Traffic Engineering Fundamentals

Session 2 – Traffic Design

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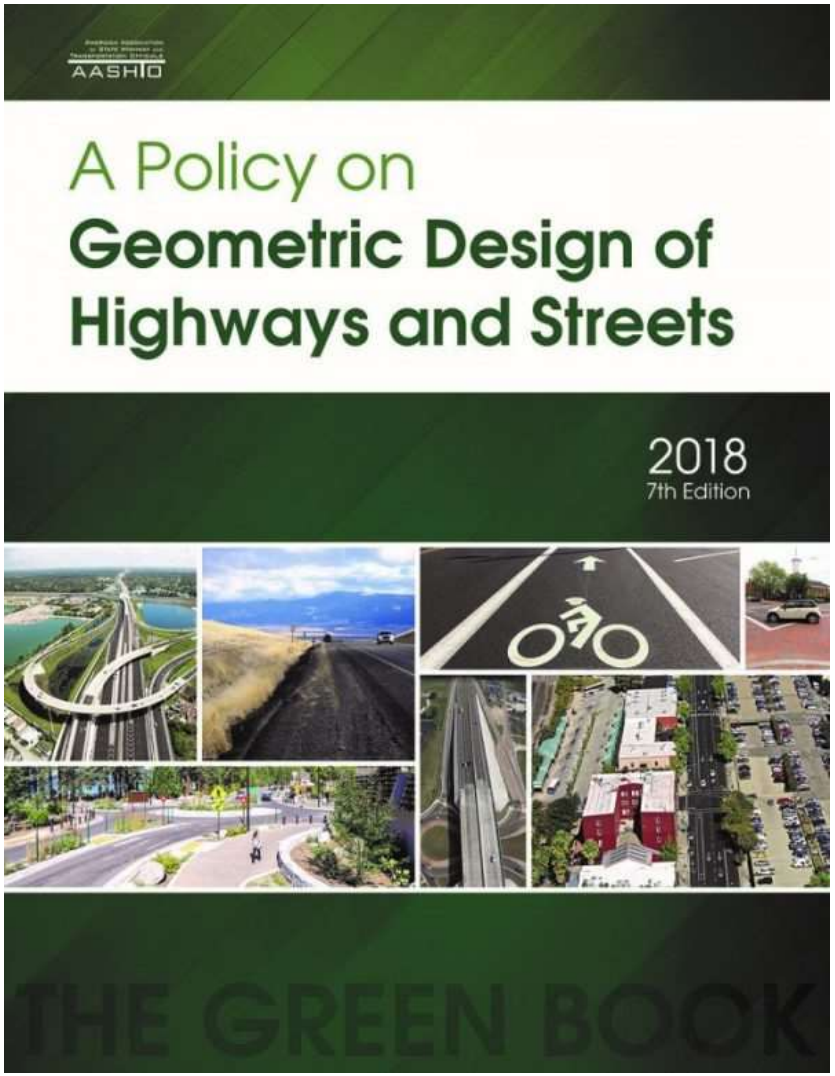
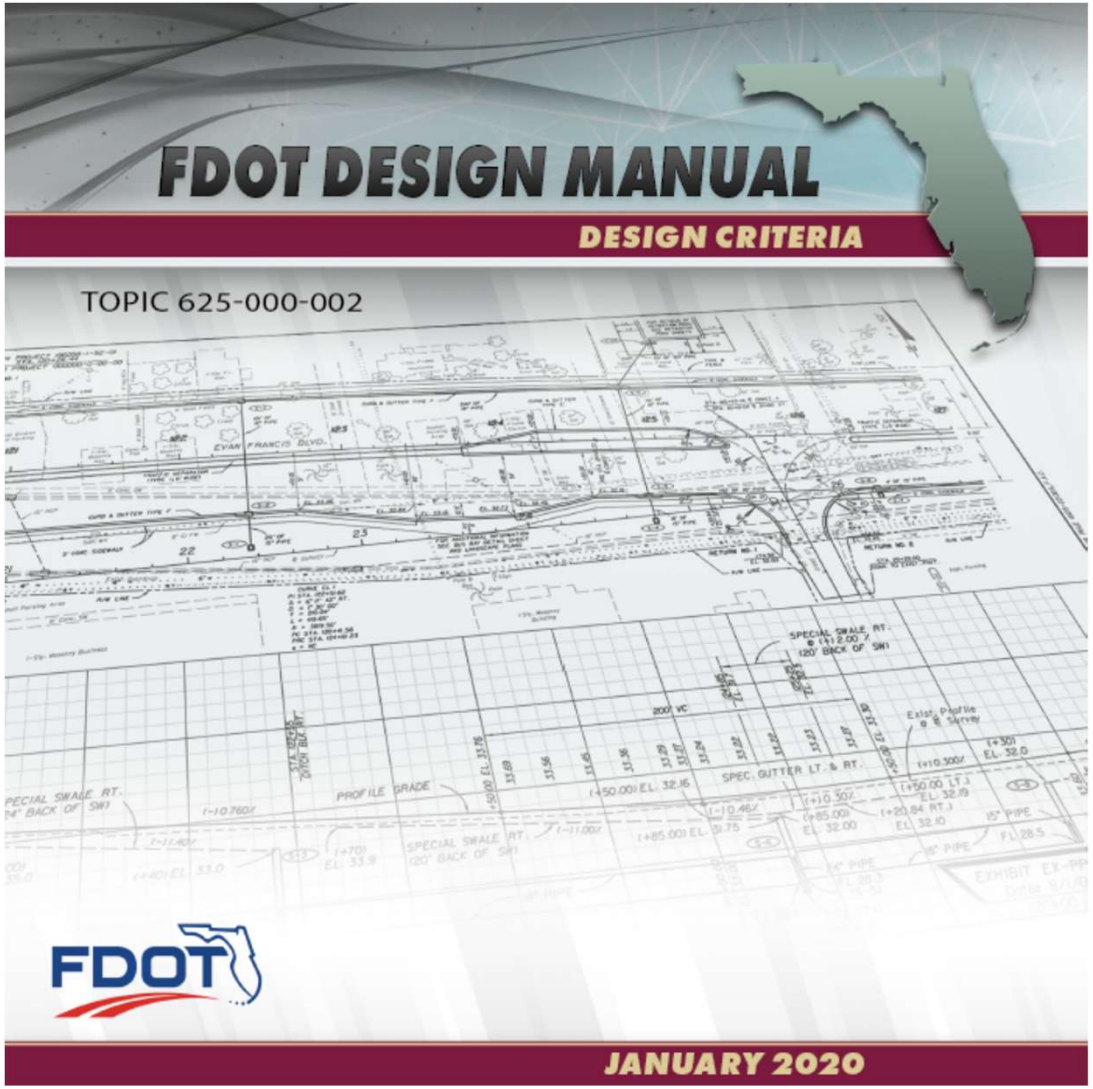
Traffic Engineering Fundamentals

General Design Considerations

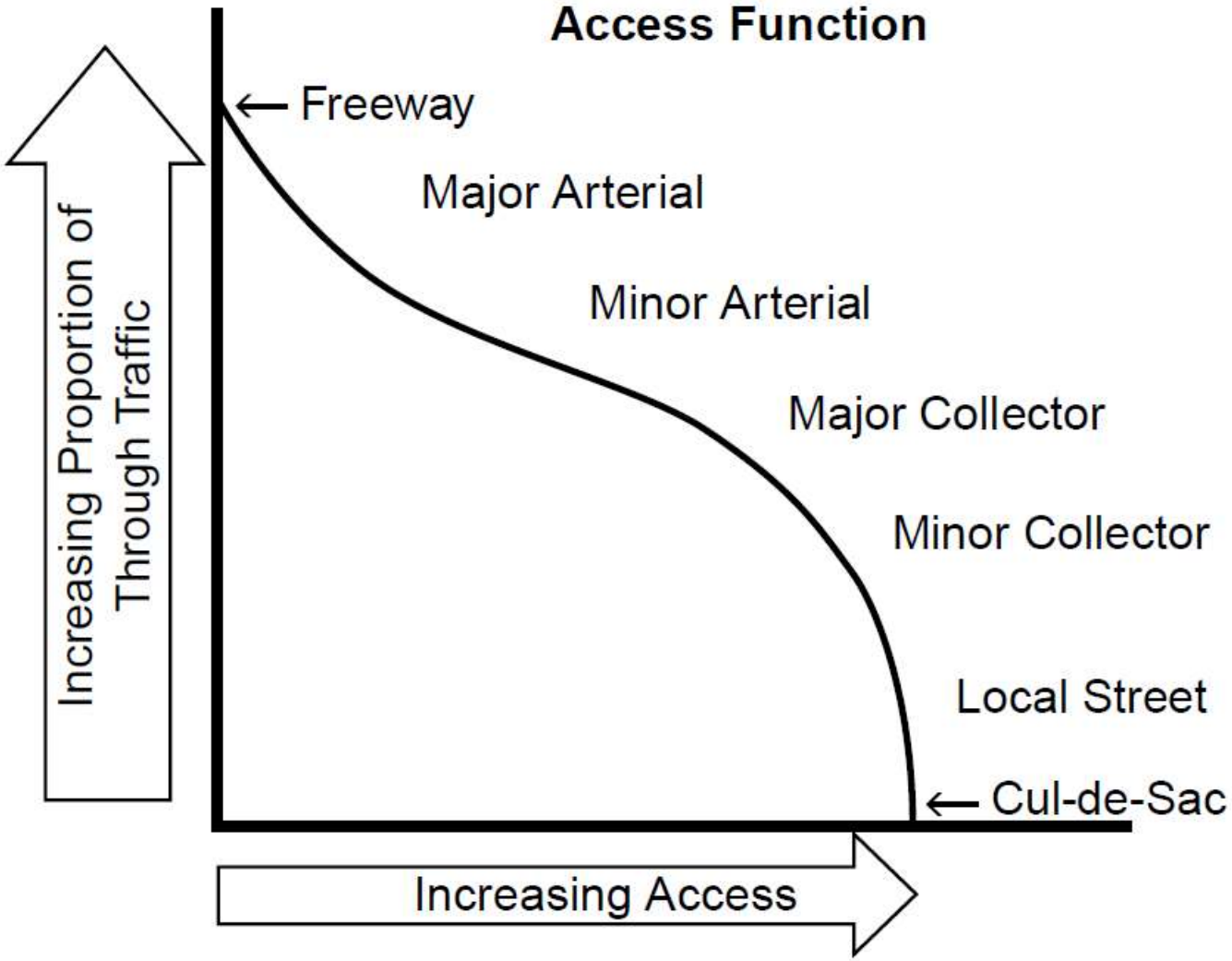
AASHTO Green Book



FDOT Design Manual



Functional Classification



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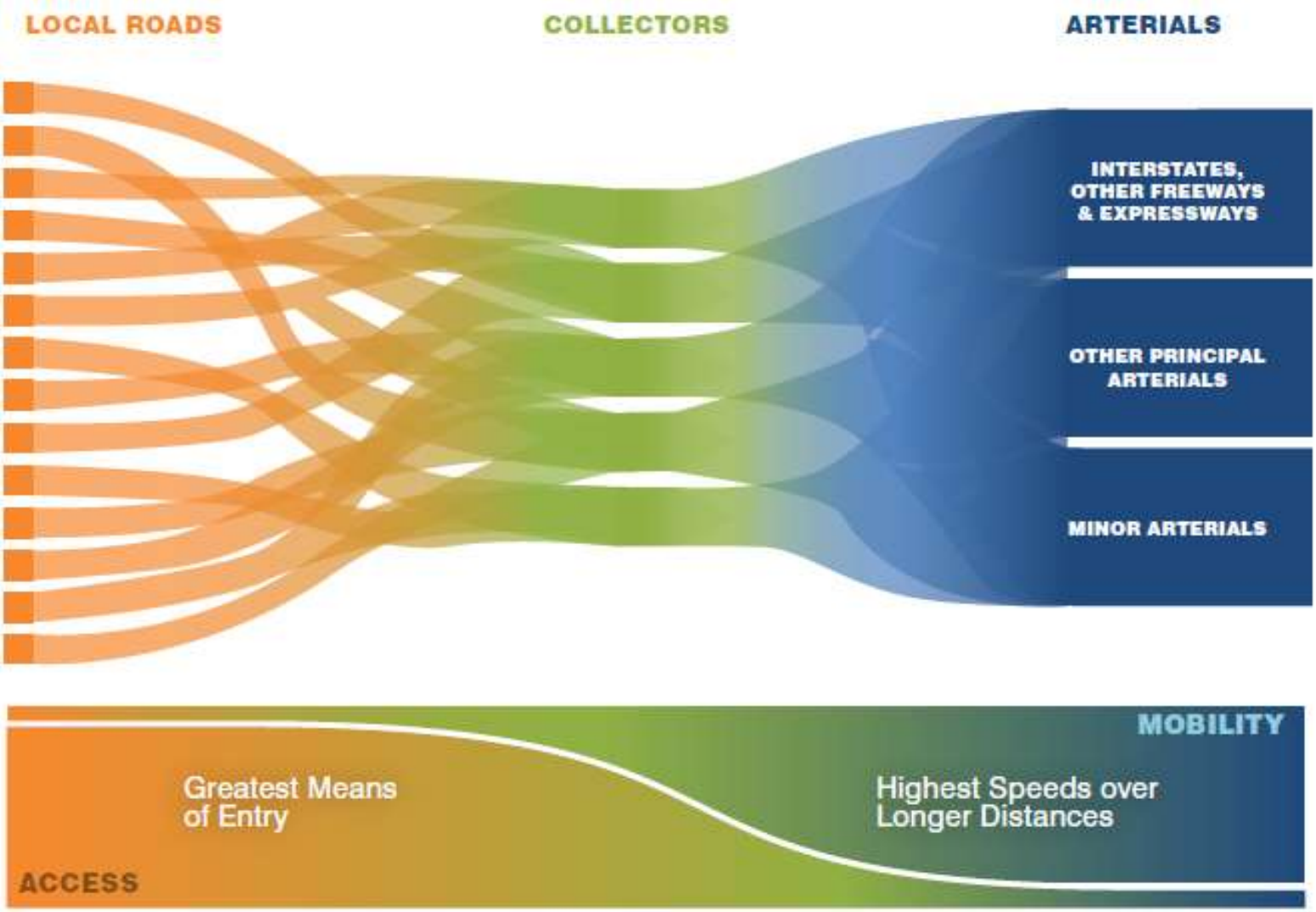

FDOT Context Classifications

FIGURE 2 FDOT CONTEXT CLASSIFICATIONS

C1-Natural
Lands preserved in a natural or wilderness condition, including lands unsuitable for settlement due to natural conditions.

C2-Rural
Sparsely settled lands; may include agricultural land, grassland, woodland, and wetlands.

C2T-Rural Town
Small concentrations of developed areas immediately surrounded by rural and natural areas; includes many historic towns.

C3R-Suburban Residential
Mostly residential uses within large blocks and a disconnected or sparse roadway network.

C3C-Suburban Commercial
Mostly non-residential uses with large building footprints and large parking lots within large blocks and a disconnected or sparse roadway network.

C4-Urban General
Mix of uses set within small blocks with a well-connected roadway network. May extend long distances. The roadway network usually connects to residential neighborhoods immediately along the corridor or behind the uses fronting the roadway.

C5-Urban Center
Mix of uses set within small blocks with a well-connected roadway network. Typically concentrated around a few blocks and identified as part of a civic or economic center of a community, town, or city.

C6-Urban Core
Areas with the highest densities and building heights, and within FDOT classified Large Urbanized Areas (population >1,000,000). Many are regional centers and destinations. Buildings have mixed uses, are built up to the roadway, and are within a well-connected roadway network.

FDOT Context Classifications

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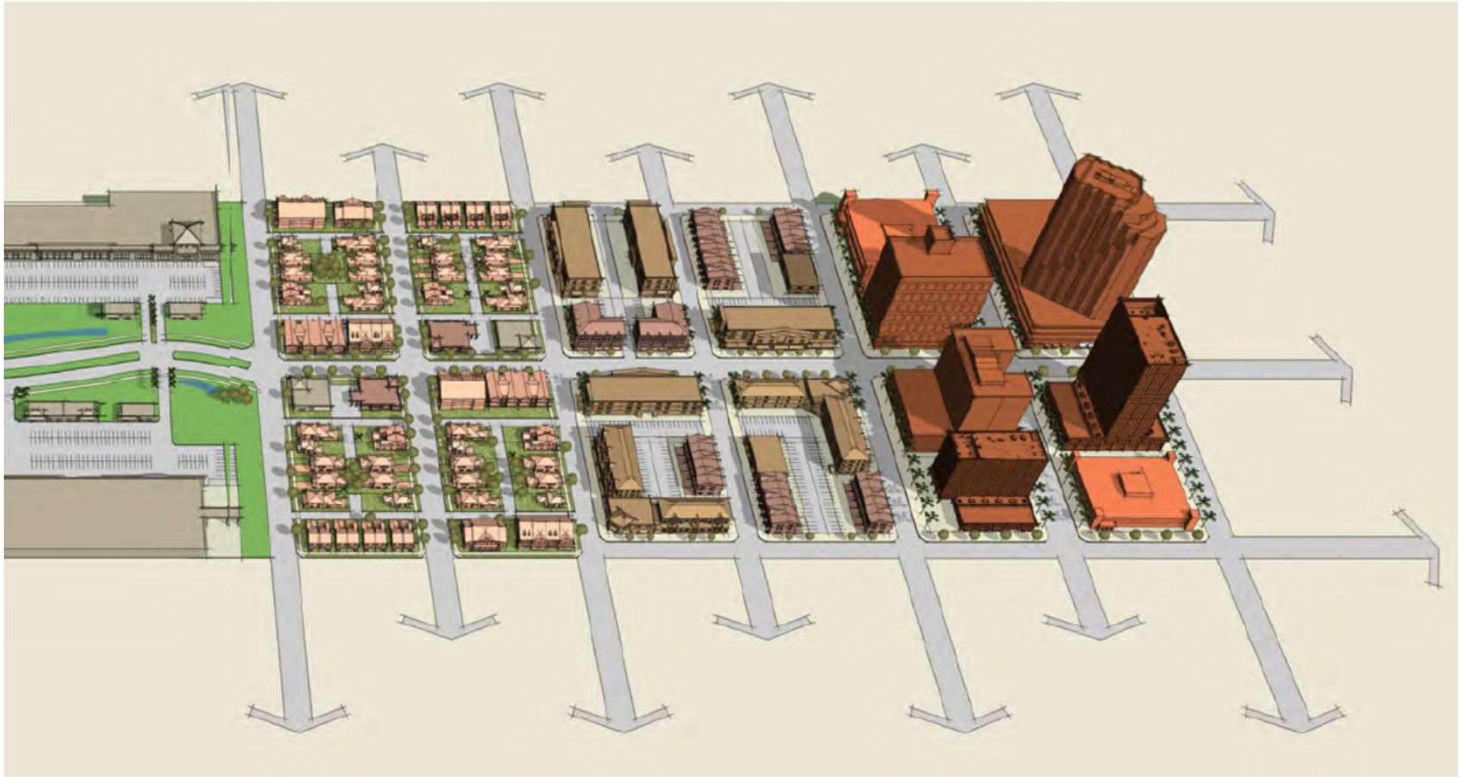
FDOT Context Classifications



C3C-Suburban Commercial
Mostly non-residential uses with large building footprints and large parking lots within large blocks and a disconnected or sparse roadway network.

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FDOT Context Classifications–Rural

C1-Natural
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Sparsely settled lands; may include agricultural land, grassland, woodland, and wetlands.

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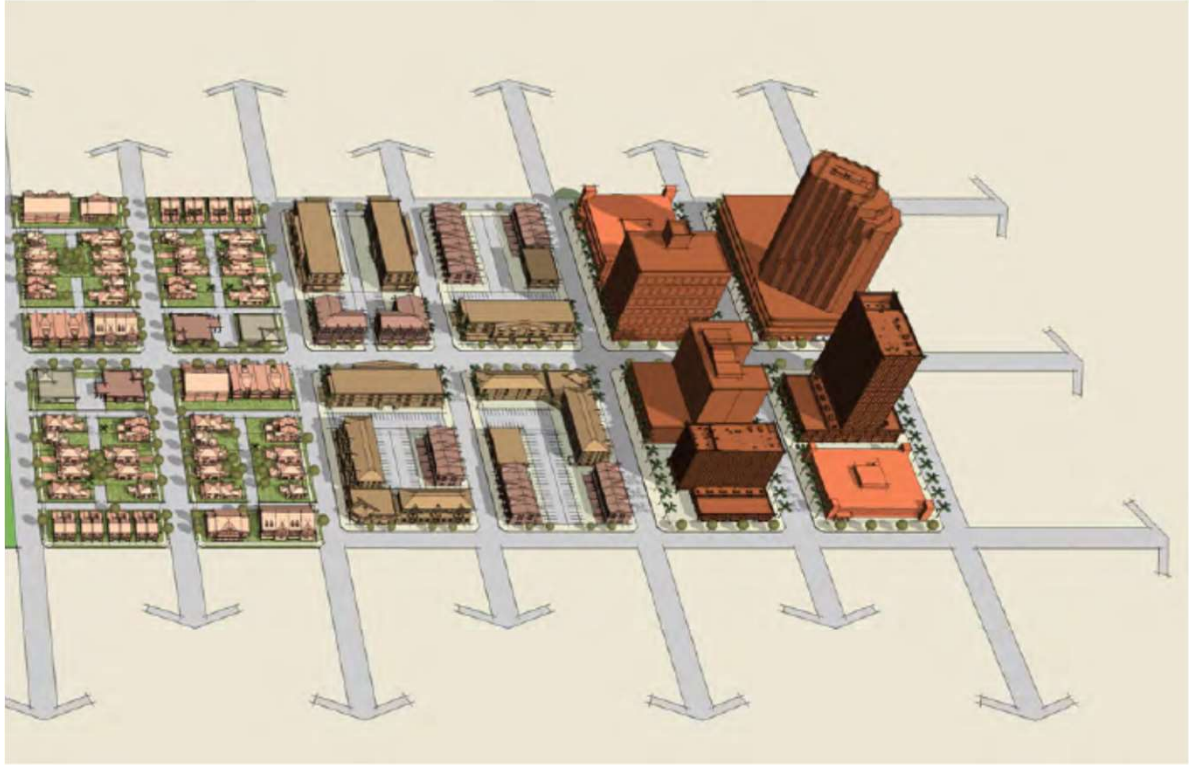
FDOT Context Classifications–Suburban

C3R-Suburban Residential
Mostly residential uses within large blocks and a disconnected or sparse roadway network.

C3C-Suburban Commercial
Mostly non-residential uses with large building footprints and large parking lots within large blocks and a disconnected or sparse roadway network.

FDOT Context Classifications–Urban



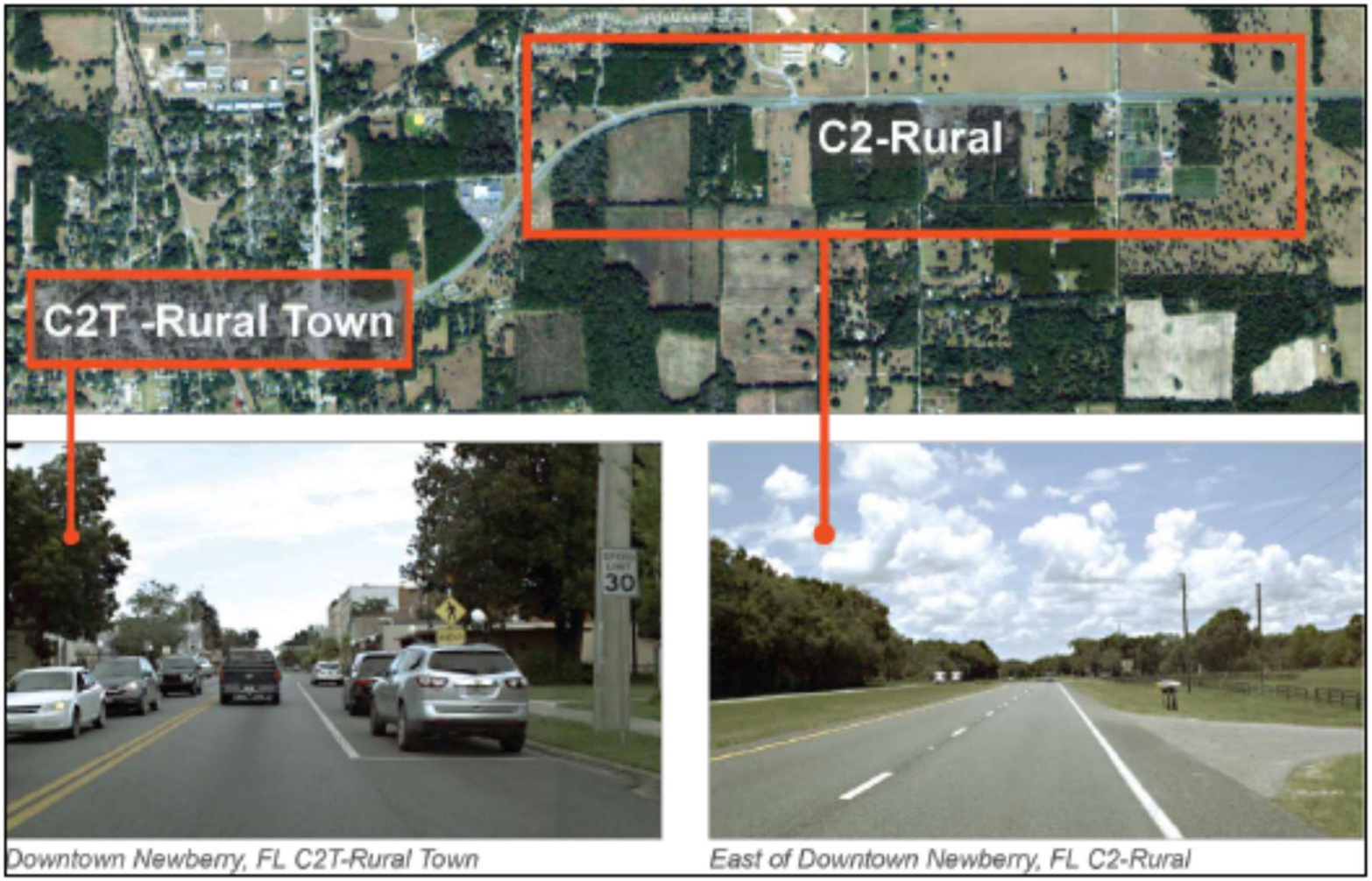
C4-Urban General
Mix of uses set within small blocks with a well-connected roadway network. May extend long distances. The roadway network usually connects to residential neighborhoods immediately along the corridor or behind the uses fronting the roadway.

C5-Urban Center
Mix of uses set within small blocks with a well-connected roadway network. Typically concentrated around a few blocks and identified as part of a civic or economic center of a community, town, or city.

C6-Urban Core
Areas with the highest densities and building heights, and within FDOT classified Large Urbanized Areas (population >1,000,000). Many are regional centers and destinations. Buildings have mixed uses, are built up to the roadway, and are within a well-connected roadway network.

Speed Management Through Design

Figure 202.4.1 Example of Transition Zone (SR 26 through Newberry, FL)

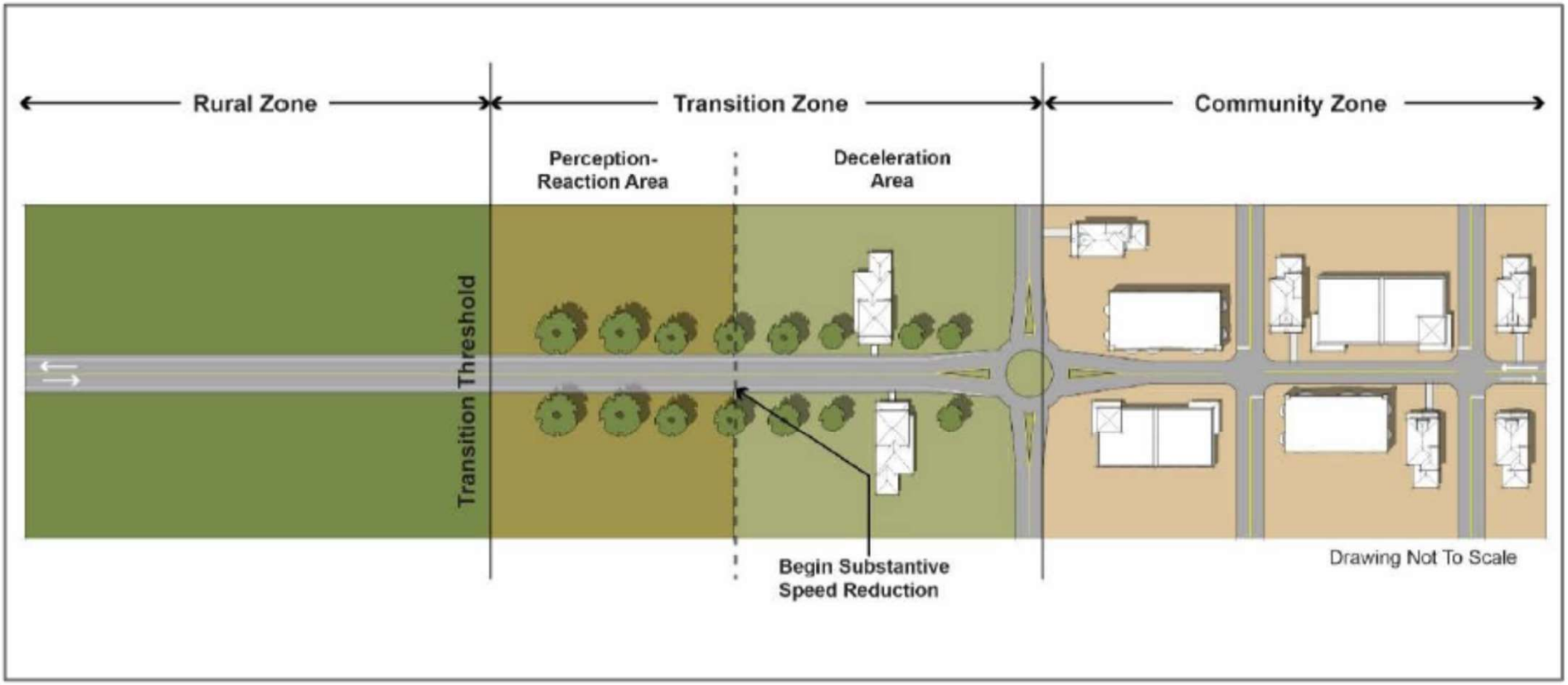


Downtown Newberry, FL C2T-Rural Town

East of Downtown Newberry, FL C2-Rural

Speed Management Through Design

Figure 202.4.2 Transition Zone from C1/C2 to C2T Context Classification



One sign effective at reducing speeds:

Questions?

Traffic Engineering Fundamentals

Intersection Design

Intersections

Intersection Types

- Two-way STOP controlled intersection
- All-way STOP controlled intersection
- Traffic Signal
- Roundabout

Two-way STOP Controlled

- Most common intersection type
- One roadway typically free flow, one roadway has to stop
- Defies motorist expectancy if uncontrolled movements are at right angles

SR 52 in Pasco County

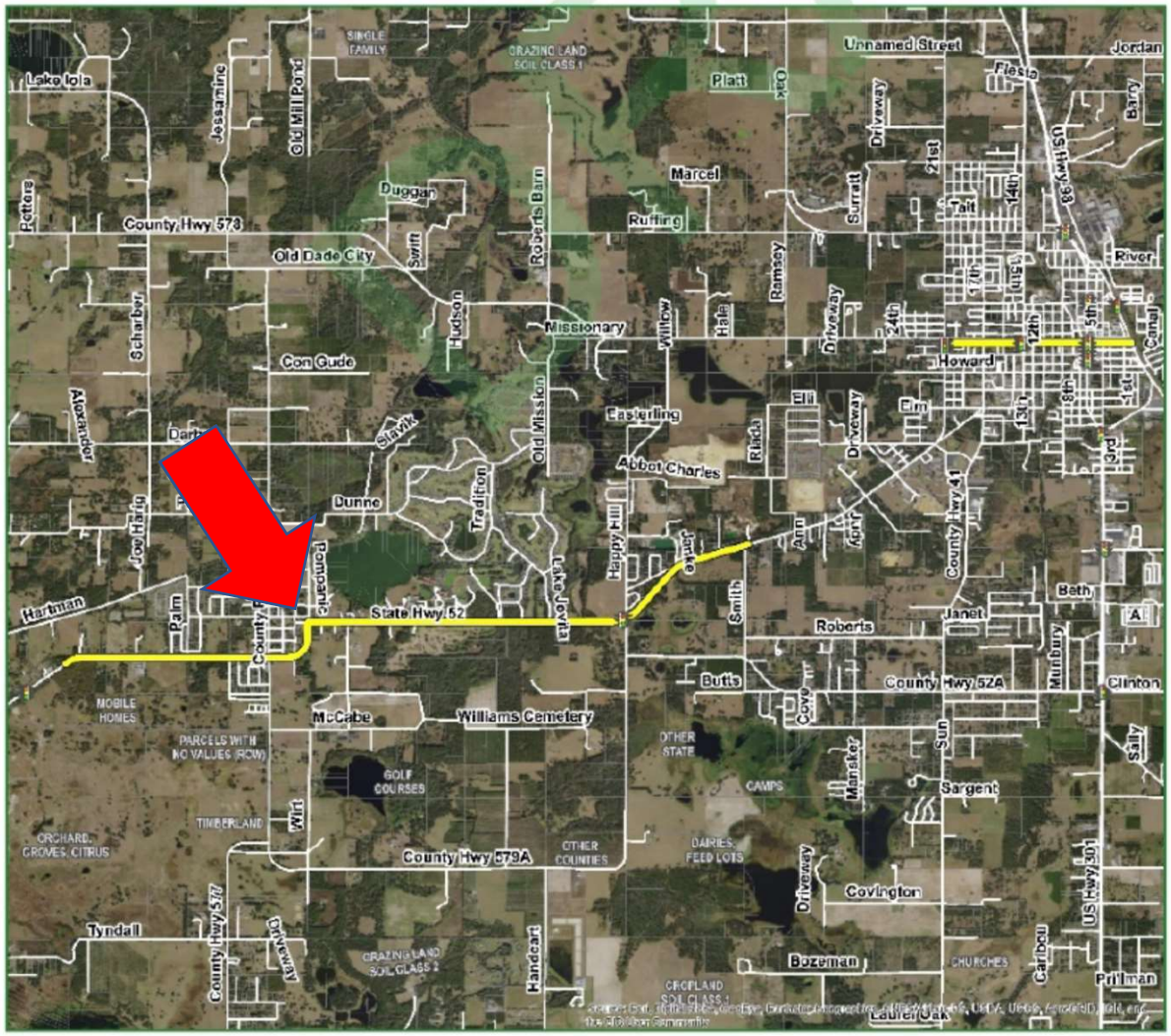


Figure 1:
Project Limits

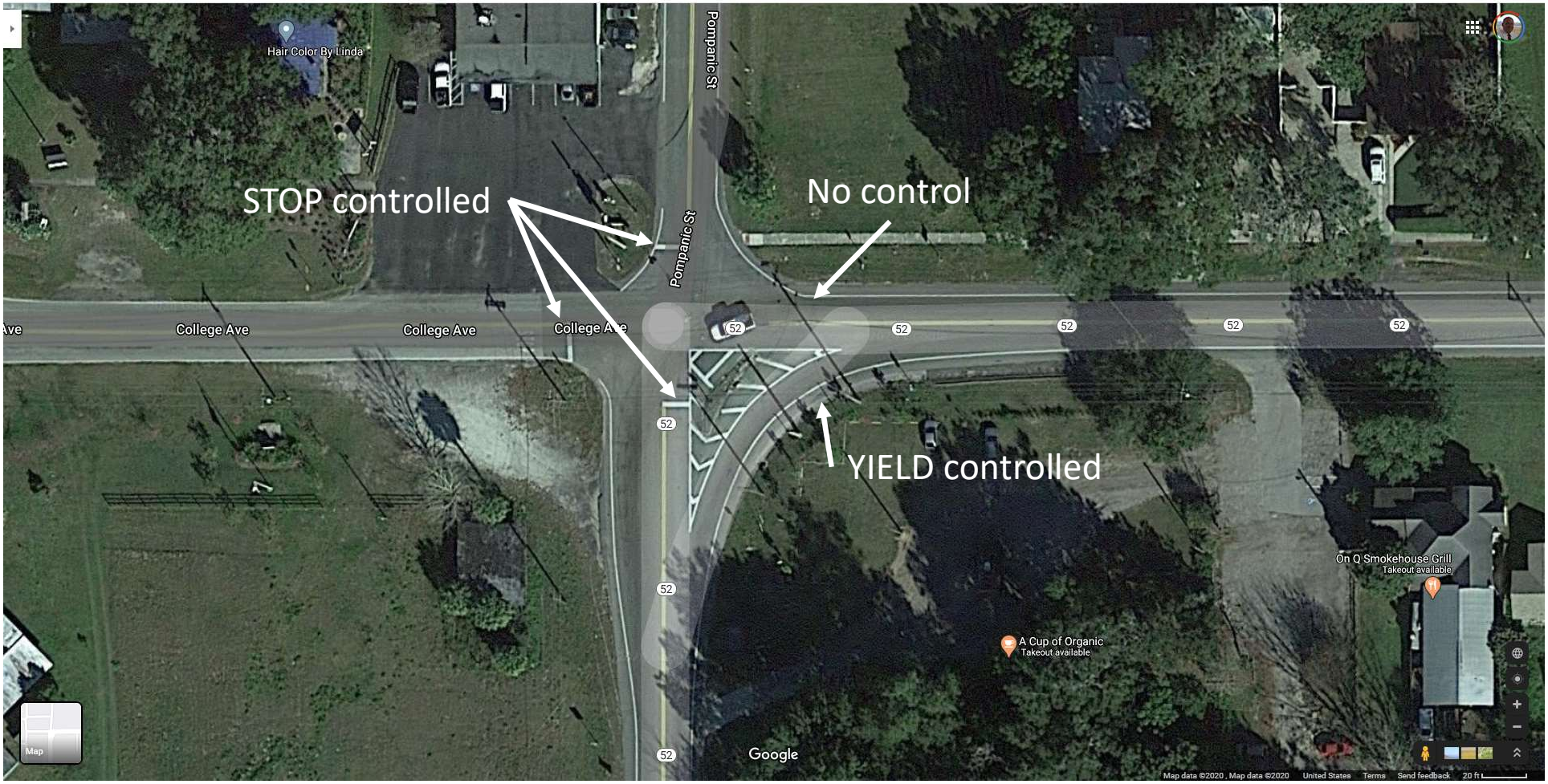
Legend

- Traffic Signals
- Project Limits
- Parcels 2017v2

N

0 2,050 4,100 8,200
Feet

SR 52 in Pasco County



All-way STOP Controlled

- Typically the safest intersection type
- Typically the least efficient
- Should NOT be used for speed control
- Rarely the best traffic control option

All-way STOP "Warrants"

The decision to install multi-way stop control should be based on an engineering study.

The following criteria should be considered in the engineering study for a multi-way STOP sign installation:

A. *Where traffic control signals are justified, the multi-way stop is an interim measure that can be installed quickly to control traffic while arrangements are being made for the installation of the traffic control signal.*

B. *Five or more reported crashes in a 12-month period that are susceptible to correction by a multi-way stop installation. Such crashes include right-turn and left-turn collisions as well as right-angle collisions.*

C. *Minimum volumes:*

   1. *The vehicular volume entering the intersection from the major street approaches (total of both approaches) averages at least 300 vehicles per hour for any 8 hours of an average day; and*
   2. *The combined vehicular, pedestrian, and bicycle volume entering the intersection from the minor street approaches (total of both approaches) averages at least 200 units per hour for the same 8 hours, with an average delay to minor-street vehicular traffic of at least 30 seconds per vehicle during the highest hour; but*
   3. *If the 85th-percentile approach speed of the major-street traffic exceeds 40 mph, the minimum vehicular volume warrants are 70 percent of the values provided in Items 1 and 2.*

D. *Where no single criterion is satisfied, but where Criteria B, C.1, and C.2 are all satisfied to 80 percent of the minimum values. Criterion C.3 is excluded from this condition.*

From 2009 MUTCD

Traffic Signals

- Typically provide for an orderly flow of traffic by assigning right-of-way
- Often increase the intersection capacity
- Reduce the frequency and severity of <u>some crash types</u>

Traffic Signals

- NOT the safest intersection type
- Crashes typically increase when signals are installed
- Can be coordinated with adjacent signals

Engineering Study is Required

An engineering study of traffic conditions, pedestrian characteristics, and physical characteristics of the location shall be performed to determine whether installation of a traffic control signal is justified at a particular location.

From 2009 MUTCD

Signal Warrants

- **Warrant 1, Eight-Hour Vehicular Volume**
- **Warrant 2, Four-Hour Vehicular Volume**
- **Warrant 3, Peak Hour**
- **Warrant 4, Pedestrian Volume**
- **Warrant 5, School Crossing**
- **Warrant 6, Coordinated Signal System**
- **Warrant 7, Crash Experience**
- **Warrant 8, Roadway Network**
- **Warrant 9, Intersection Near a Grade Crossing**

Important Note:

"The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal."

From 2009 MUTCD

Table 4C-1. Warrant 1, Eight-Hour Vehicular Volume

Condition A—Minimum Vehicular Volume

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1	1	500	400	350	280	150	120	105	84
2 or more	1	600	480	420	336	150	120	105	84
2 or more	2 or more	600	480	420	336	200	160	140	112
1	2 or more	500	400	350	280	200	160	140	112

Condition B—Interruption of Continuous Traffic

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1	1	750	600	525	420	75	60	53	42
2 or more	1	900	720	630	504	75	60	53	42
2 or more	2 or more	900	720	630	504	100	80	70	56
1	2 or more	750	600	525	420	100	80	70	56

[a] Basic minimum hourly volume

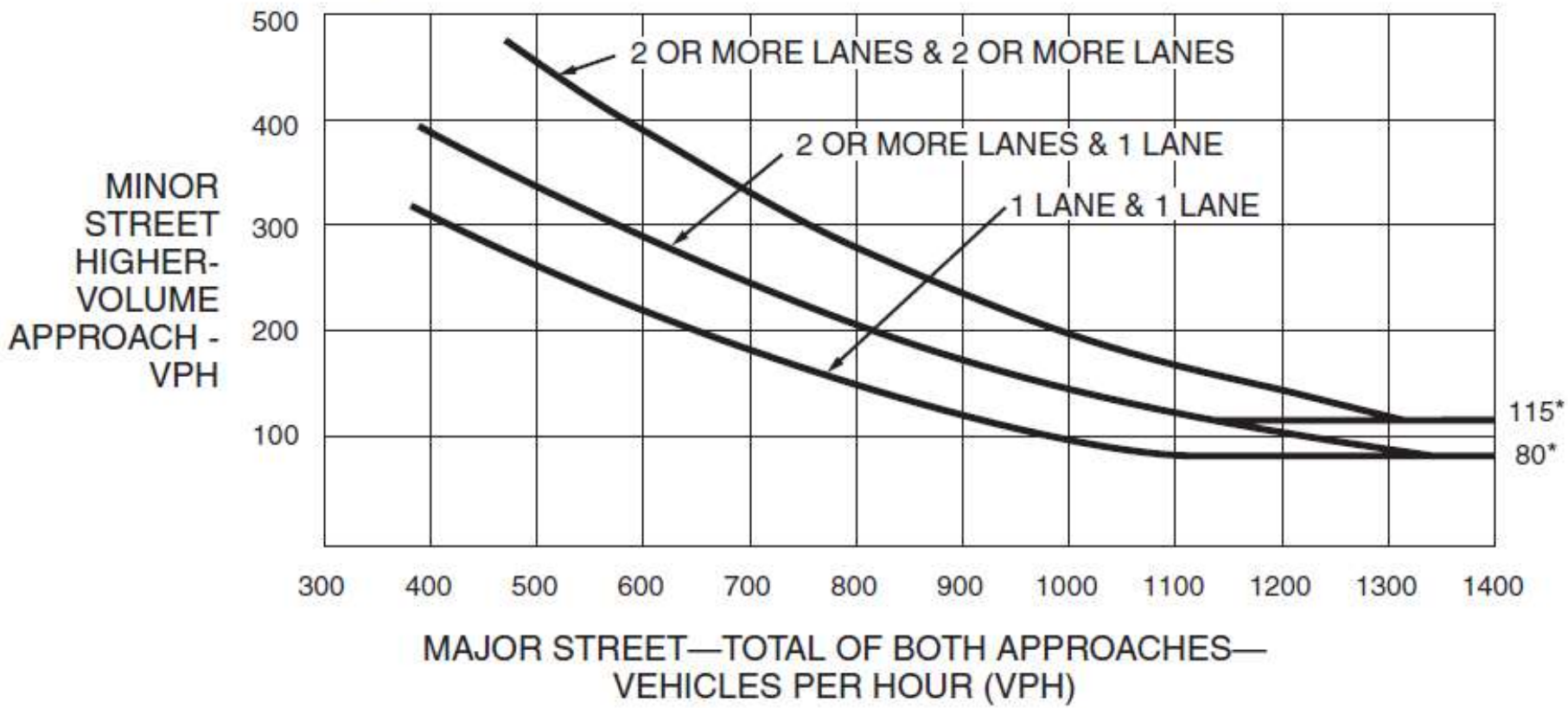
[b] Used for combination of Conditions A and B after adequate trial of other remedial measures

[c] May be used when the major-street speed exceeds 40 mph or in an isolated community with a population of less than 10,000

[d] May be used for combination of Conditions A and B after adequate trial of other remedial measures when the major-street speed exceeds 40 mph or in an isolated community with a population of less than 10,000

Warrant 2, Four-Hour Vehicular Volume

Figure 4C-1. Warrant 2, Four-Hour Vehicular Volume

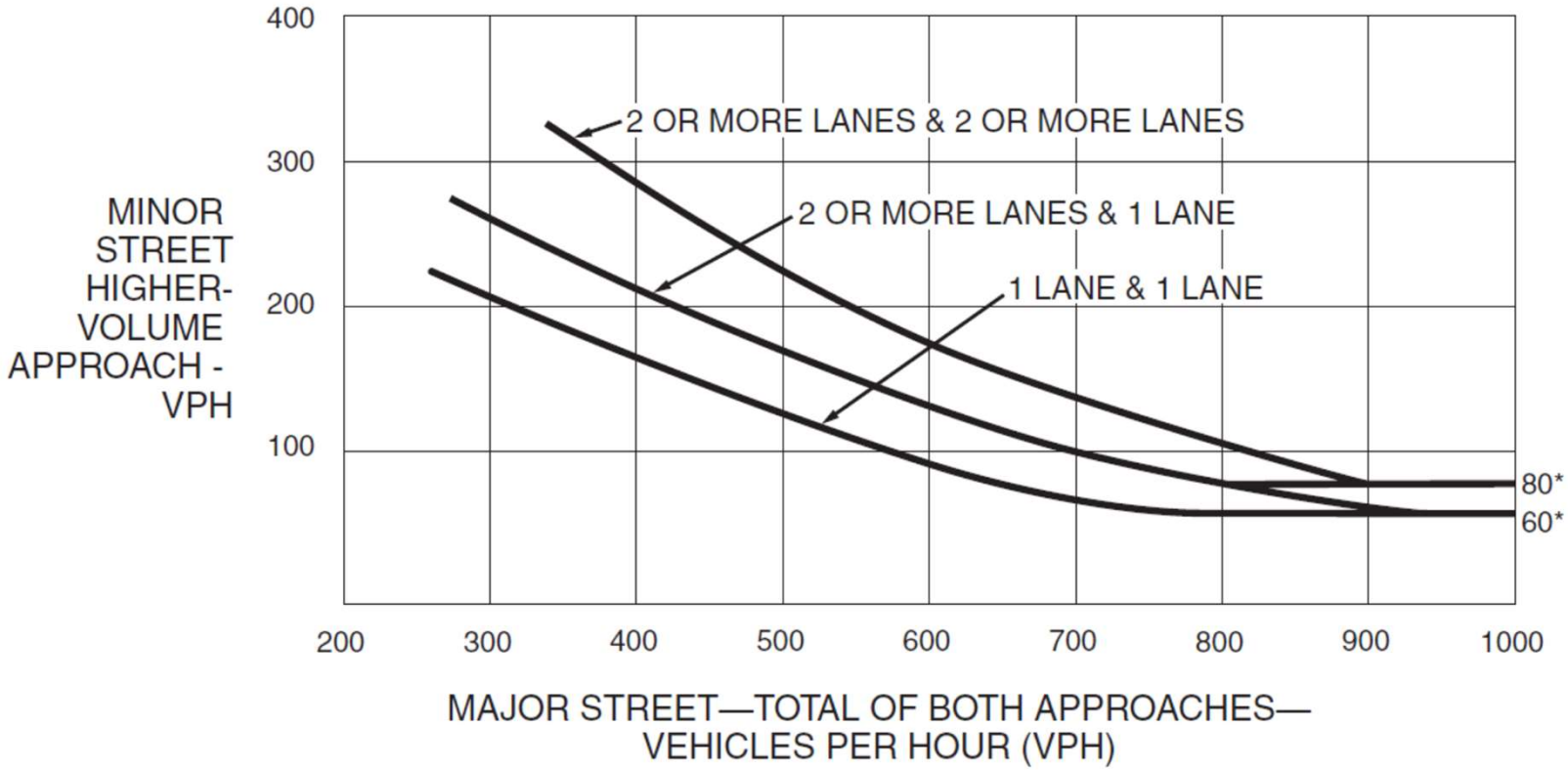


*Note: 115 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 80 vph applies as the lower threshold volume for a minor-street approach with one lane.

Warrant 2, Four-Hour Vehicular Volume

Figure 4C-2. Warrant 2, Four-Hour Vehicular Volume (70% Factor)

(COMMUNITY LESS THAN 10,000 POPULATION OR ABOVE 40 MPH ON MAJOR STREET)



*Note: 80 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 60 vph applies as the lower threshold volume for a minor-street approach with one lane.

Warrant 3, Peak Hour

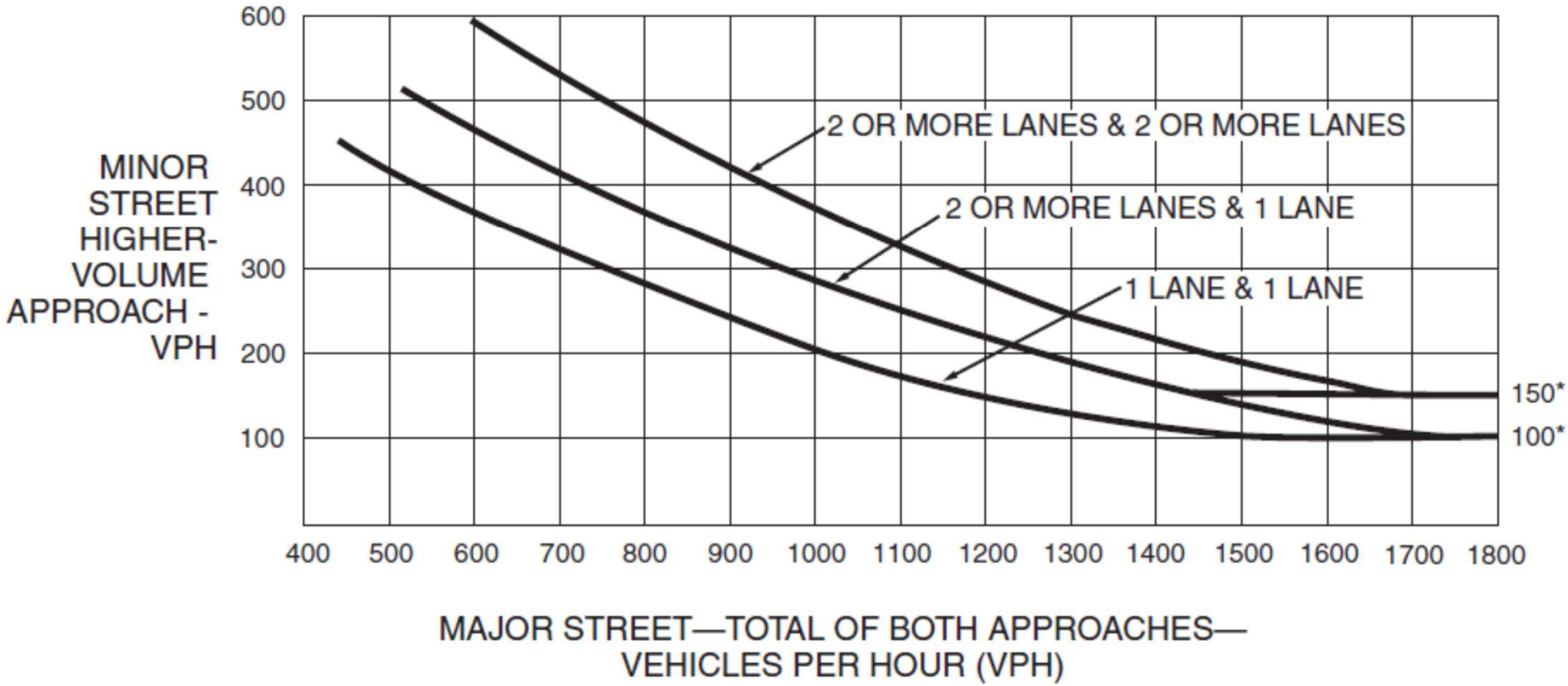
This signal warrant shall be applied only in unusual cases, such as office complexes, manufacturing plants, industrial complexes, or high-occupancy vehicle facilities that attract or discharge large numbers of vehicles over a short time.

Warrant 3, Peak Hour

- Signals installed under Warrant 3 (peak hour):
  - should be traffic-actuated, and
  - may be operated in flashing mode during off-peak hours

Warrant 3, Peak Hour

Figure 4C-3. Warrant 3, Peak Hour

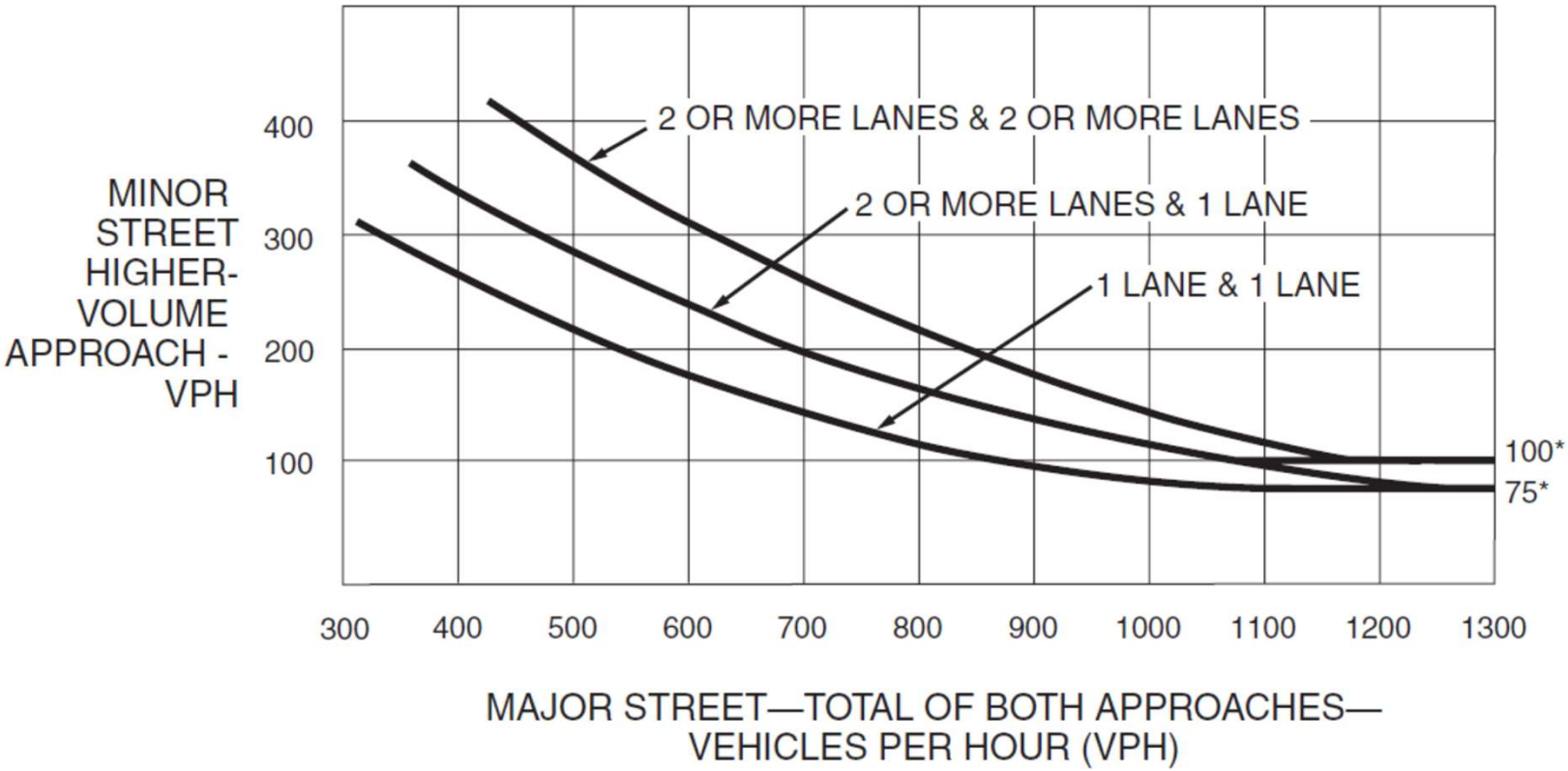


*Note: 150 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 100 vph applies as the lower threshold volume for a minor-street approach with one lane.

Warrant 3, Peak Hour

Figure 4C-4. Warrant 3, Peak Hour (70% Factor)

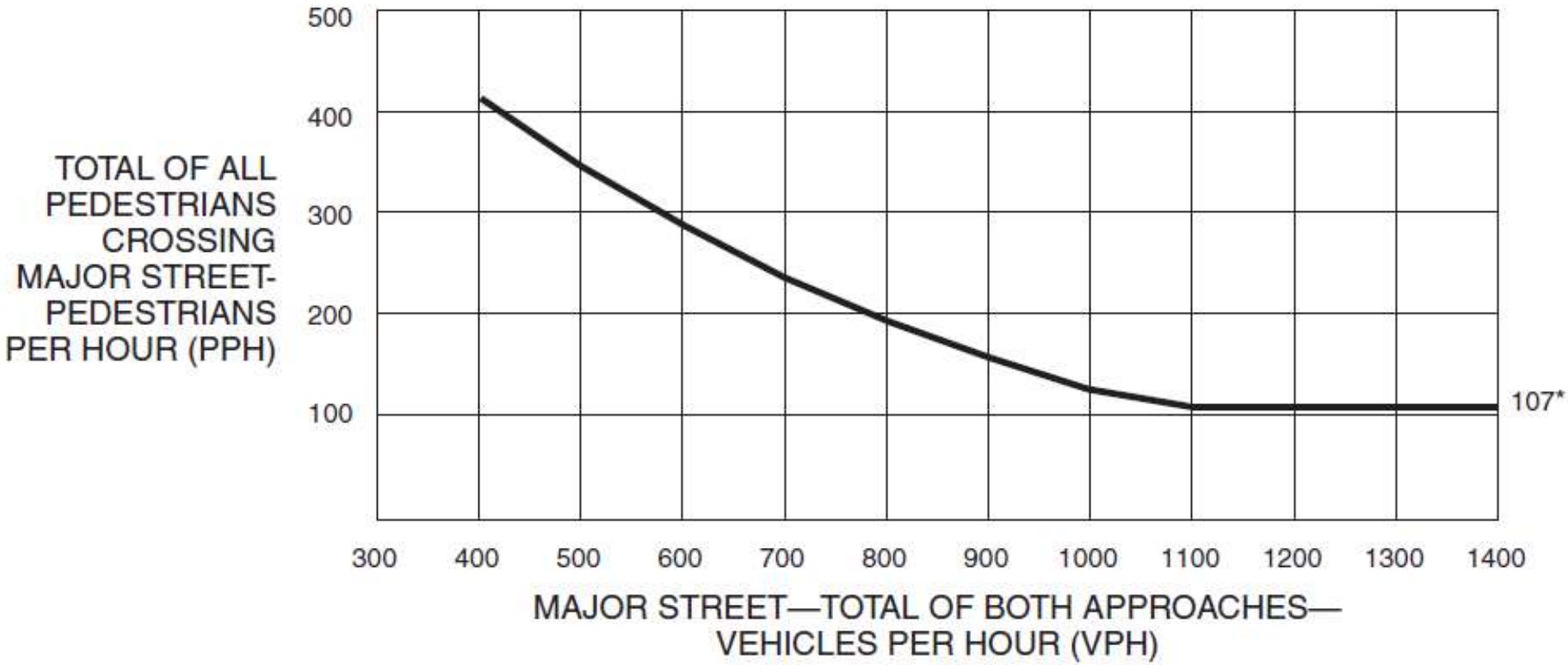
(COMMUNITY LESS THAN 10,000 POPULATION OR ABOVE 40 MPH ON MAJOR STREET)



*Note: 100 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 75 vph applies as the lower threshold volume for a minor-street approach with one lane.

Warrant 4, Pedestrian Volume

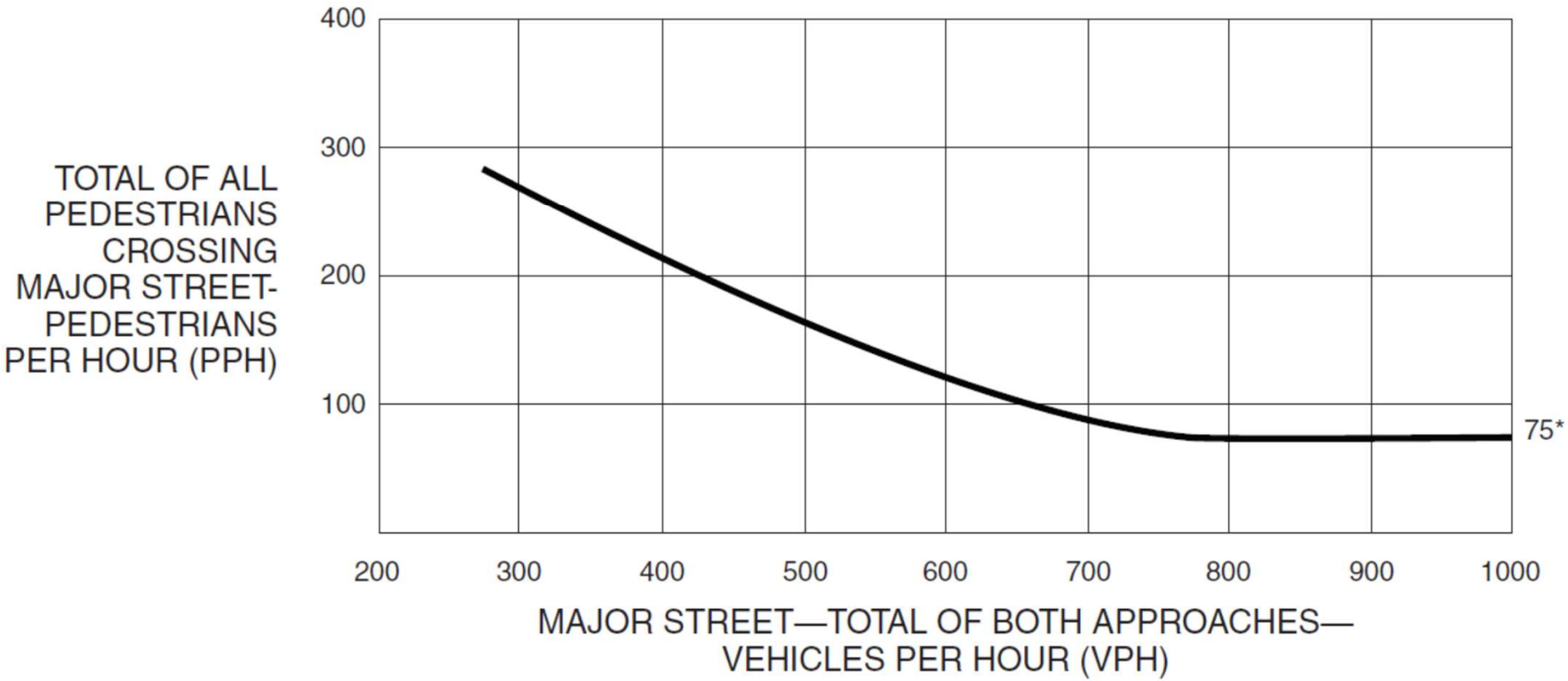
Figure 4C-5. Warrant 4, Pedestrian Four-Hour Volume



*Note: 107 pph applies as the lower threshold volume.

Warrant 4, Pedestrian Volume

Figure 4C-6. Warrant 4, Pedestrian Four-Hour Volume (70% Factor)



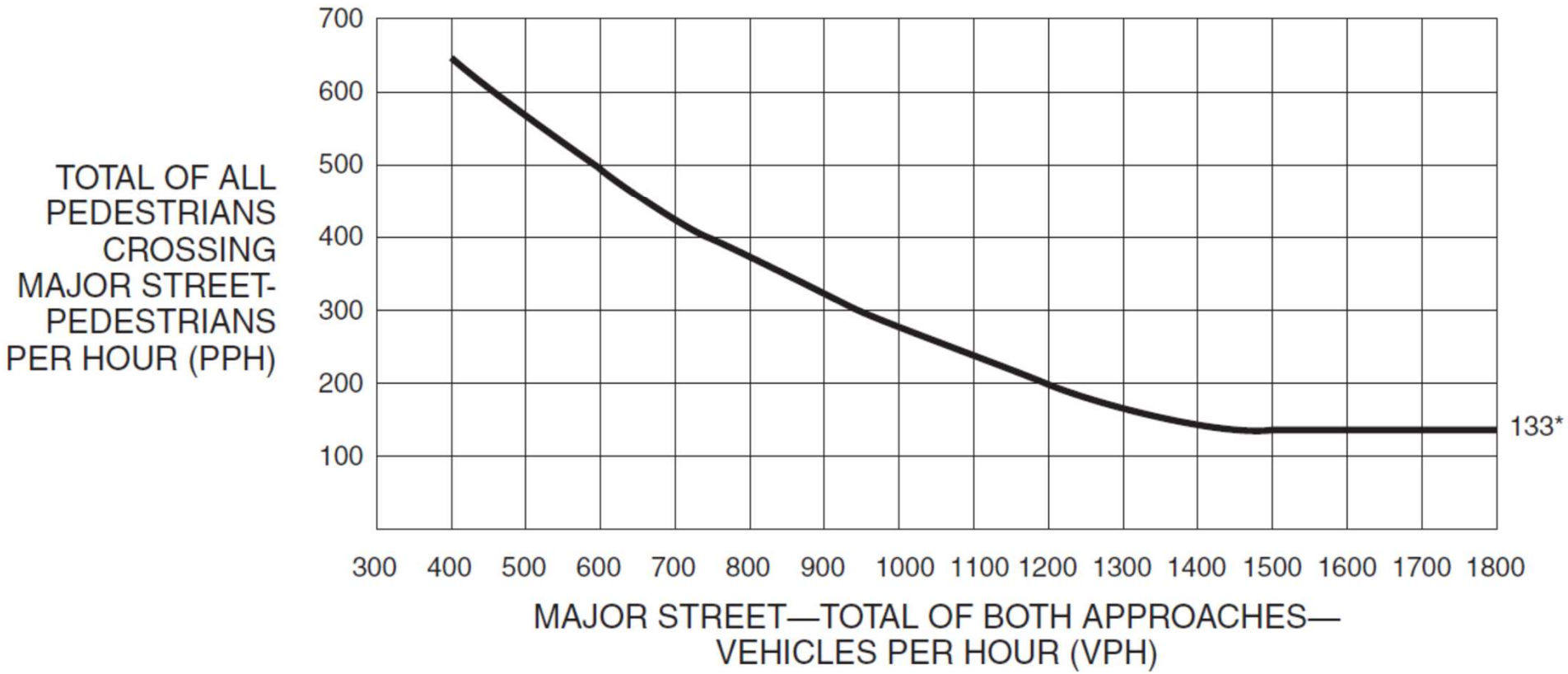
*Note: 75 pph applies as the lower threshold volume.

What's the 70% factor?

If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 35 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 4C-6 may be used in place of Figure 4C-5 to evaluate Criterion A in Paragraph 2, and Figure 4C-8 may be used in place of Figure 4C-7 to evaluate Criterion B in Paragraph 2.

Warrant 4, Pedestrian Volume

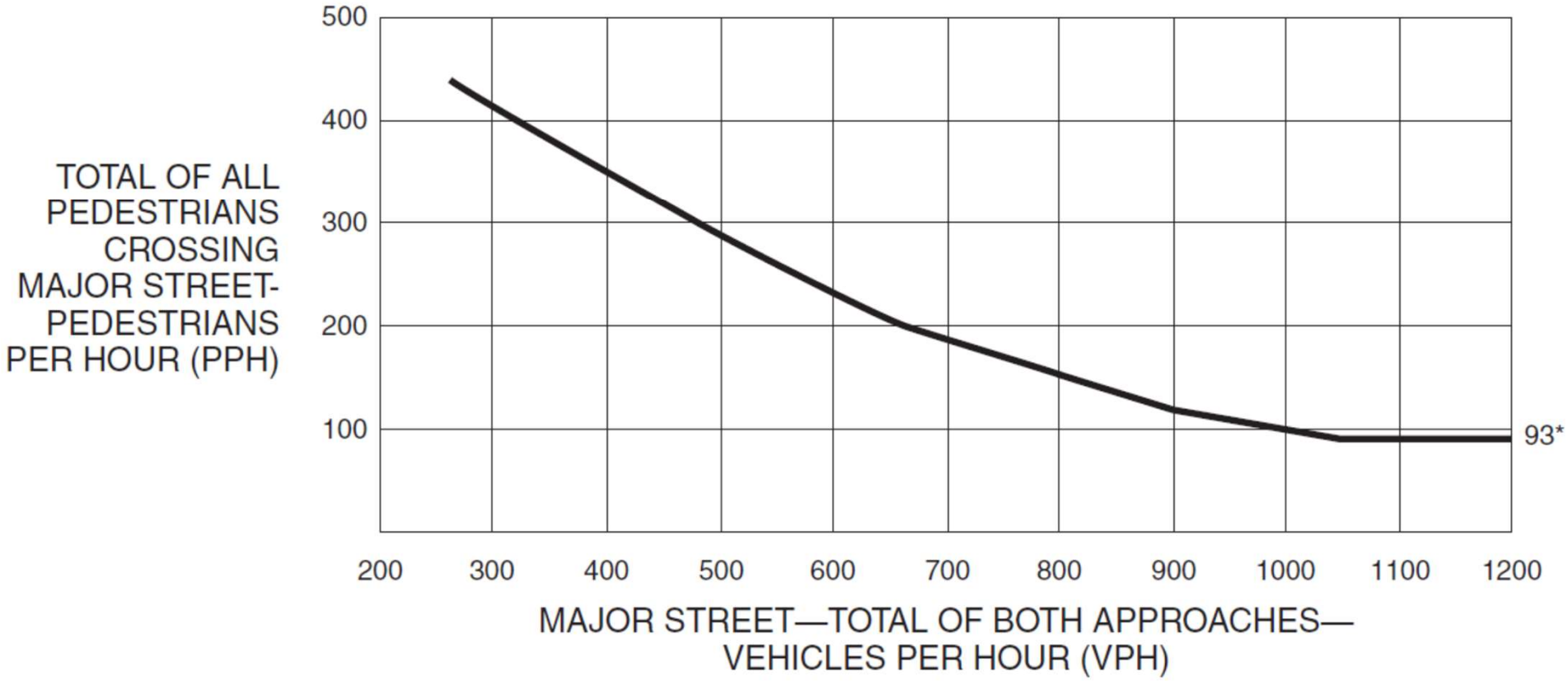
Figure 4C-7. Warrant 4, Pedestrian Peak Hour



*Note: 133 pph applies as the lower threshold volume.

Warrant 4, Pedestrian Volume

Figure 4C-8. Warrant 4, Pedestrian Peak Hour (70% Factor)



*Note: 93 pph applies as the lower threshold volume.

Warrant 5, School Crossing

The need for a traffic control signal shall be considered when an engineering study of the frequency and adequacy of gaps in the vehicular traffic stream as related to the number and size of groups of schoolchildren at an established school crossing across the major street shows that the number of adequate gaps in the traffic stream during the period when the schoolchildren are using the crossing is less than the number of minutes in the same period (see Section 7A.03) and there are a minimum of 20 schoolchildren during the highest crossing hour.

Warrant 5, School Crossing

Before a decision is made to install a traffic control signal, consideration shall be given to the implementation of other remedial measures, such as warning signs and flashers, school speed zones, school crossing guards, or a grade-separated crossing.

Warrant 6, Coordinated Signal System

The need for a traffic control signal shall be considered if an engineering study finds that one of the following criteria is met:

- **A. On a one-way street or a street that has traffic predominantly in one direction, the adjacent traffic control signals are so far apart that they do not provide the necessary degree of vehicular platooning.**
- **B. On a two-way street, adjacent traffic control signals do not provide the necessary degree of platooning and the proposed and adjacent traffic control signals will collectively provide a progressive operation.**

Warrant 7, Crash Experience

Three parts to crash experience warrant:

1. **Adequate trial of alternatives with satisfactory observance and <u>enforcement</u> has failed to reduce the crash frequency; AND**

Warrant 7, Crash Experience

2. **Five or more reported crashes, <u>of types susceptible to correction by a traffic control signal</u>, have occurred within a 12-month period, each crash involving personal injury or property damage apparently exceeding the applicable requirements for a reportable crash; AND**

Warrant 7, Crash Experience

3. **Must have at least 80% of the vehicular traffic from the 8-hour volume warrant or 80% of the warranting pedestrian volume**

Note that ALL THREE conditions must be met in order to warrant a traffic signal by crash experience.

Warrant 8, Roadway Network

The need for a traffic control signal shall be considered if an engineering study finds that the common intersection of two or more major routes meets one or both of the following criteria:

A. The intersection has a total existing, or immediately projected, entering volume of at least 1,000 vehicles per hour during the peak hour of a typical weekday and has 5-year projected traffic volumes, based on an engineering study, that meet one or more of Warrants 1, 2, and 3 during an average weekday; or

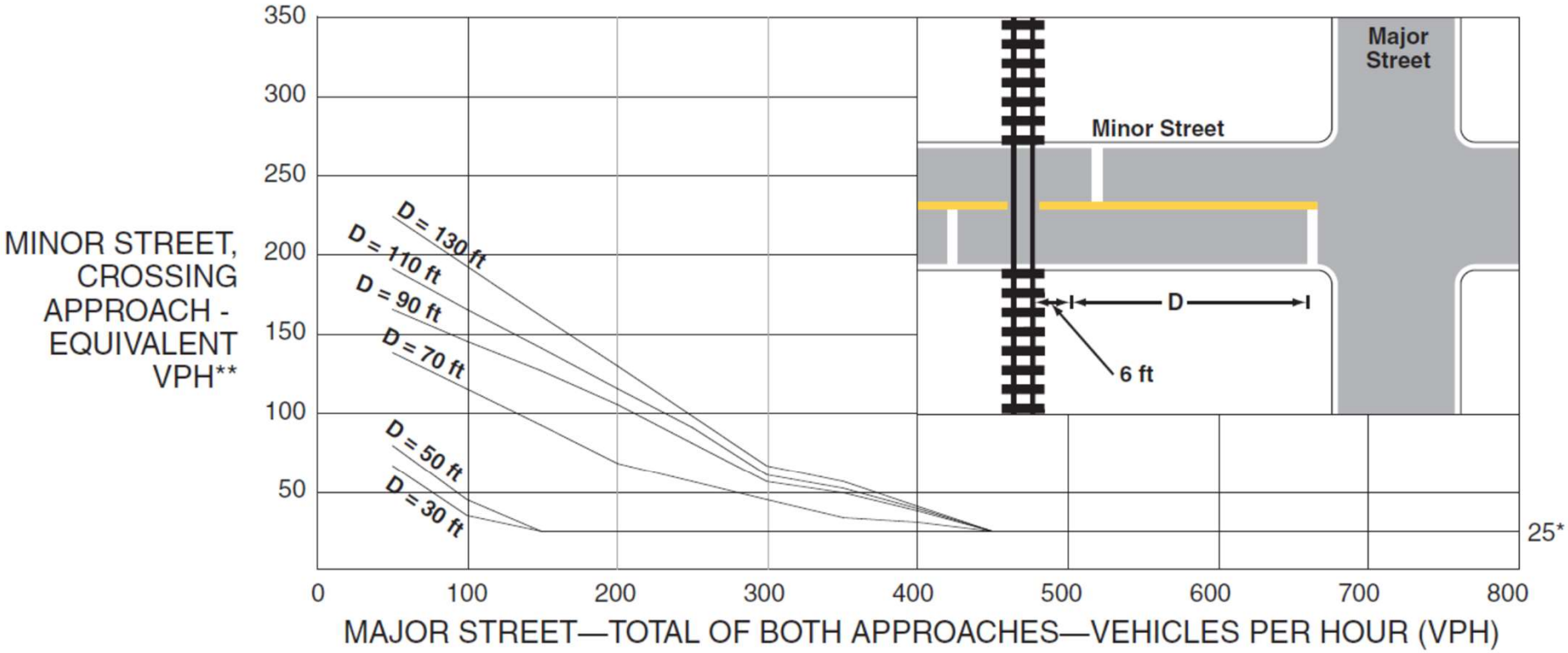
Warrant 8, Roadway Network

The need for a traffic control signal shall be considered if an engineering study finds that the common intersection of two or more major routes meets one or both of the following criteria:

B. The intersection has a total existing or immediately projected entering volume of at least 1,000 vehicles per hour for each of any 5 hours of a non-normal business day (Saturday or Sunday).

Warrant 9, Intersection Near RR X-ing

Figure 4C-9. Warrant 9, Intersection Near a Grade Crossing (One Approach Lane at the Track Crossing)

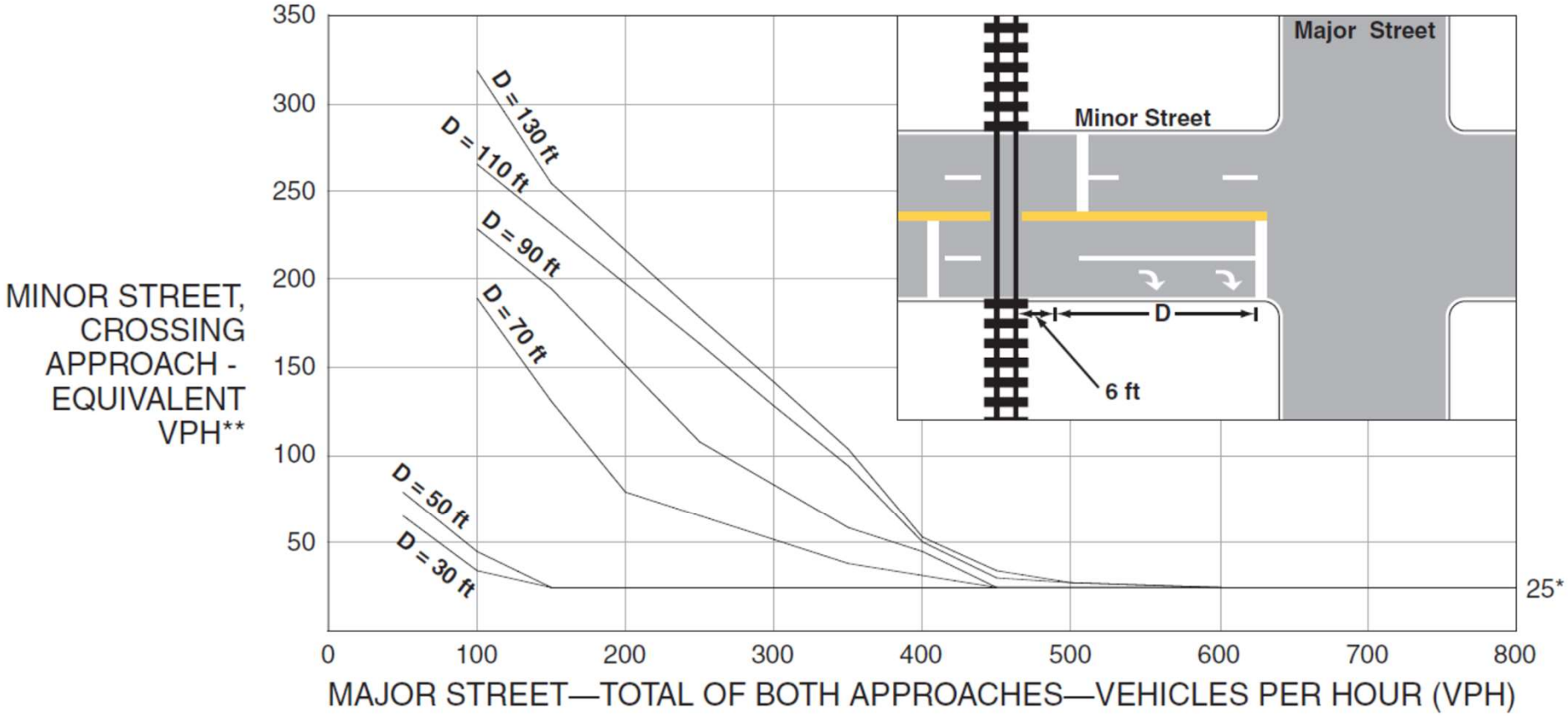


* 25 vph applies as the lower threshold volume

** VPH after applying the adjustment factors in Tables 4C-2, 4C-3, and/or 4C-4, if appropriate

Warrant 9, Intersection Near RR X-ing

Figure 4C-10. Warrant 9, Intersection Near a Grade Crossing (Two or More Approach Lanes at the Track Crossing)



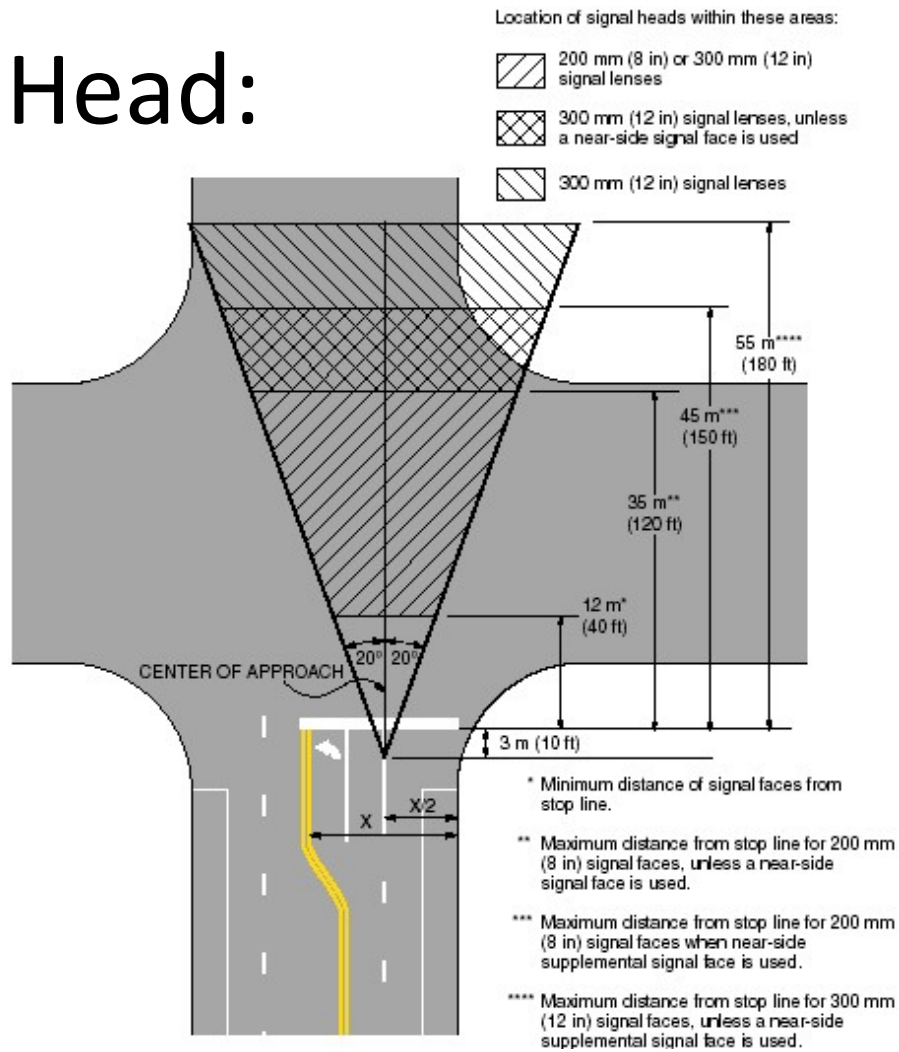
* 25 vph applies as the lower threshold volume

** VPH after applying the adjustment factors in Tables 4C-2, 4C-3, and/or 4C-4, if appropriate

SIGNAL VISIBILITY

At Least One Signal Head:

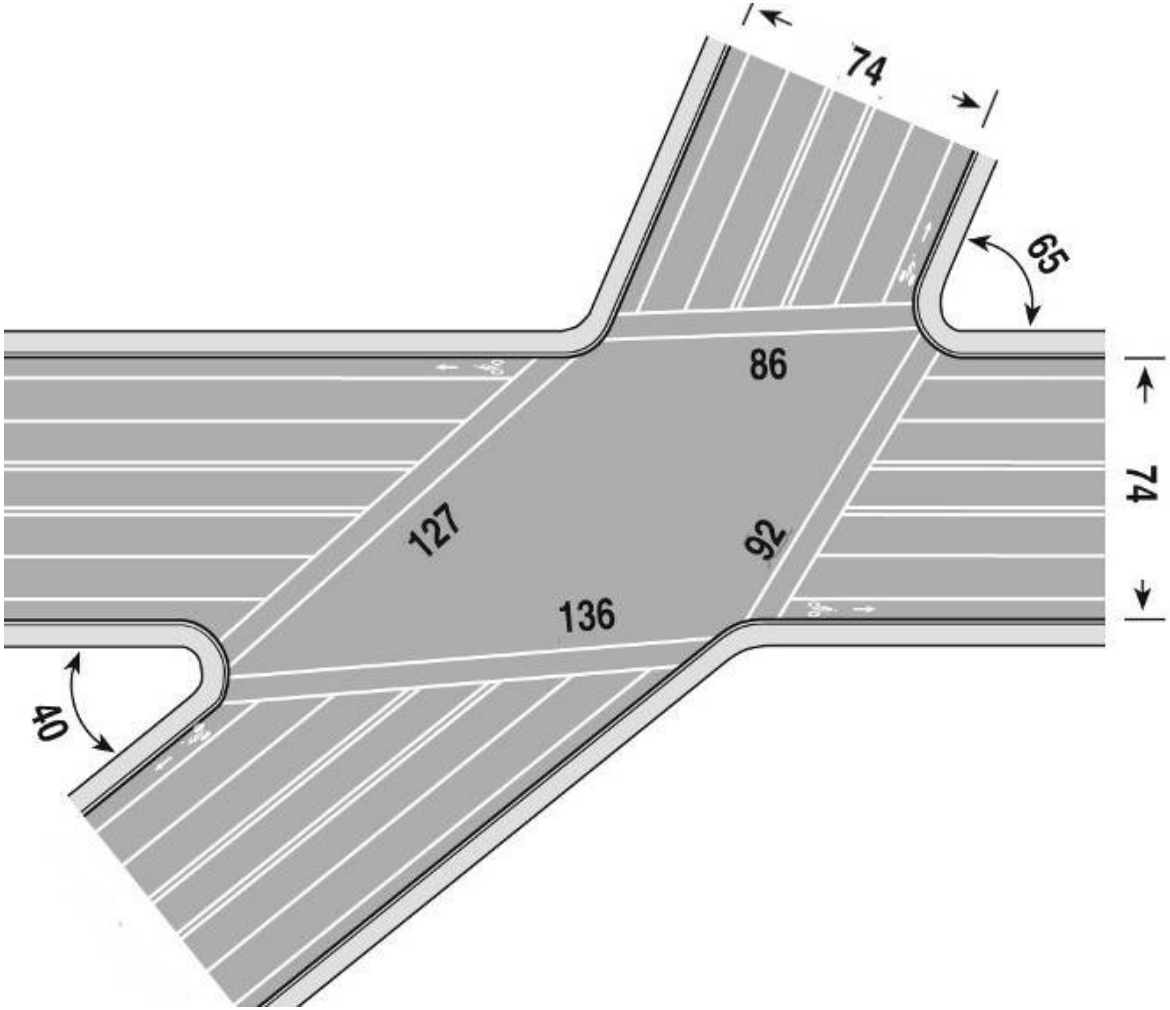
- > 40’ from stop line
- < 180’ from stop line
- Within 20° angle left and right of centerline of approach
- Mounting height
  - 15 ft to bottom (min.)
  - 25.6 ft to top (max.)



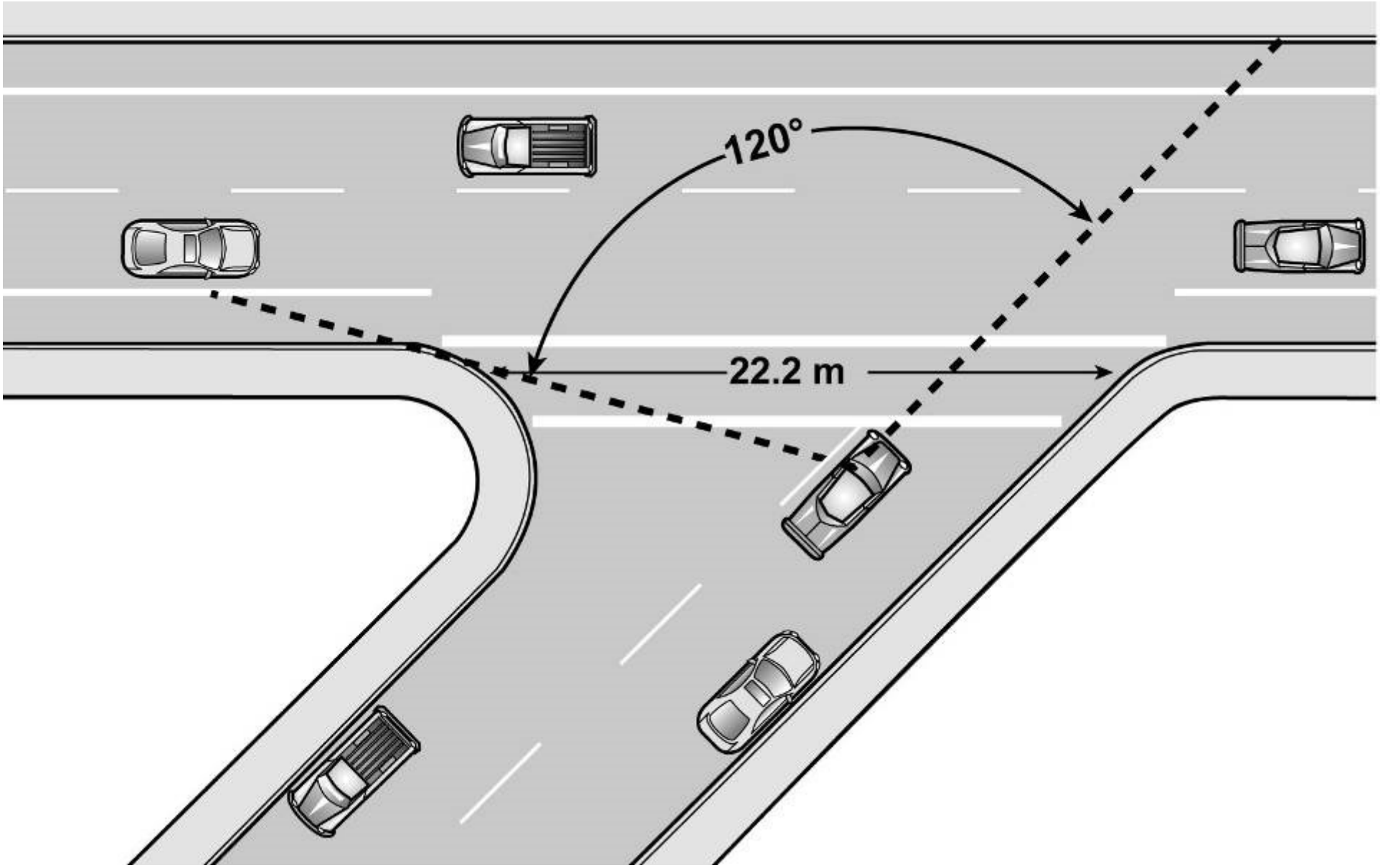
Questions?

Intersection Design Controls

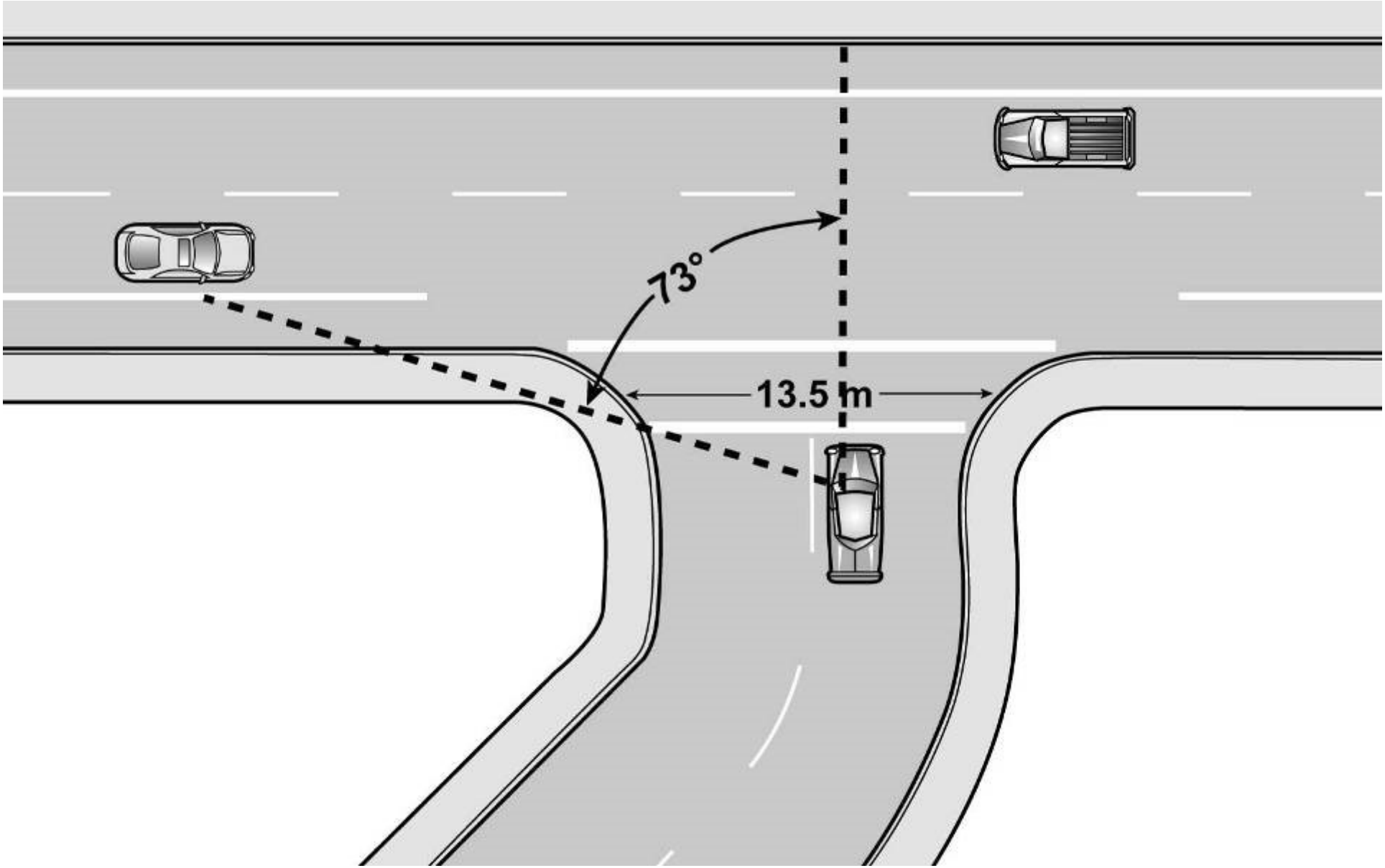
Skewed Intersections



Skew increases crossing distance & speed of turning cars



Skew increases crosswalk length, decreases visibility



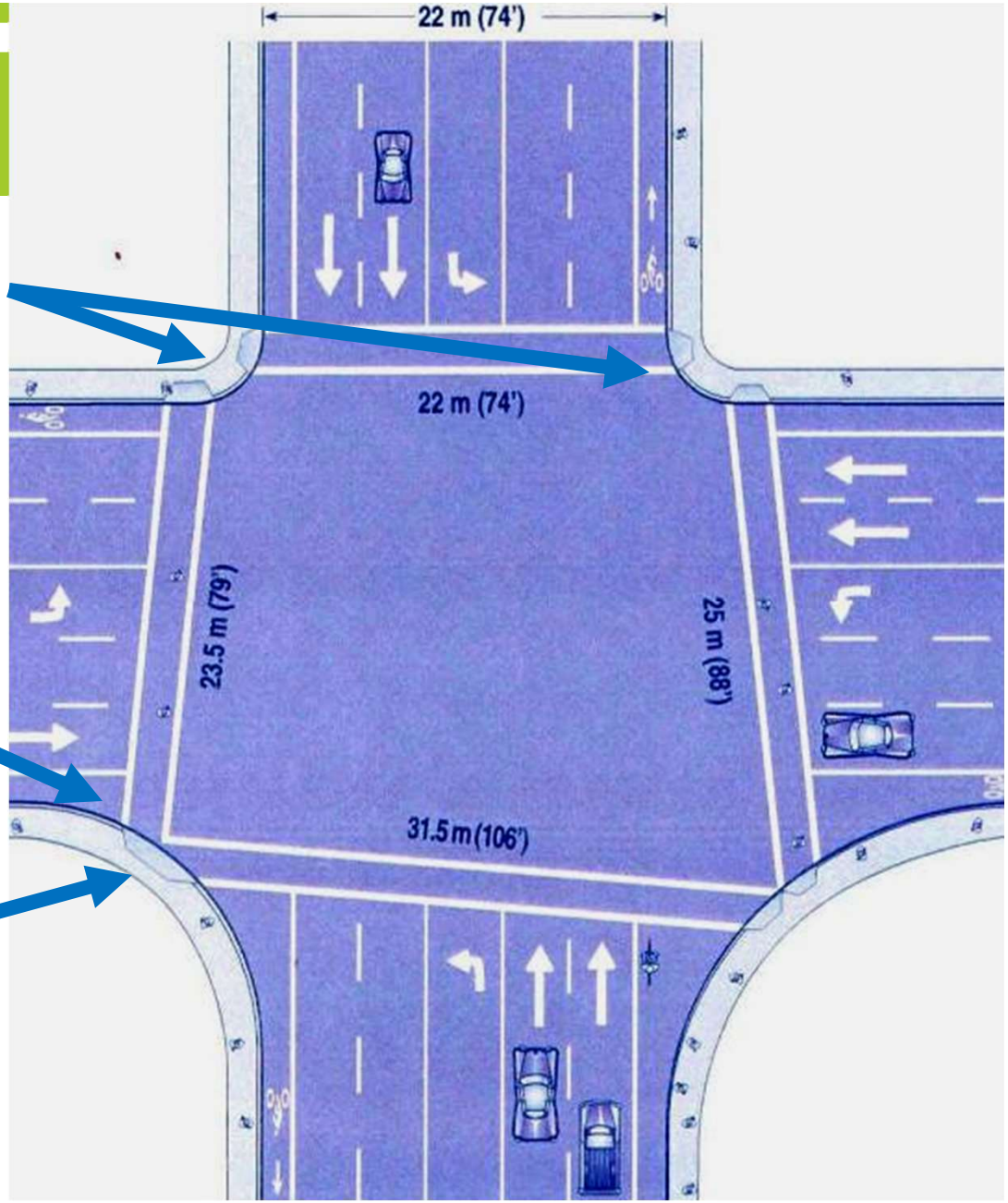
Right angle decreases crosswalk length, increases visibility

Curb Radii

Small radii are safer for pedestrians

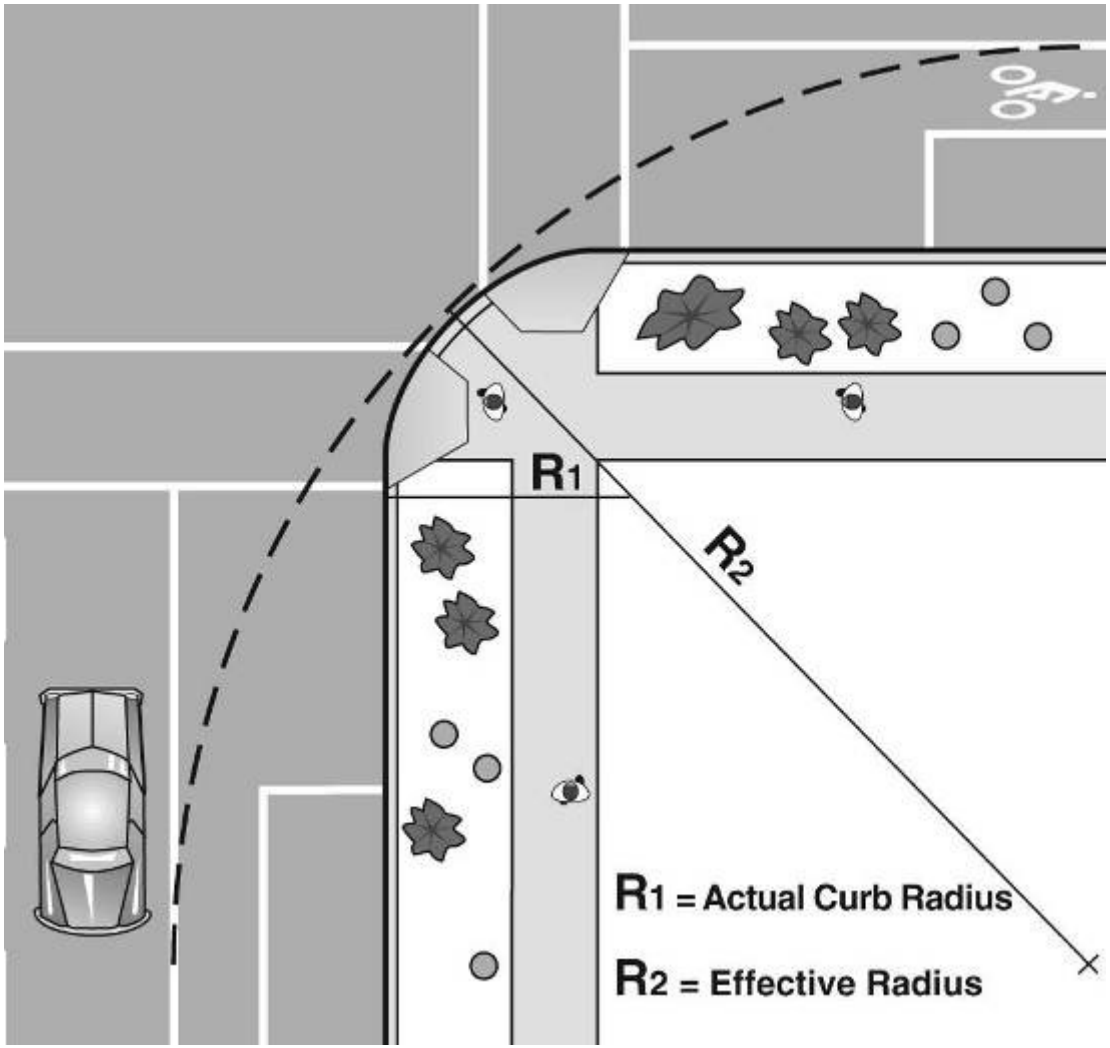
Large radii

1. **Increase crossing distance and**
2. **Make crosswalk & ramp placement more difficult**



Keeping it tight: curb radius

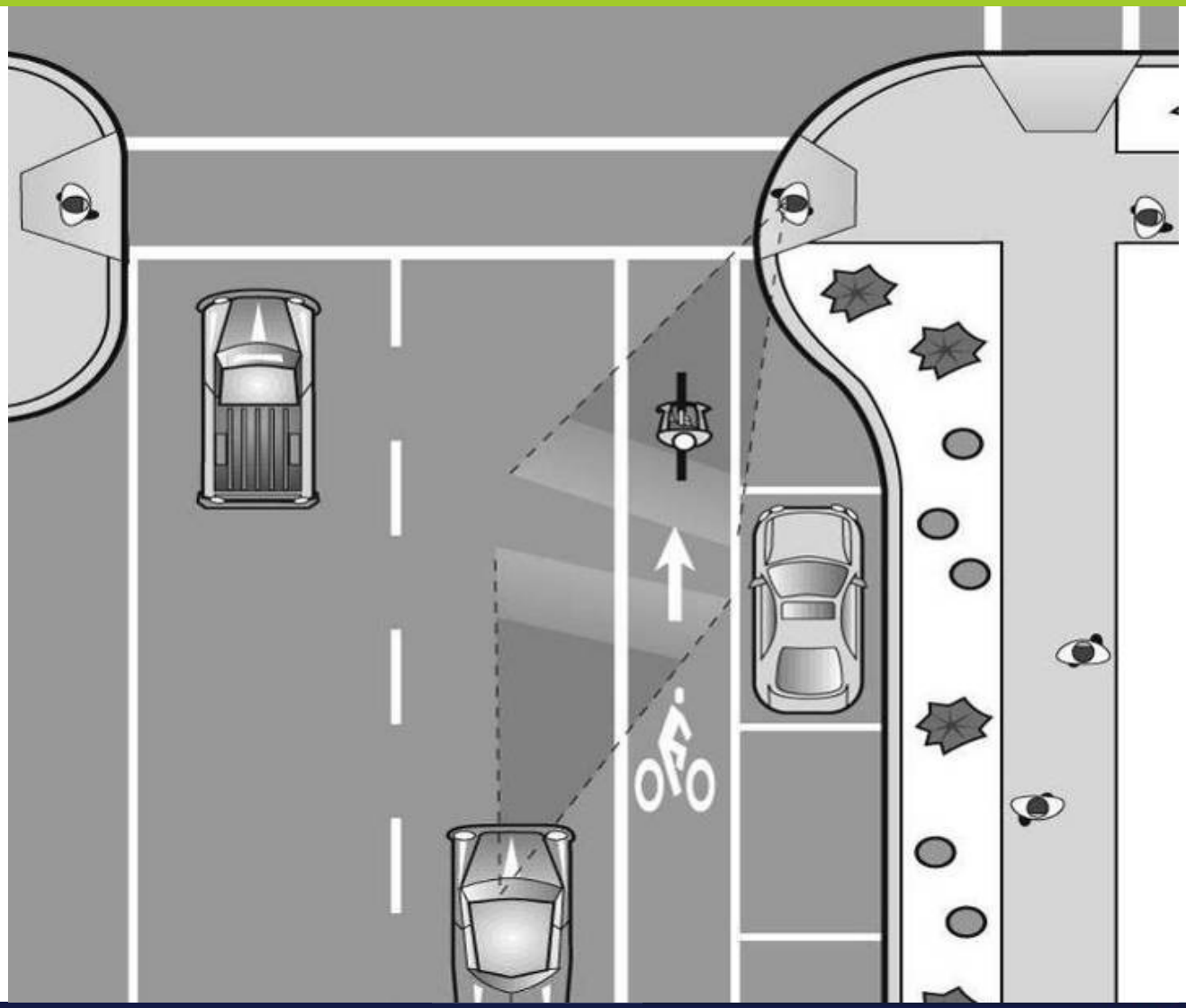
Effective radius is larger than built radius if travel lanes are offset from curb w/ parking/bike lane



Canyonville OR

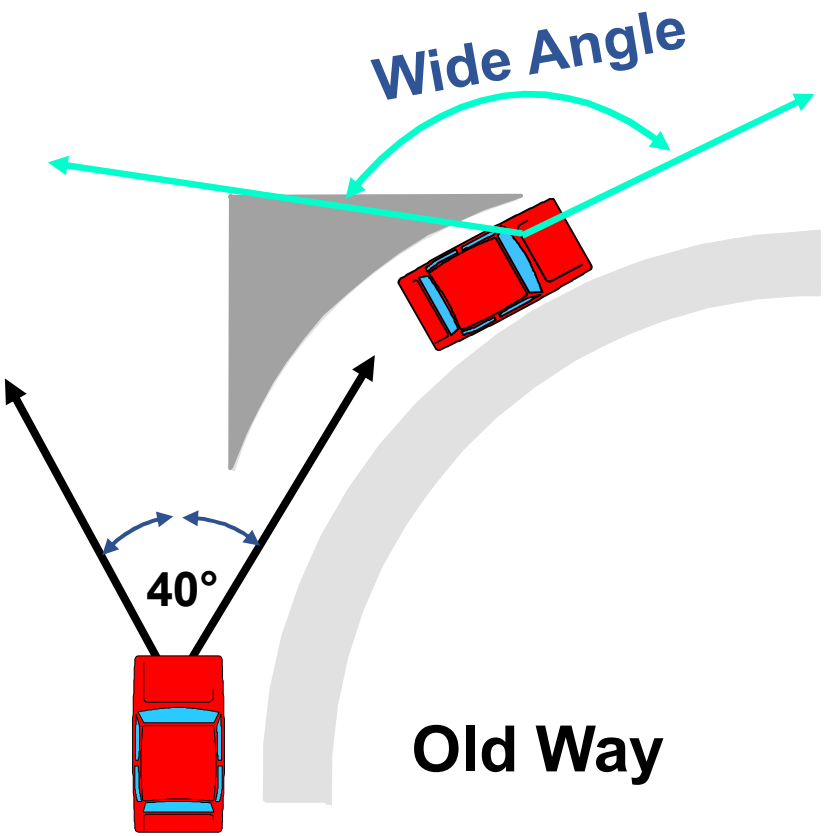
Must consider design vehicle, but don't choose larger vehicle than necessary

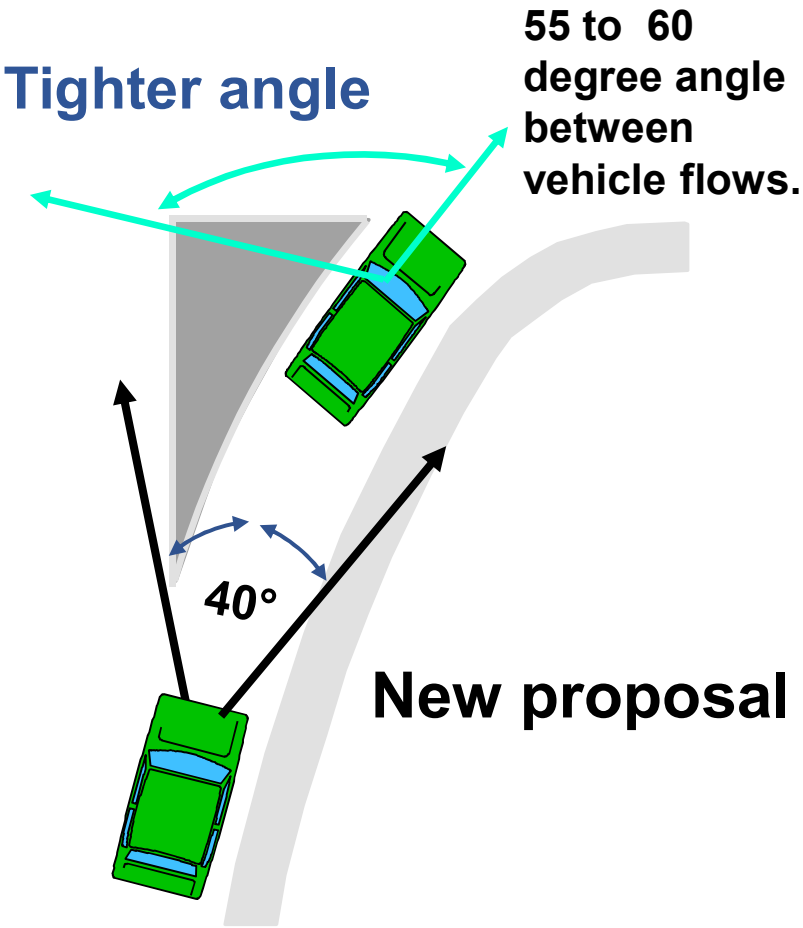
Bulb outs to improve visibility



Water flows down hill – unless under pressure

Right Turn Slip Lane Design

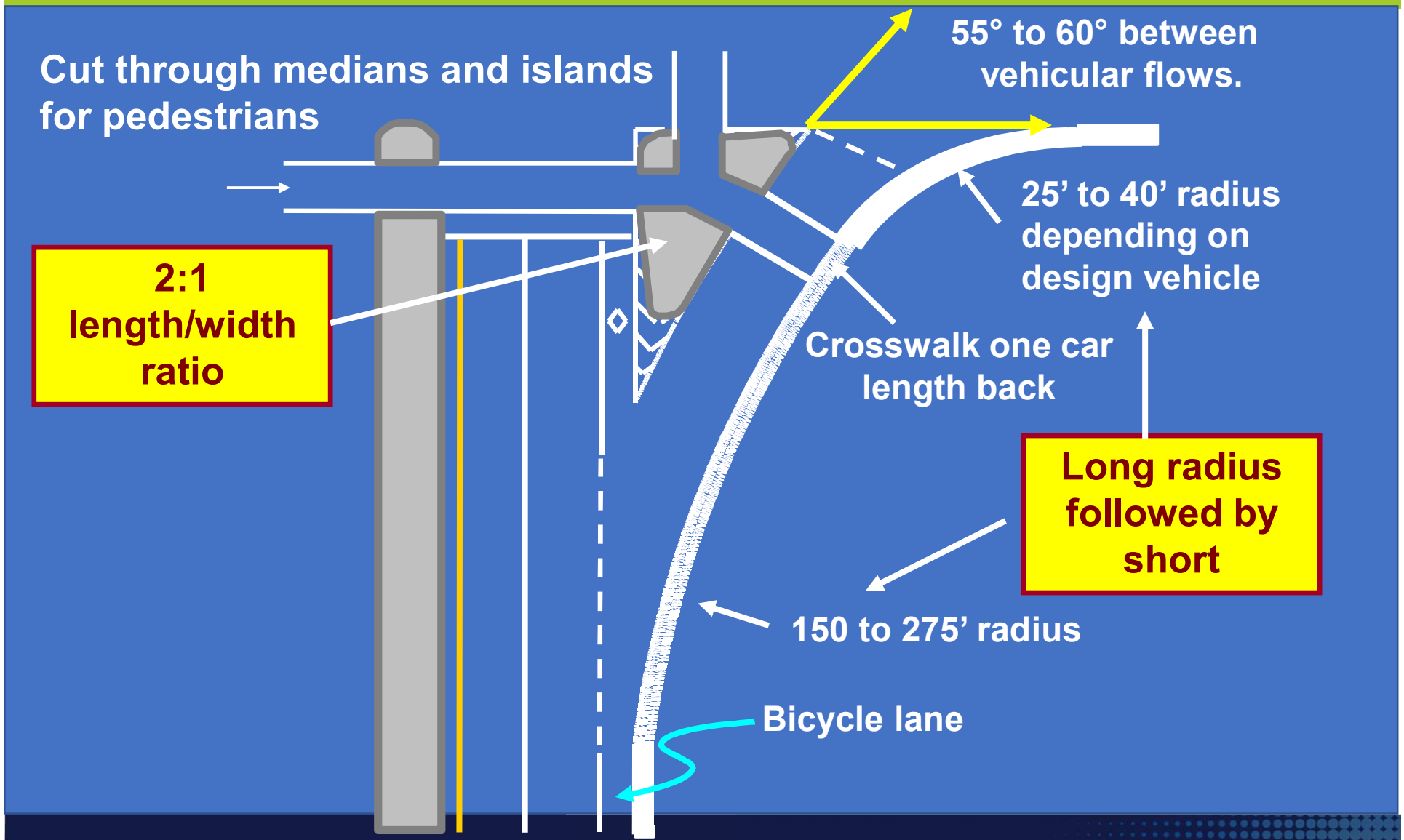




High speed, head turner = low visibility of pedestrians

Slow speed, good angle = good visibility of pedestrians

Right-Turn Slip Lane - Details



Importance of Sight Distance

- Provide sufficient driver time for:
  - Perception
  - Reaction
  - Stop

Stopping Sight Distance (SSD)

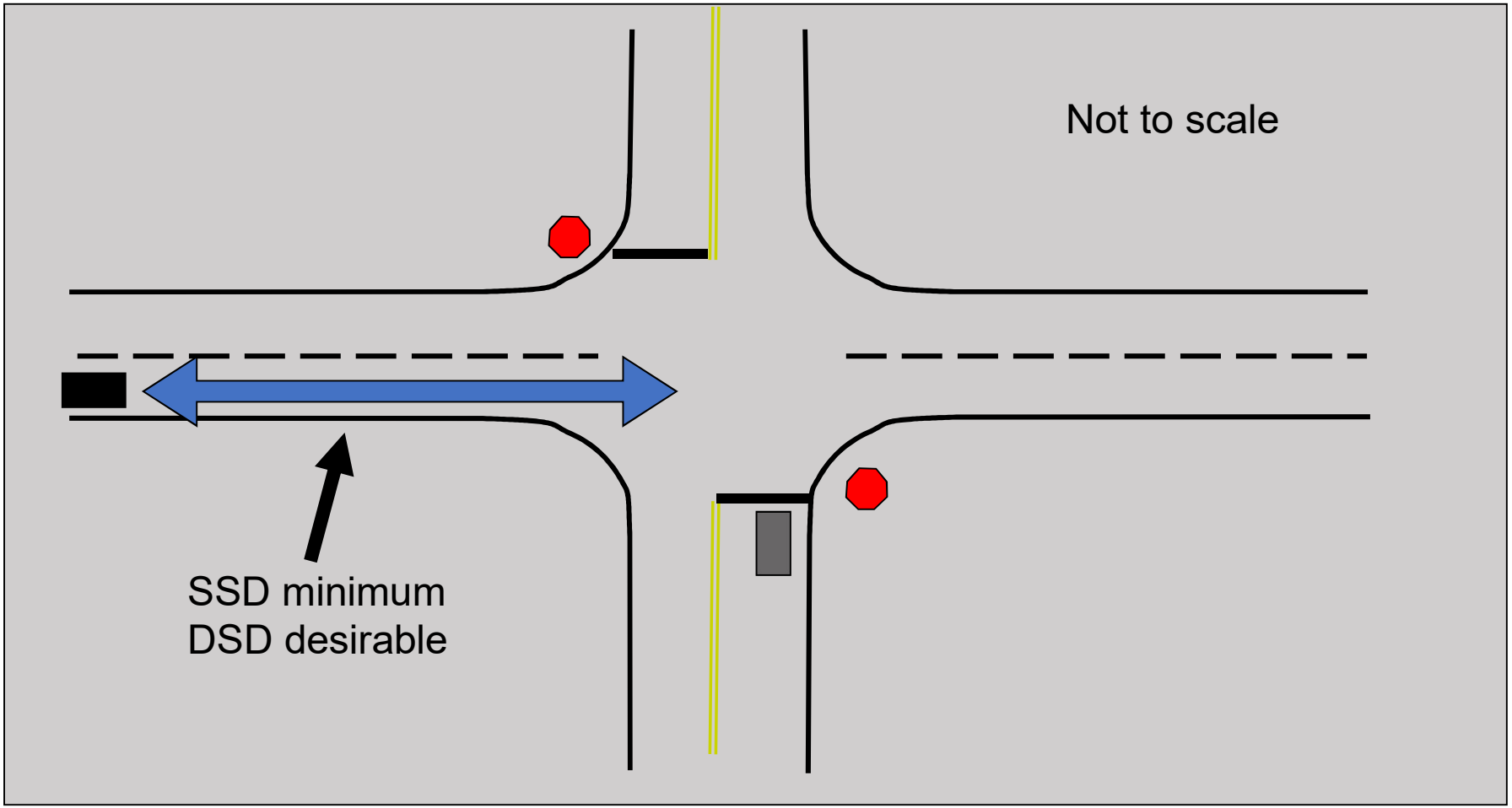
- Enable safe:
  - Stop / maneuver
  - Turn
  - Intersection crossing

Intersection Sight Distance (ISD)

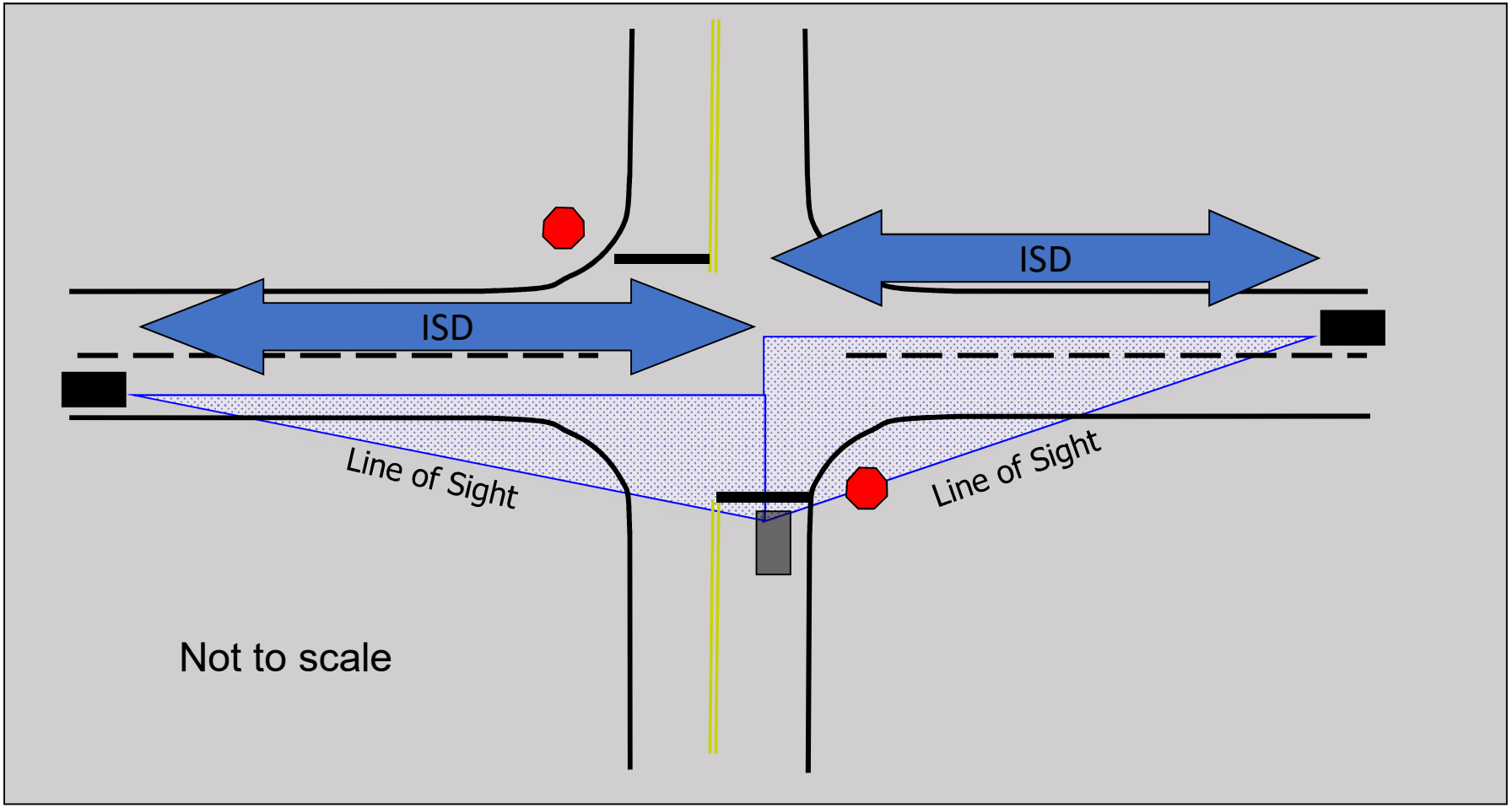
- Permit adequate consideration of choices

Decision Sight Distance (DSD)

Sight Distances



Sight Distances



Sight Distance Variables

- Design speeds
- Intersection controls
- Vertical and horizontal alignments
- Desired driver action
- Driver eye and object height
- Complexity of the decision

Stopping Sight Distance (SSD)

- Deceleration = 11.2 ft/sec^2
- 3.5 foot driver height
- 2.0 foot object height
- 2.5 second brake reaction time

Stopping Sight Distance (SSD)

US Customary				
Design speed (mph)	Brake reaction distance (ft)	Braking distance on level (ft)	Stopping sight distance	
			Calculated (ft)	Design (ft)
15	55.1	21.6	76.7	80
20	73.5	38.4	111.9	115
25	91.9	60.0	151.9	155
30	110.3	86.4	196.7	200
35	128.6	117.6	246.2	250
40	147.0	153.6	300.6	305
45	165.4	194.4	359.8	360
50	183.8	240.0	423.8	425
55	202.1	290.3	492.4	495
60	220.5	345.5	566.0	570
65	238.9	405.5	644.4	645
70	257.3	470.3	727.6	730
75	275.6	539.9	815.5	820

Decision Sight Distance (DSD)

Distance needed to:

- Detect unexpected condition
- Recognize threat
- Decide on proper response
- Change speed or path
- Complete maneuver safely and efficiently

Decision Sight Distance (DSD)

- Where more than SSD is needed
- Information processing/workload is high
- Where there is more likelihood for driver error
- Examples: intersection approaches and cross section changes
- Could impact vertical and horizontal designs
- Often not checked

Decision Sight Distance (DSD)

US Customary					
Design speed (mph)	Decision sight distance (ft)				
	Avoidance maneuver				
	A	B	C	D	E
30	220	490	450	535	620
35	275	590	525	625	720
40	330	690	600	715	825
45	395	800	675	800	930
50	465	910	750	890	1030
55	535	1030	865	980	1135
60	610	1150	990	1125	1280
65	695	1275	1050	1220	1365
70	780	1410	1105	1275	1445
75	875	1545	1180	1365	1545
80	970	1685	1260	1455	1650

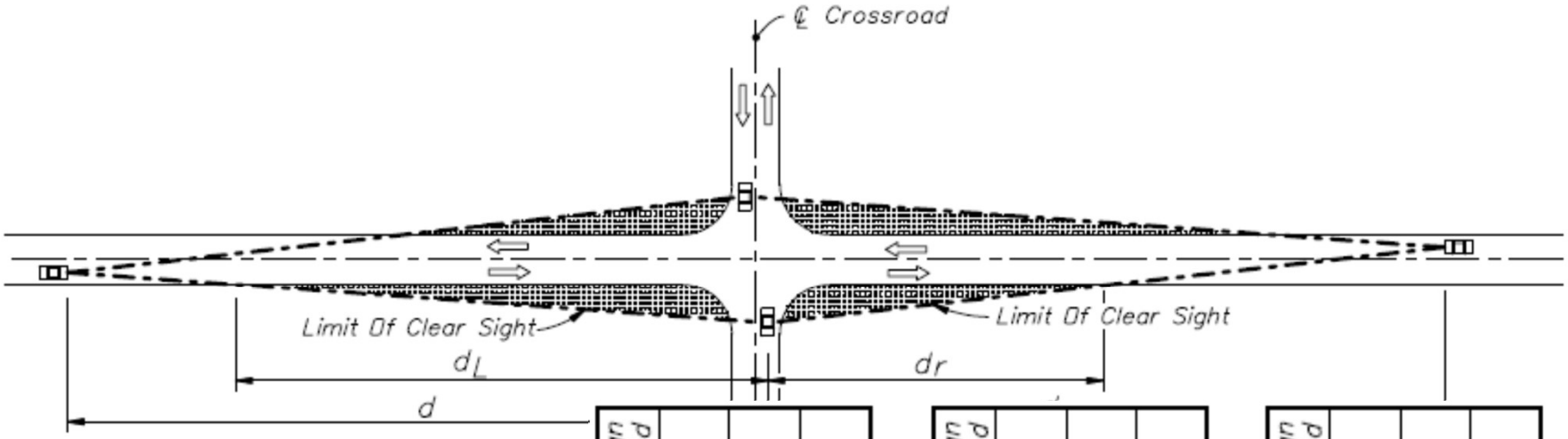
Potential DSD Alternatives

- Separate decision points
- Simplify decisions
- Increase sight distance
- Reduce speed
- Avoid too many options
- Provide advance information

Urban Vision Triangle Ordinances

Poor corner sight distance can adversely affect gap acceptance and stopped approach capacity.

Intersection Sight Distance



2 LANE UNDIVIDED

Design Speed	d	d_L	d_r
30	335	240	150
35	390	275	175
40	445	315	200
45	500	350	225
50	555	390	250
55	610	430	275
60	665	470	300
65	720	510	325

Passenger Vehicle

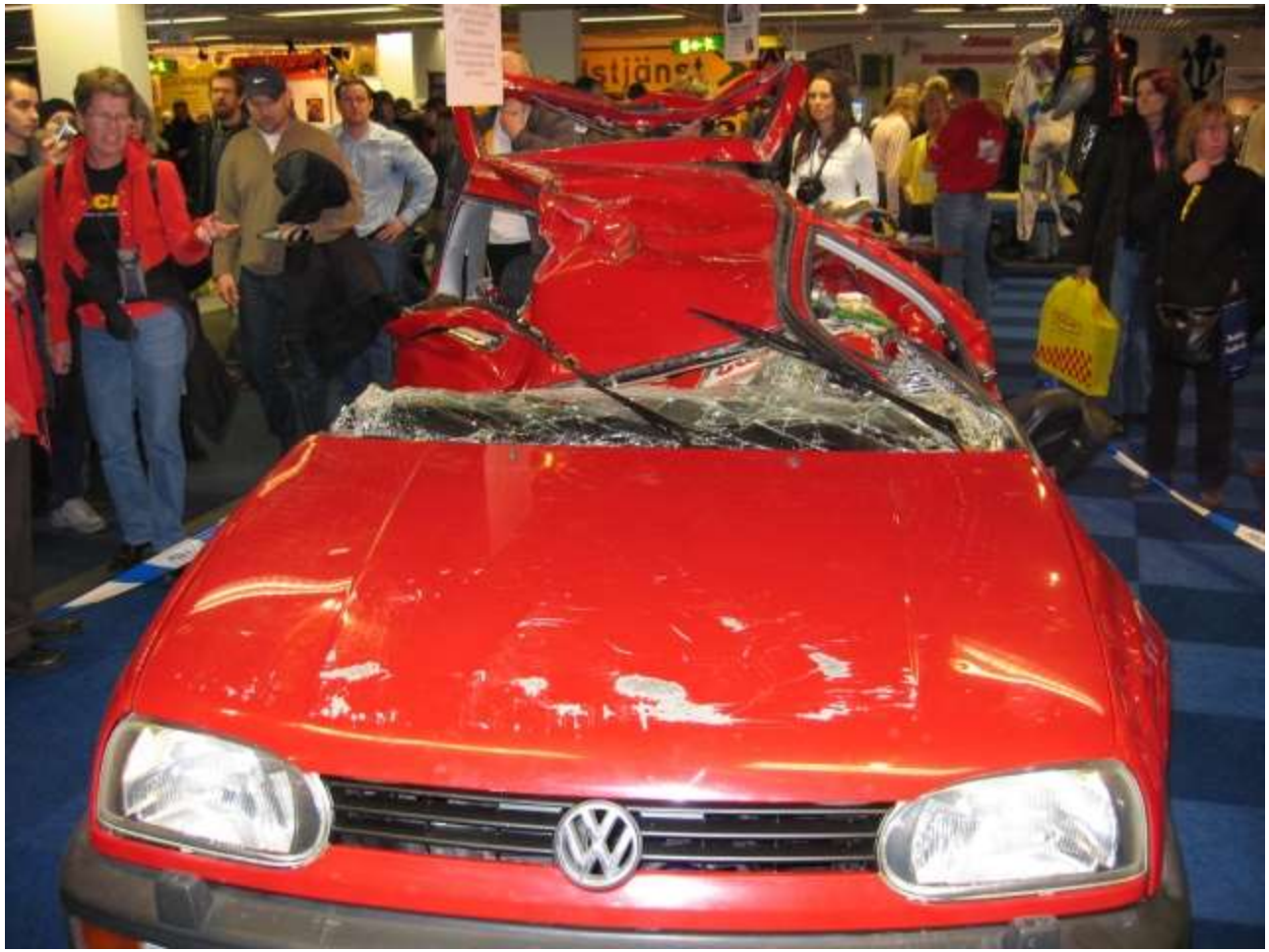
Design Speed	d	d_L	d_r
30	420	295	190
35	490	345	220
40	560	395	250
45	630	445	280
50	700	495	310
55	770	545	345
60	840	595	375
65	910	645	405

SU Vehicle

Design Speed	d	d_L	d_r
30	510	360	225
35	595	420	265
40	680	480	305
45	765	540	340
50	845	600	375
55	930	660	415
60	1015	720	450
65	1100	780	490

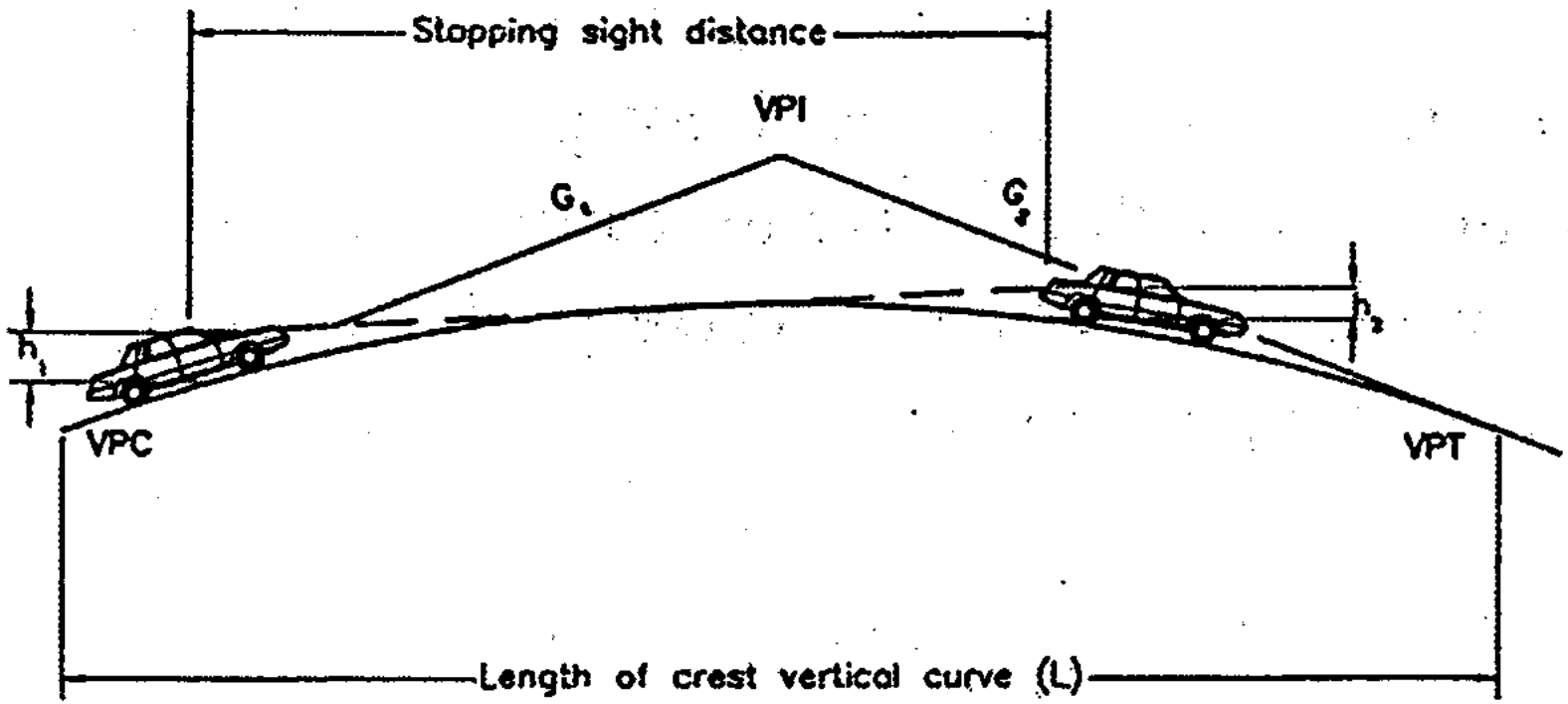
Combination Vehicle

Intersection Sight Distance

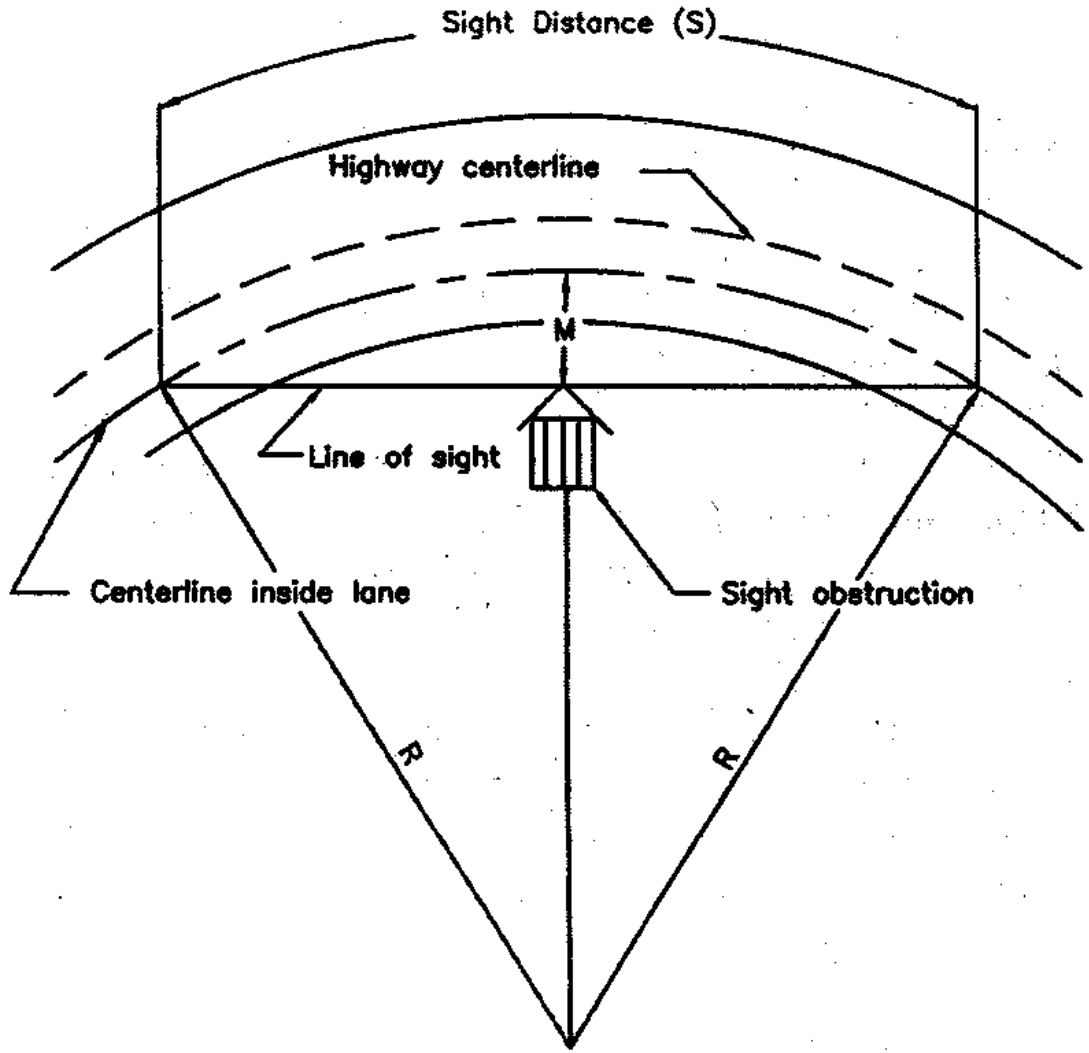


Castrol

SSD on Vertical Curve



SSD on Horizontal Curve



Sight Distance in Parking Lots

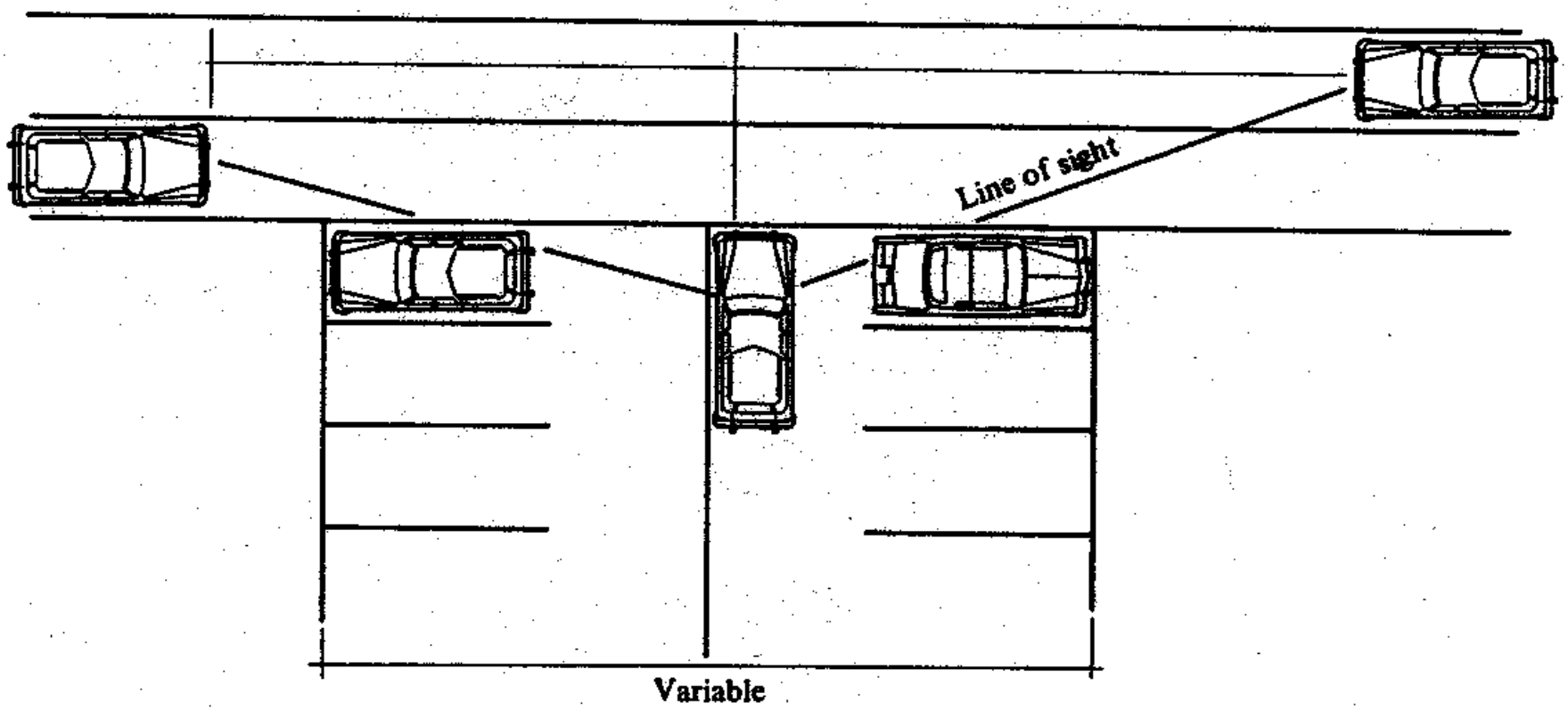
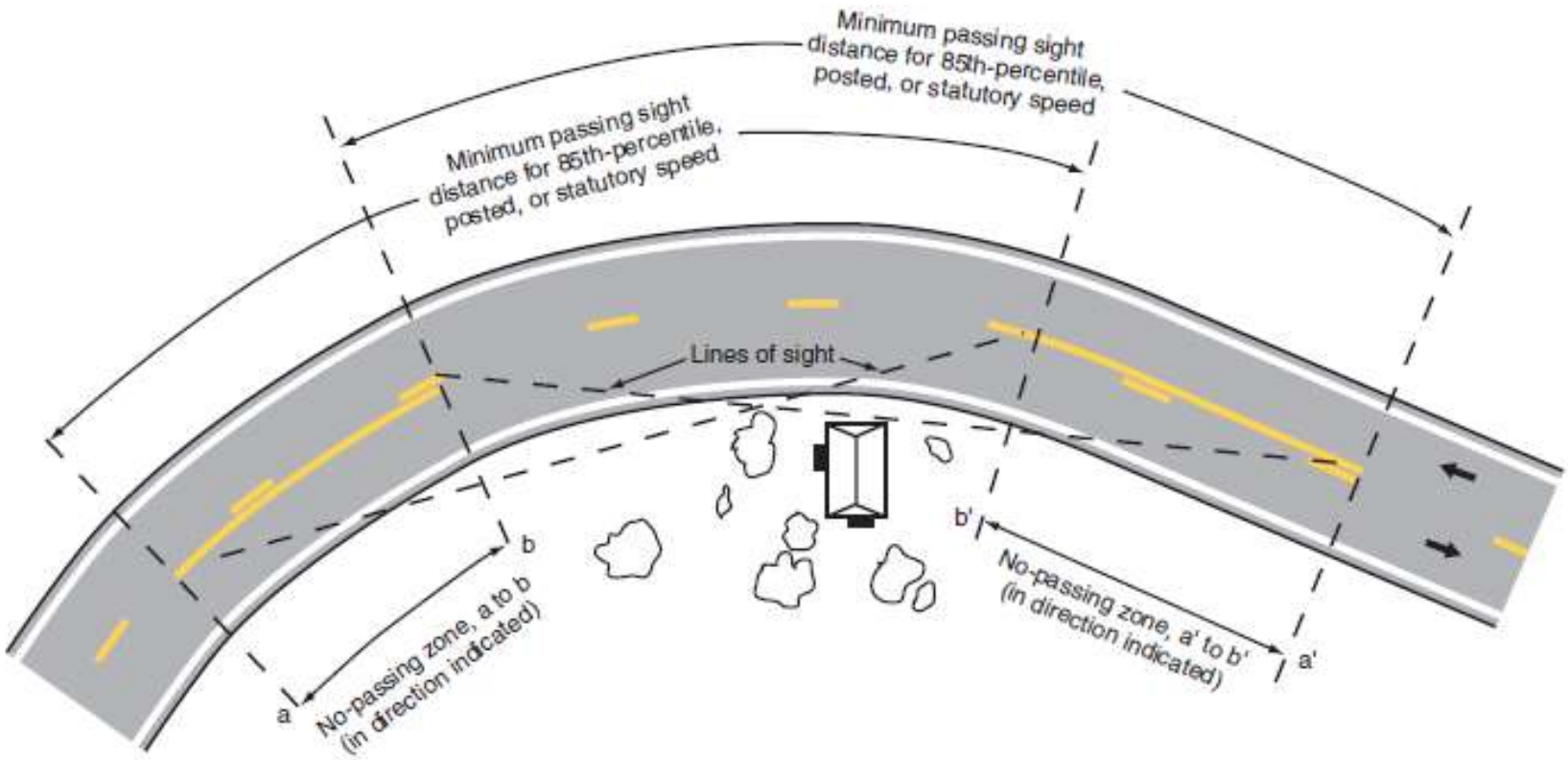


Figure 7-14 Minimum sight distance obstructed when end-stall parking is permitted.

Passing Sight Distance



ONE LANE
BRIDGE
WEIGHT
LIMIT
16T
23T

Questions?

Modern Roundabouts

Modern Roundabouts

- Circular intersection where traffic in the circle has the right-of-way
- Typically have low crash rates and low crash severity
- Little delay to intersection users

Roundabout Advantages

- Improved intersection operation
- Improved aesthetics
- Lower costs (than signals)
- Lower crash rates and severity

Roundabout Disadvantages

- Higher costs (than STOP control)
- Right-of-way requirements
- Driver unfamiliarity

A modern roundabout is <u>not</u>:

1. A New England style rotary, with large size & high speeds

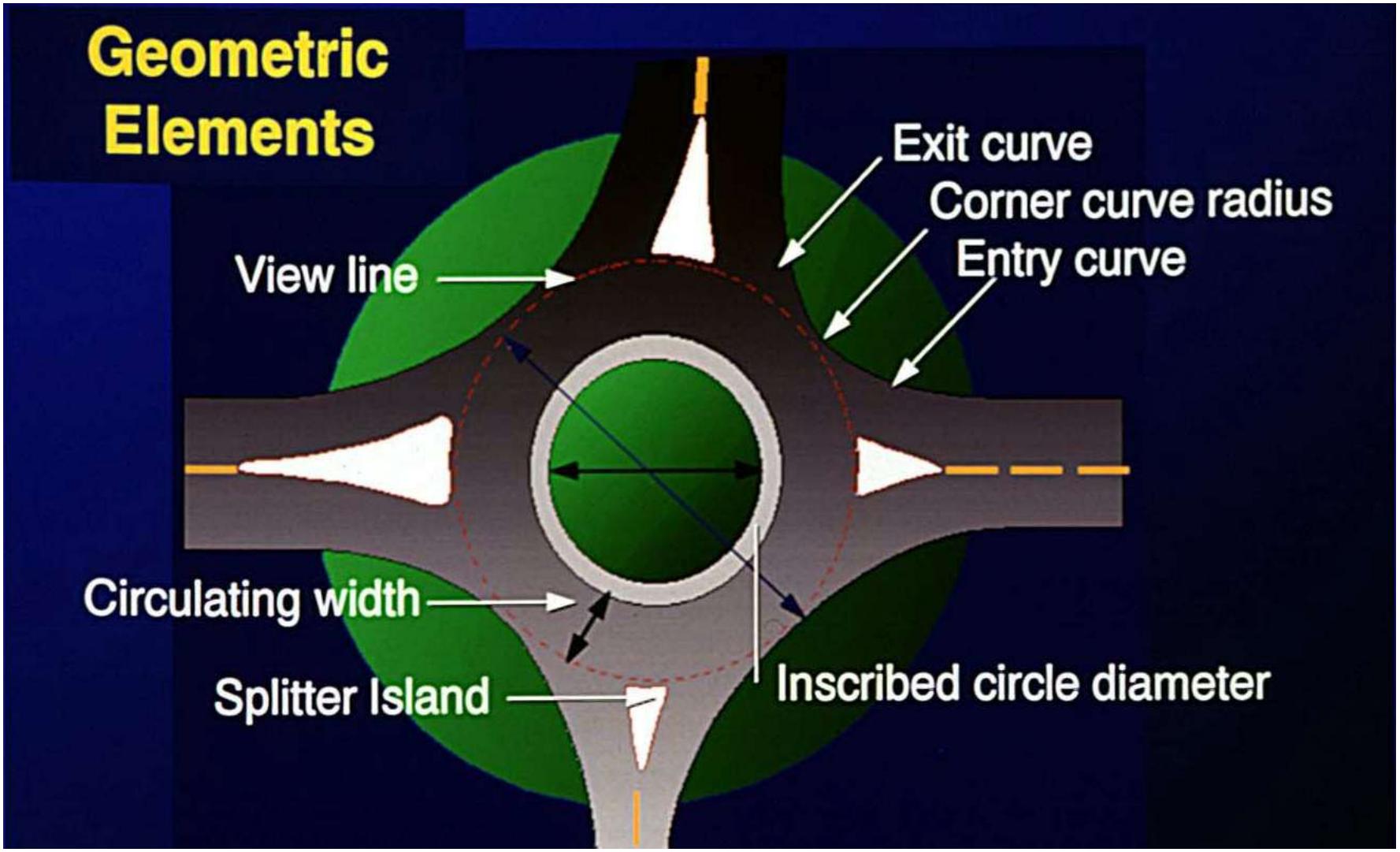
A modern roundabout is <u>not</u>:
2. A Washington DC style circle, with traffic signal controls

A modern roundabout is <u>not</u>:

3. A traffic-calming mini circle

A modern roundabout is <u>not</u>:
4. Paris

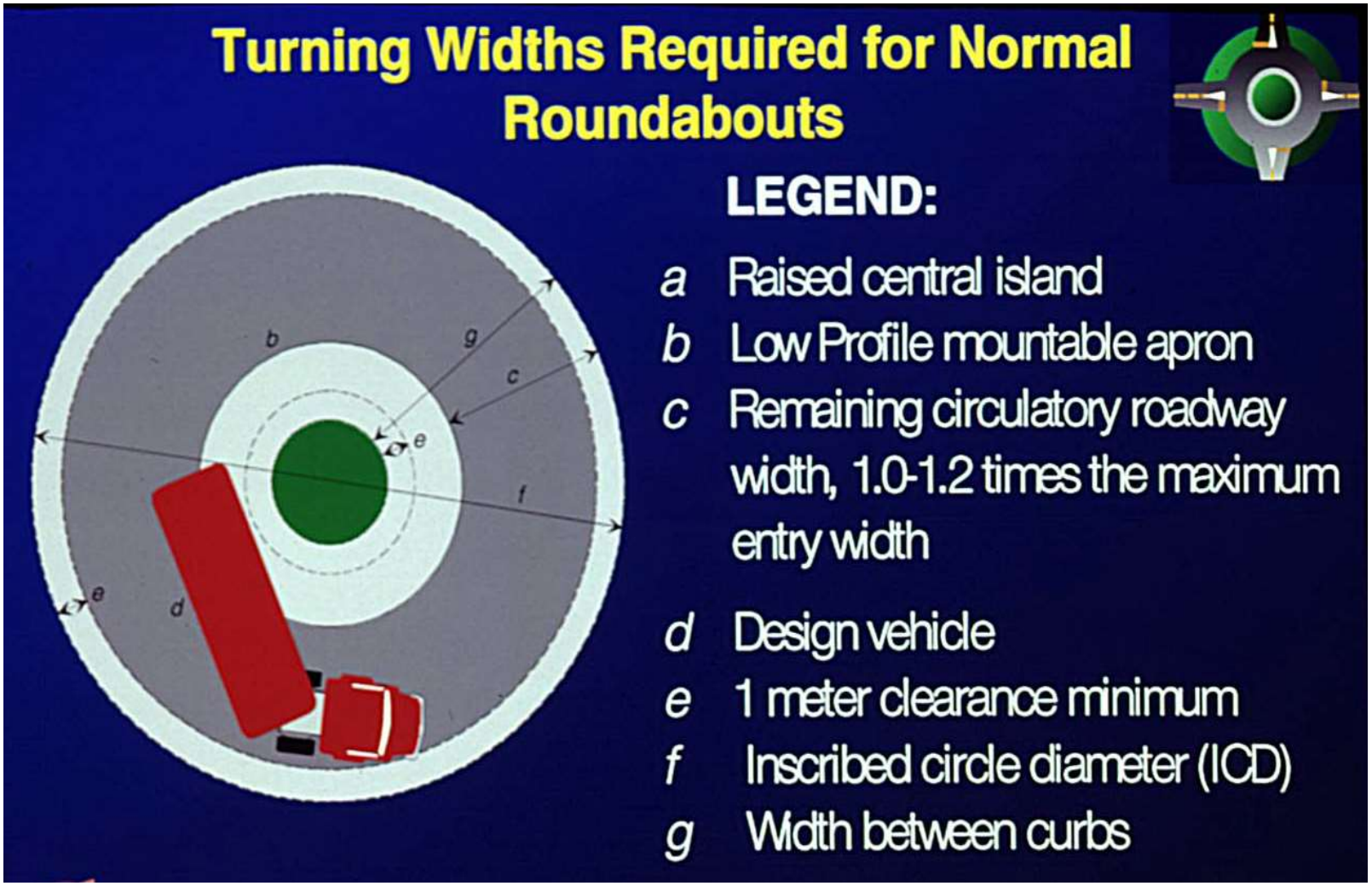
Geometry of a modern roundabout



Roundabout Operations

- Balanced Traffic Flows
- High proportion of left turns
- High crash reduction numbers for turning vehicles
- Intersection with five or more legs
- T and Y intersections
- Traffic calming

Roundabouts can handle large vehicles



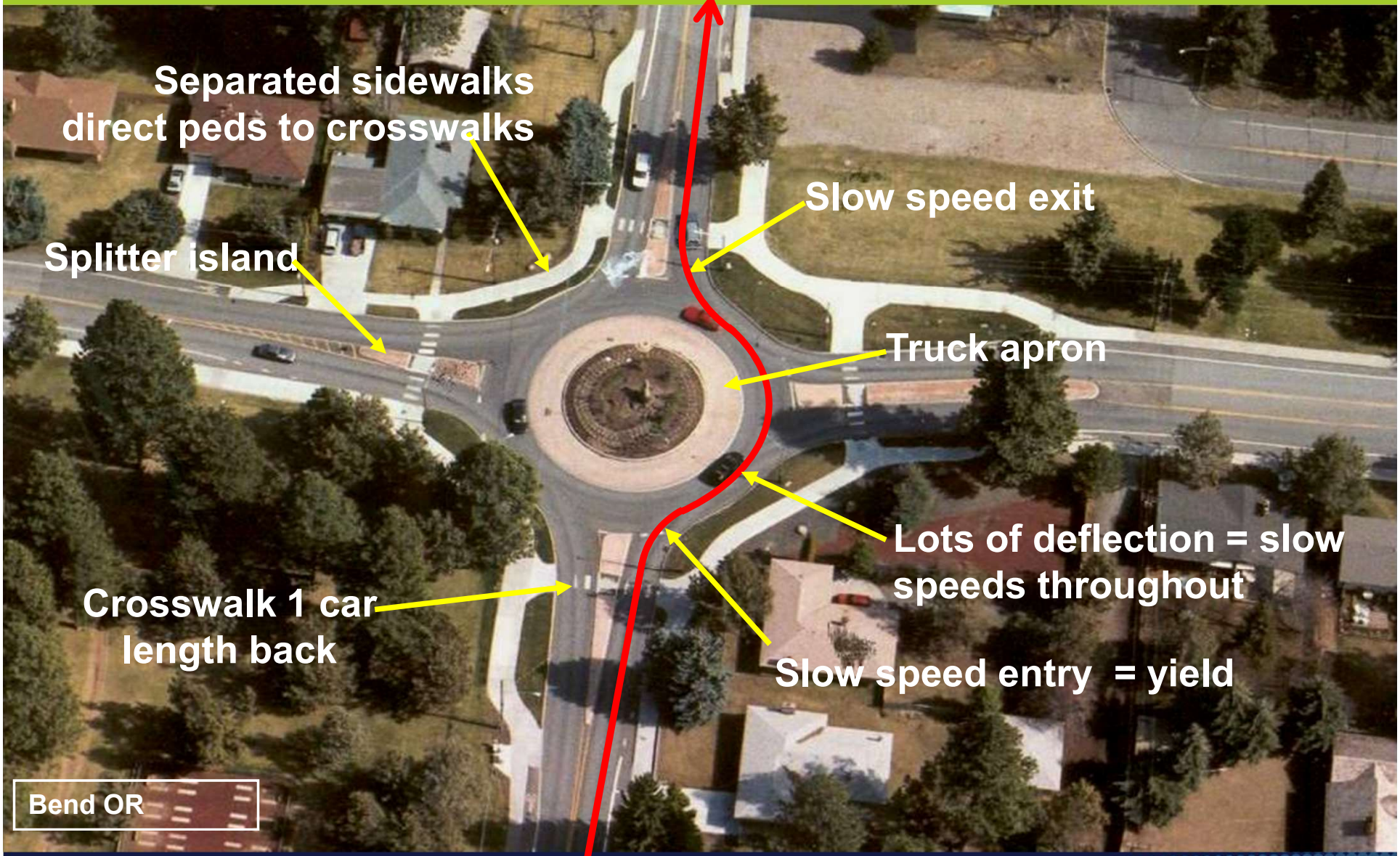
Truck Apron

Neighborhood Roundabouts

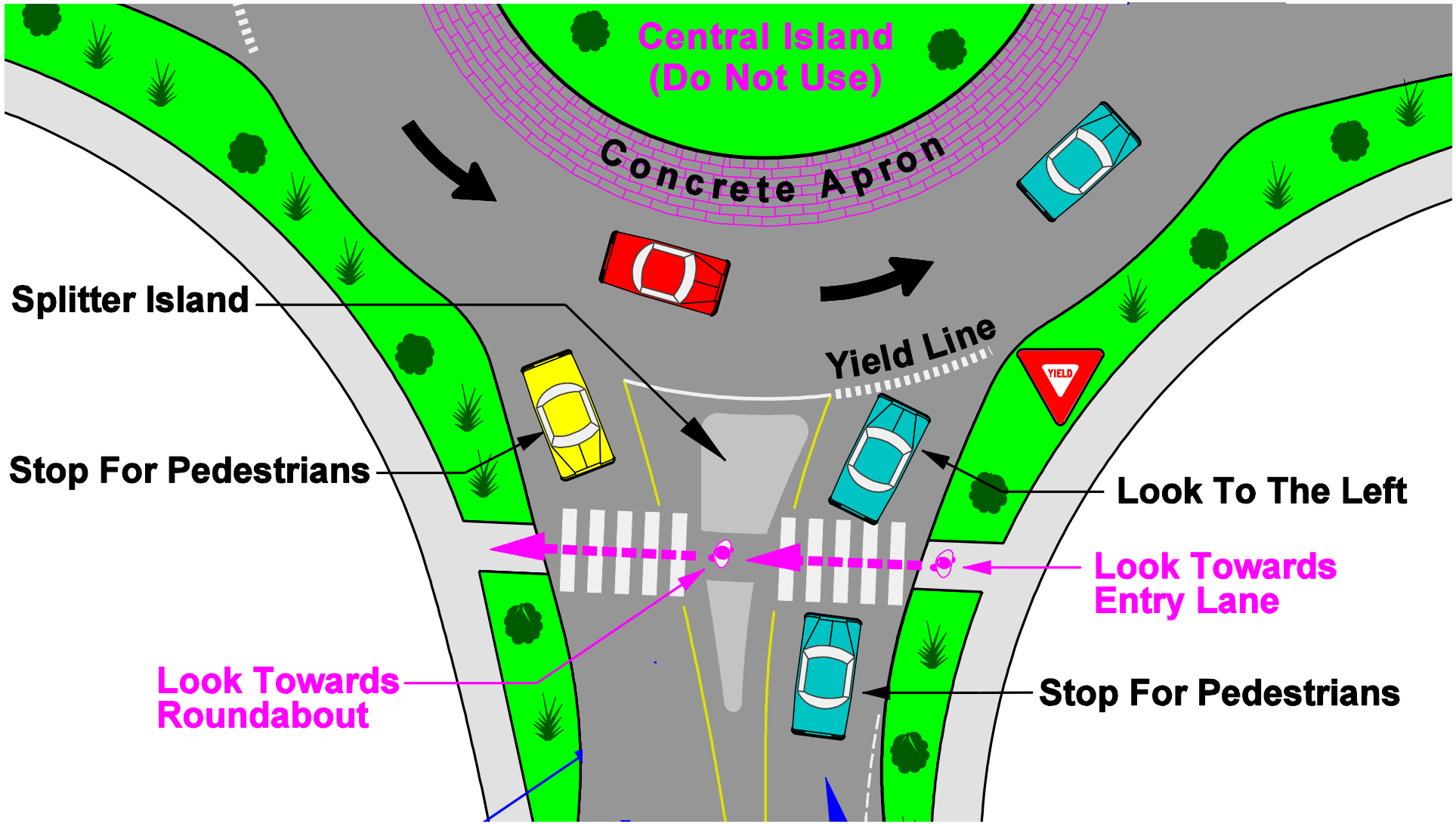
Clearwater Roundabout then…

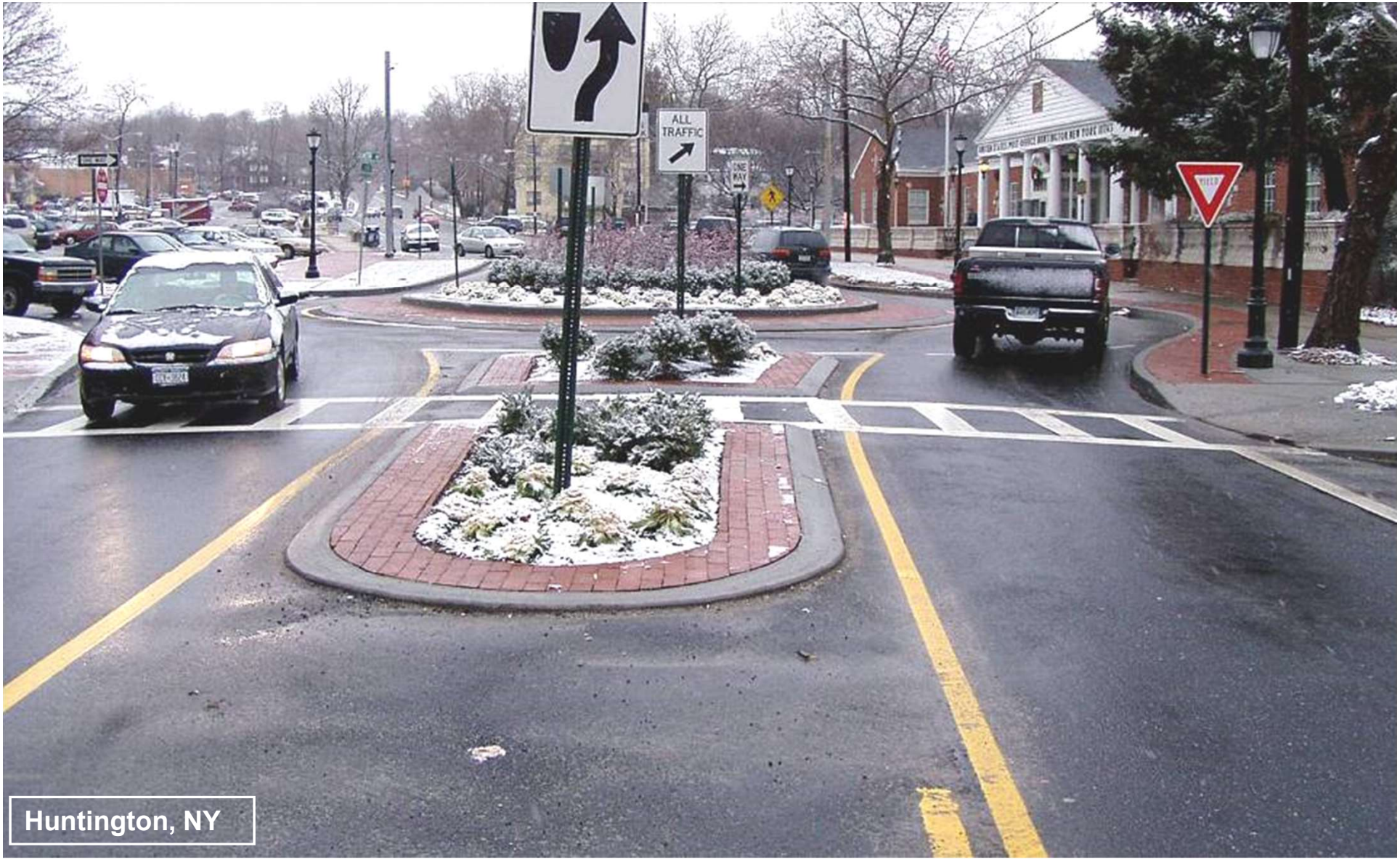
Clearwater Roundabout now…

Essential roundabout characteristics



Pedestrian safety at a roundabout





Constrained entry slows drivers

Well defined crossings & splitter islands

2. At exit lane

Well defined crossings & splitter islands

Truck apron keeps roadway narrower

Roundabout problems for blind pedestrians:

- Circulating traffic masks the sound cues the blind use to identify gaps and masks the sound of yielding vehicles
- Tangential circulating roadway, tangential exit => high speed (worse at 2-lane roundabouts)

Multi-lane roundabouts have less deflection, higher speed;

Lack of striping encourages drivers to "slip through"

Problems for pedestrians: not enough deflection at exit, high speeds; lack of striping encourages drivers to "slip through"

Roundabouts can be used in residential neighborhoods if properly designed

Questions?

Thank you for attending!

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