic?	○	●
15th Percentile Crossing Speed	3	Existing infrastructure limit treatments?	○	●
Ped start-up/end clearance time	3	On-street parking?	●	○
Pedestrian Crossing Distance	65	Downtown area?	○	●
1st Half Crossing Distance	30	Built-up area of an isolated community?	○	●
2nd Half Crossing Distance	35	Median refuge island?	○	●
Number of Lanes	4	Sufficient width for a median?	○	●
Actual Total Pedestrian Delay				
Expected Motorist Compliance	Moderate			

◀ 2 of 2 Recommendations ▶

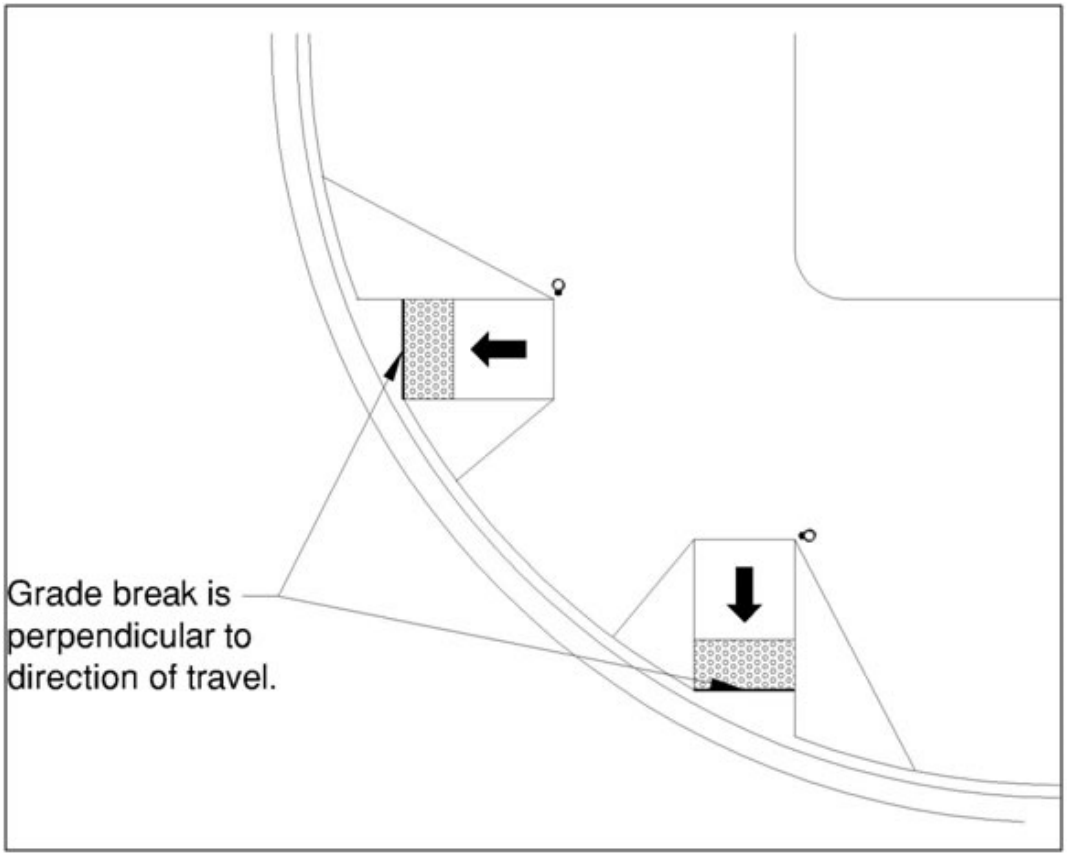
RRFB

Signalized or Unsignalized Crossing?	Unsignalized Crossing
Pedestrian LOS	F
Candidate Pedestrian Treatment Identified	**RRFB**
Candidate for Median Refuge Island?	NO
Candidate for Road Diet?	YES
Other Treatments for Consideration**	RRFB
Paired Treatments for Consideration**	Curb Extensions, Bus Bulb, Reduced Curb Radii, Staggered Pedestrian Refuge, High Visibility Crosswalk Markings, Advance Yield Lines, Advance signage

ACCESSIBILITY REQUIREMENTS

DIB 82-05

- Now allows ramps to be oriented perpendicular to a gutter grade break
- Alternative to orientation perpendicular to curb face
- Facilitates crosswalk with directional ramps at corners



BIKE/PED ACCOMMODATIONS AT INTERSECTIONS

Section 5

INTERSECTION DESIGN PRINCIPLES

Reduce speed

Minimize exposure to conflicts

Communicate right-of-way priority

Provide adequate sight distance

Shorten crossings

Keep it direct

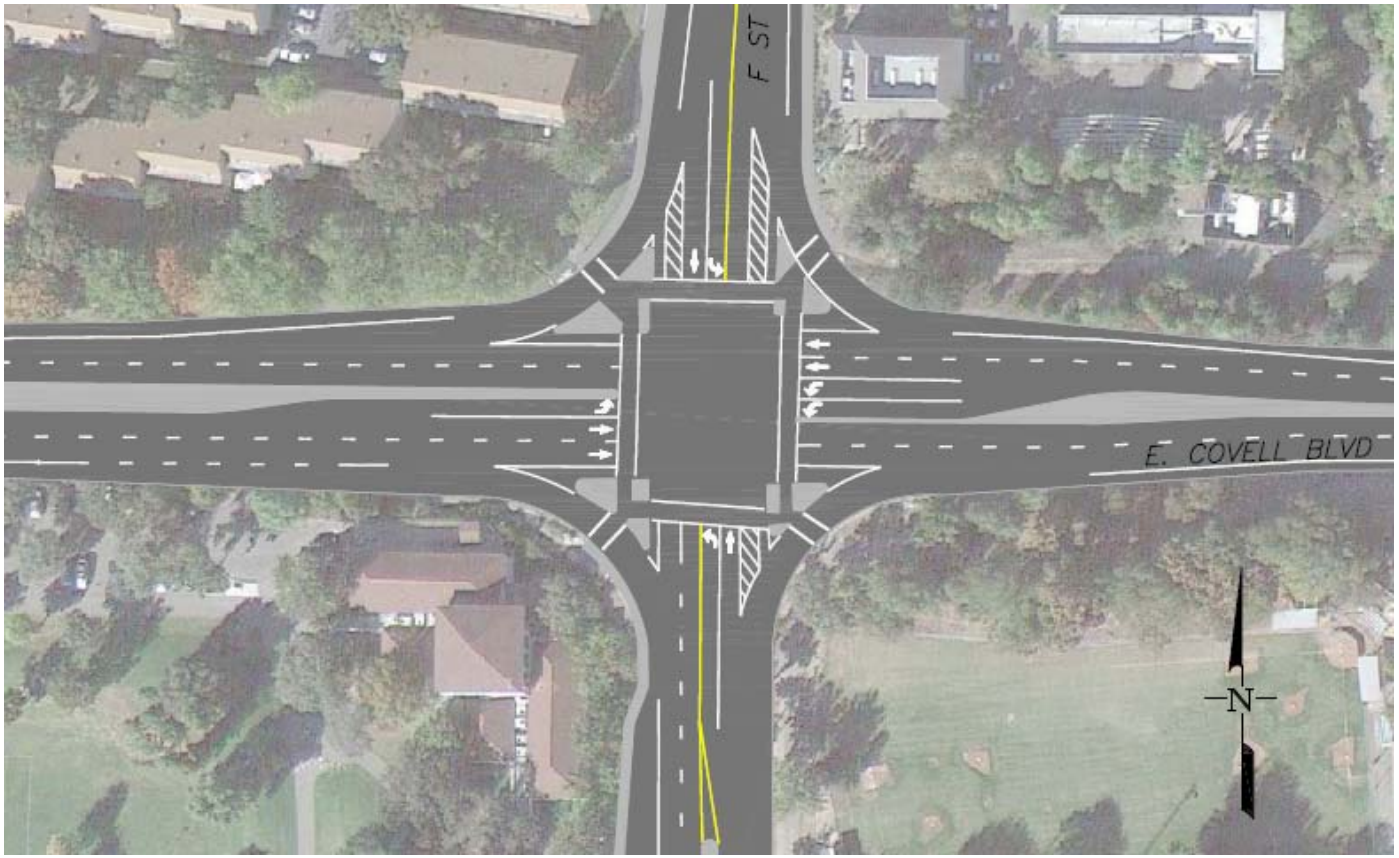
Light at night

Access for all

Source: Metro

INTERSECTION DESIGN PRINCIPLES

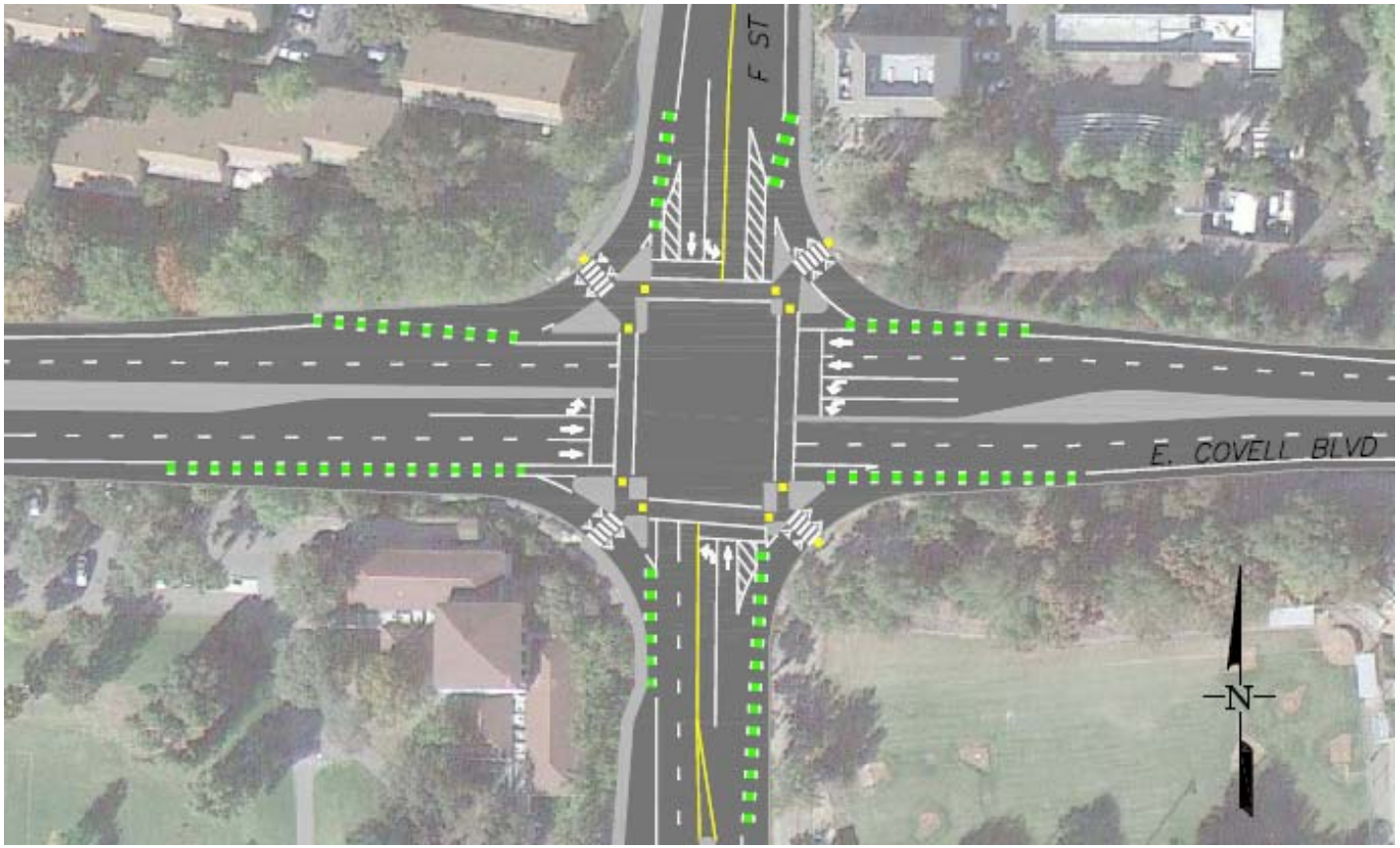
Common Issues



Source: Fehr & Peers

INTERSECTION DESIGN PRINCIPLES

Candidate Solutions (Low-Cost)



Source: Fehr & Peers

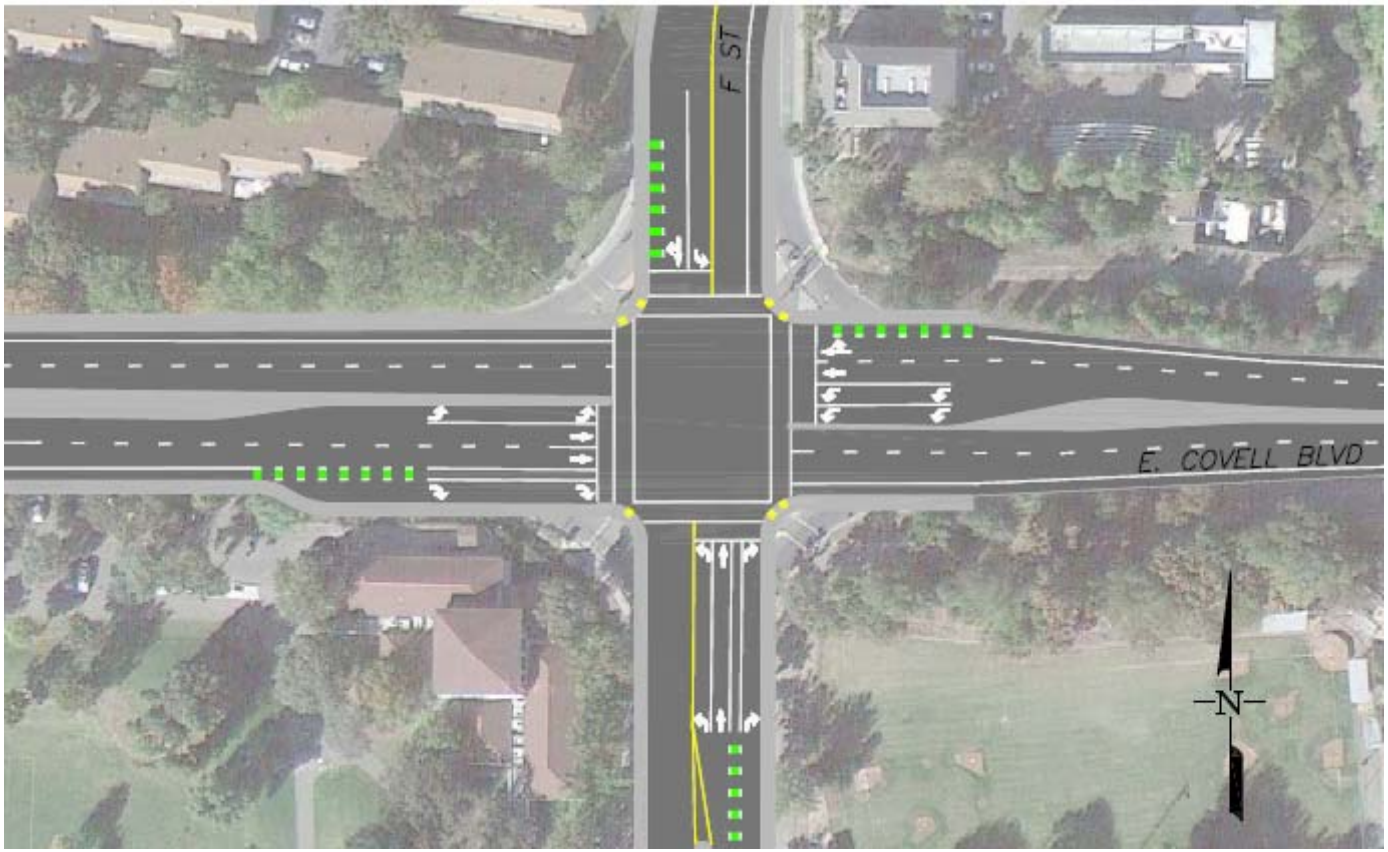
INTERSECTION DESIGN PRINCIPLES

Free Right-Turn with Raised Crosswalk

Boulder, CO
Source: Fehr & Peers

INTERSECTION DESIGN PRINCIPLES

Candidate Solutions (High Cost)



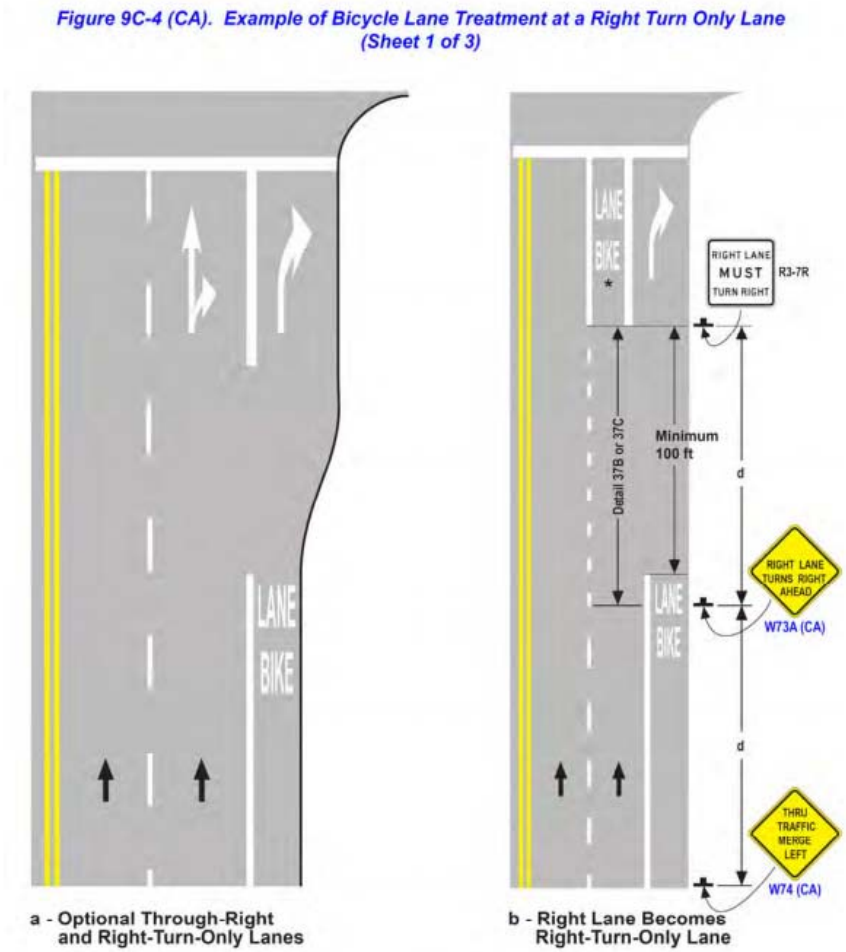
Source: Fehr & Peers

INTERSECTION DESIGN PRINCIPLES

Right-Turn Lane Design

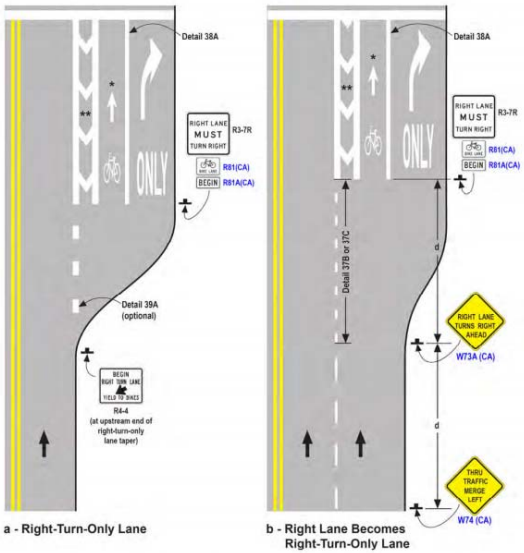
Design affects:

- Vehicle turning speeds
- Clarity of path for bicyclists
- Controlled vs. uncontrolled crosswalks
- Vehicle delay



INTERSECTION DESIGN PRINCIPLES

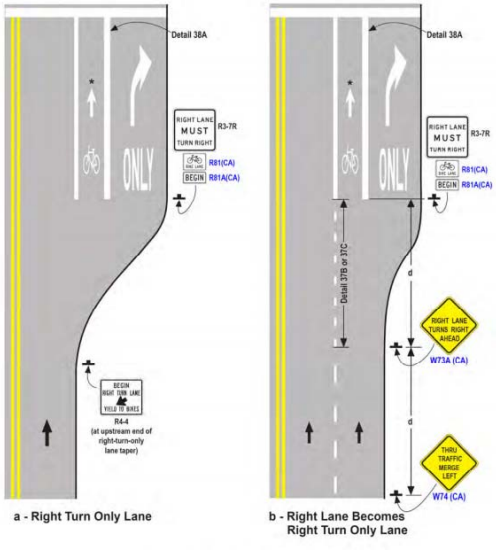
Figure 9C-4 (CA). Example of Bicycle Lane Treatment at a Right Turn Only Lane, Posted Speed > 40 mph (Sheet 2 of 3)



a - Right-Turn-Only Lane

b - Right Lane Becomes Right-Turn-Only Lane

Figure 9C-4 (CA). Example of Bicycle Lane Treatment at a Right Turn Only Lane, Posted Speed ≤ 40 mph (Sheet 3 of 3)



a - Right Turn Only Lane

b - Right Lane Becomes Right Turn Only Lane

Figure 9C-5. Example of Bicycle Lane Treatment at Parking Lane into a Right Turn Only Lane