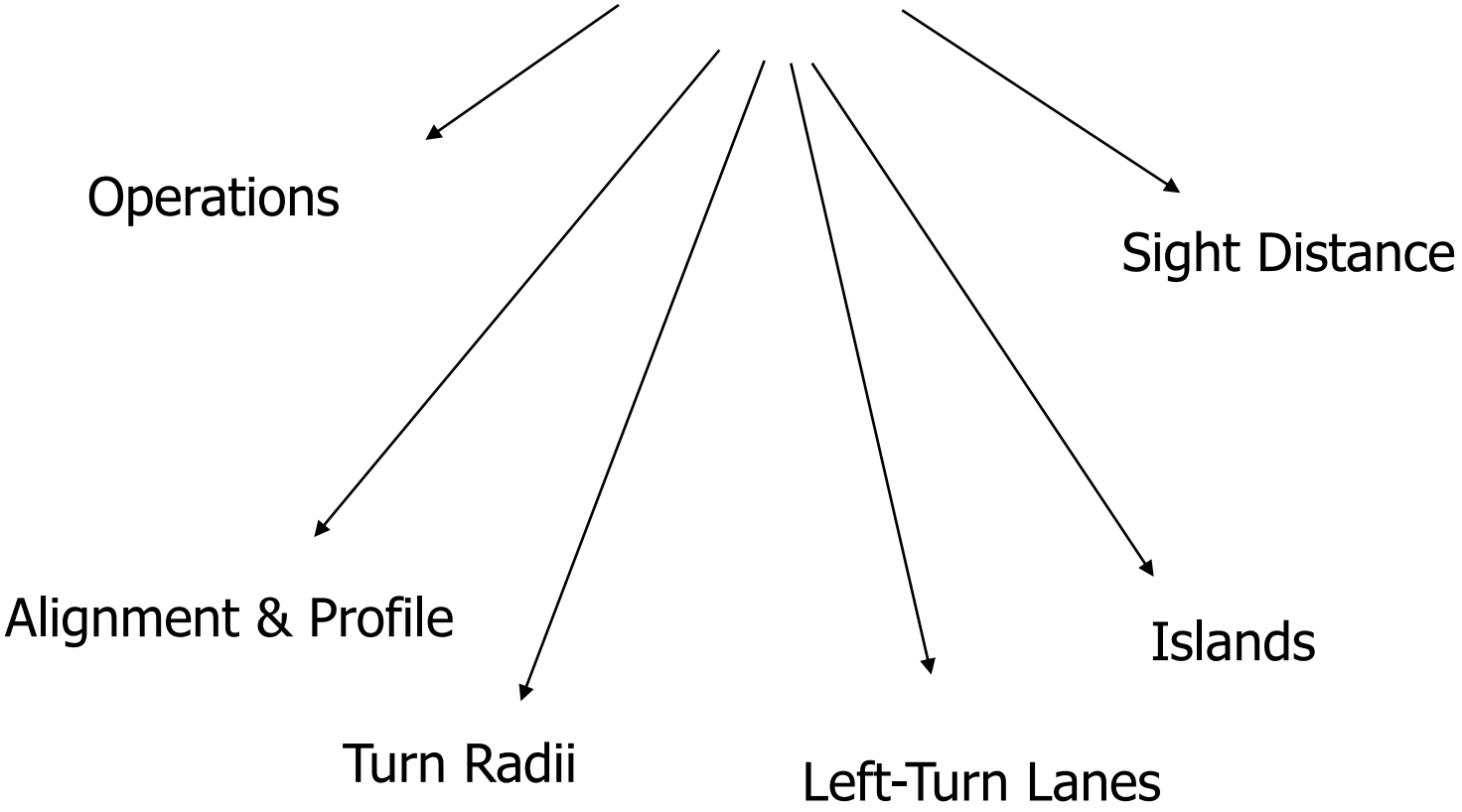
Intersection Design

Fall 2008

Intersections



Other Topics:

- Median Openings
- Railway Crossing
- Speed-Change Lanes
- Indirect Left-Turn

Intersections

- General Characteristics
  - An intersection is defined as the general area where two or more highways join or cross
  - Most common intersections have four legs
  - They are the most important part of a highway facility since efficiency, safety, speed, cost of operation and capacity depend on their design
  - Three types of intersections:
    - At-grade
    - Grade separated (without ramps)
    - interchange

Intersections

- General Design Considerations
  - Human Factors
    - Driving habits, decision and reaction time, pedestrian and bicyclist habits, etc.
  - Traffic Considerations
    - Design and actual capacity, size of vehicles, vehicle speeds, transit, crash experience, traffic volumes, etc.
  - Physical Elements
    - Alignment, sight distance, traffic control, crosswalks, lighting, angle, etc.
  - Economic factors
    - Energy consumption, costs of improvements, adjacent properties, etc.

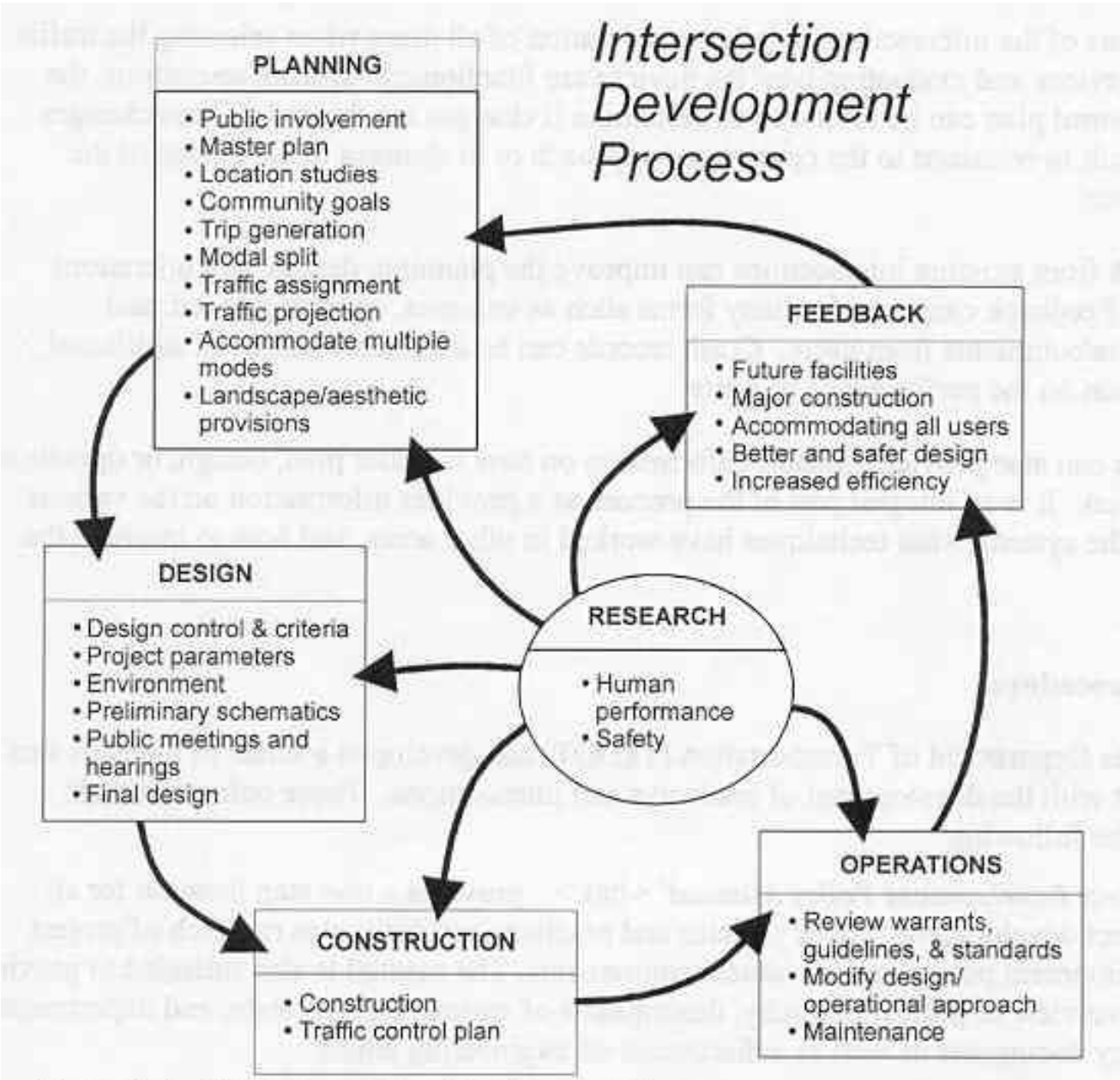


Figure 1-1. The Intersection Development Process.

Intersections

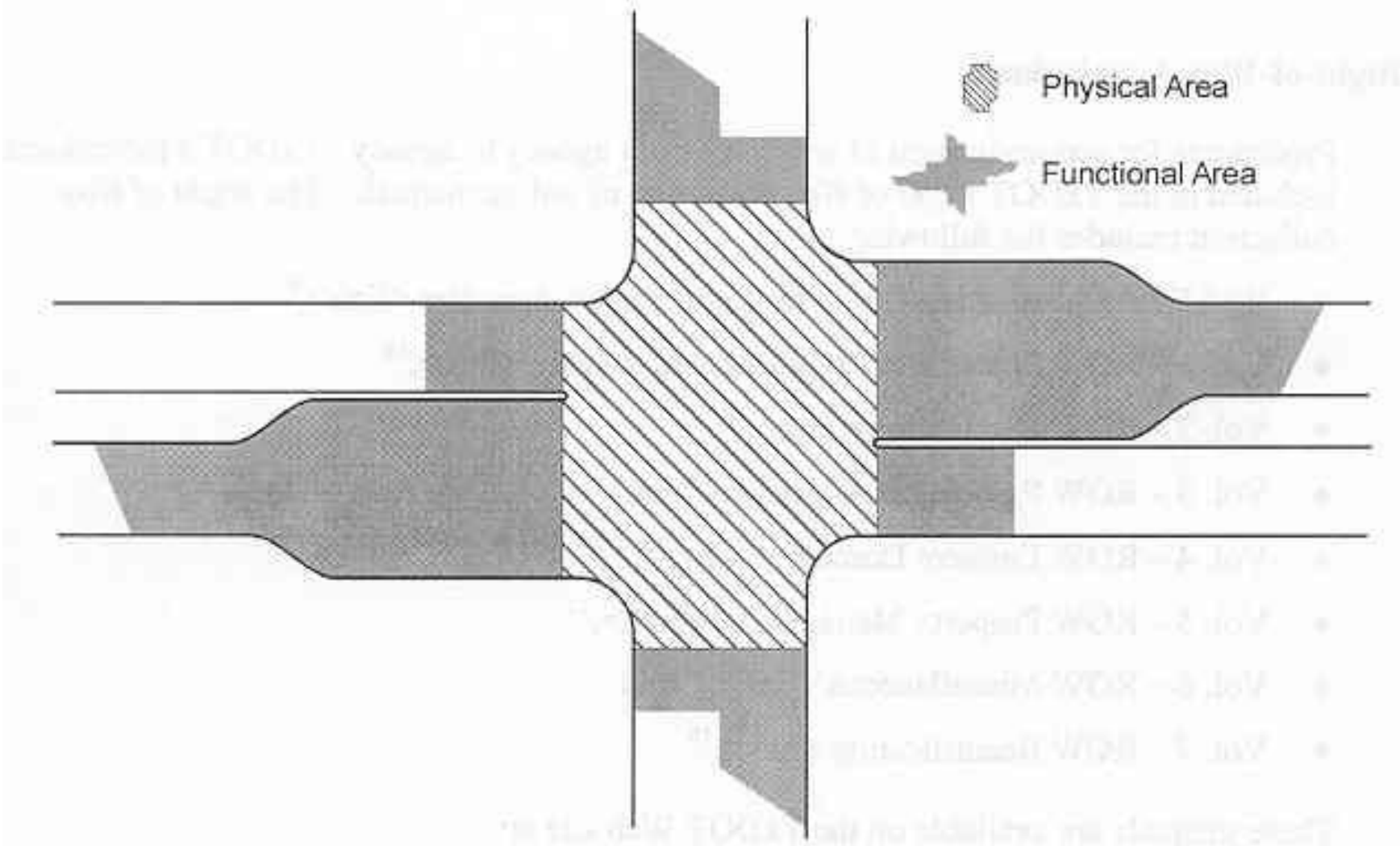


Figure 1-7. Functional Area of an Intersection.[17]

Intersections

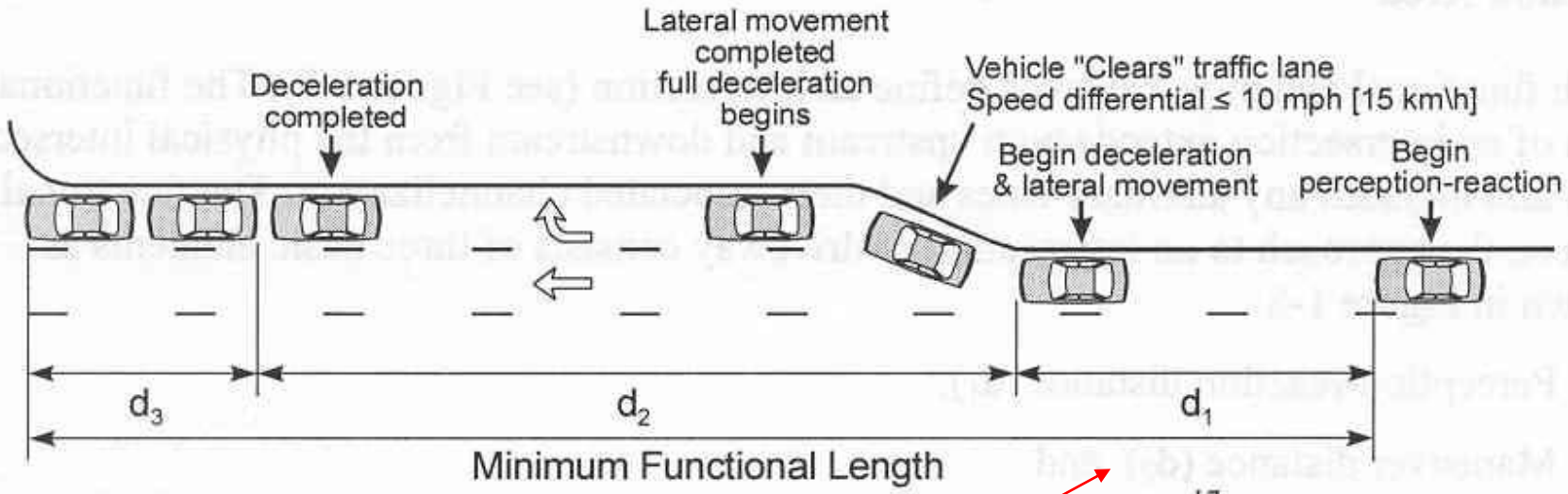


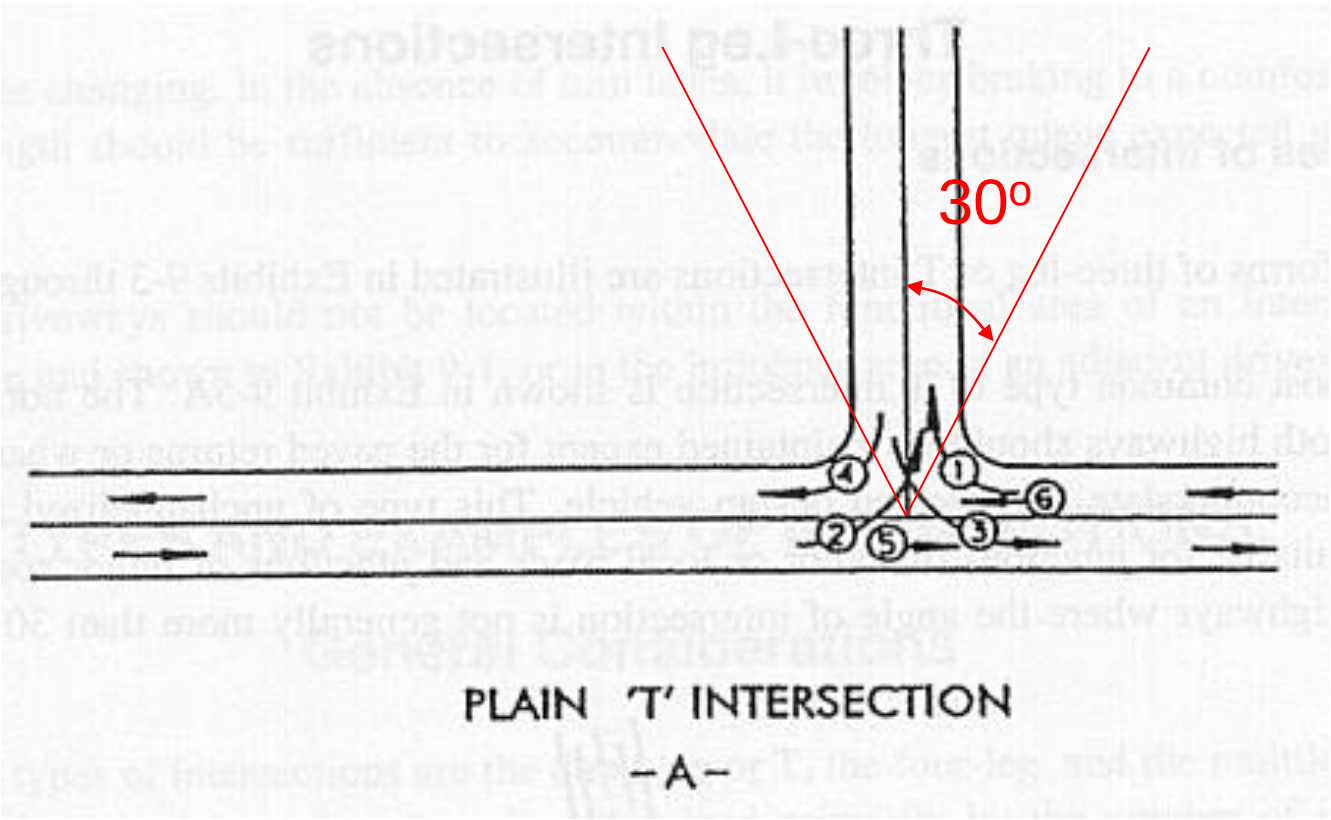
Figure 1-8. Elements of the Functional Area of an Intersection.[17]

Depends on vehicle speed, driver alertness, and driver familiarity with the location

Intersections

- Types of Intersection
  - Three types: Three-legged, four-legged, multileg
  - Basic intersection type vary greatly in scope, shape or degree of chanalization
  - Selection of intersection type influenced by: functional class, DHV, access requirements, all modes to be accommodated, and availability of right-of-way
  - Design will vary according to the traffic control: two-way stop-controlled, four-way stop controlled, fixed and actuated signal control
  - Turning bay for right turns

Three-Legged Intersections



Basic Design

Four-Legged Intersections

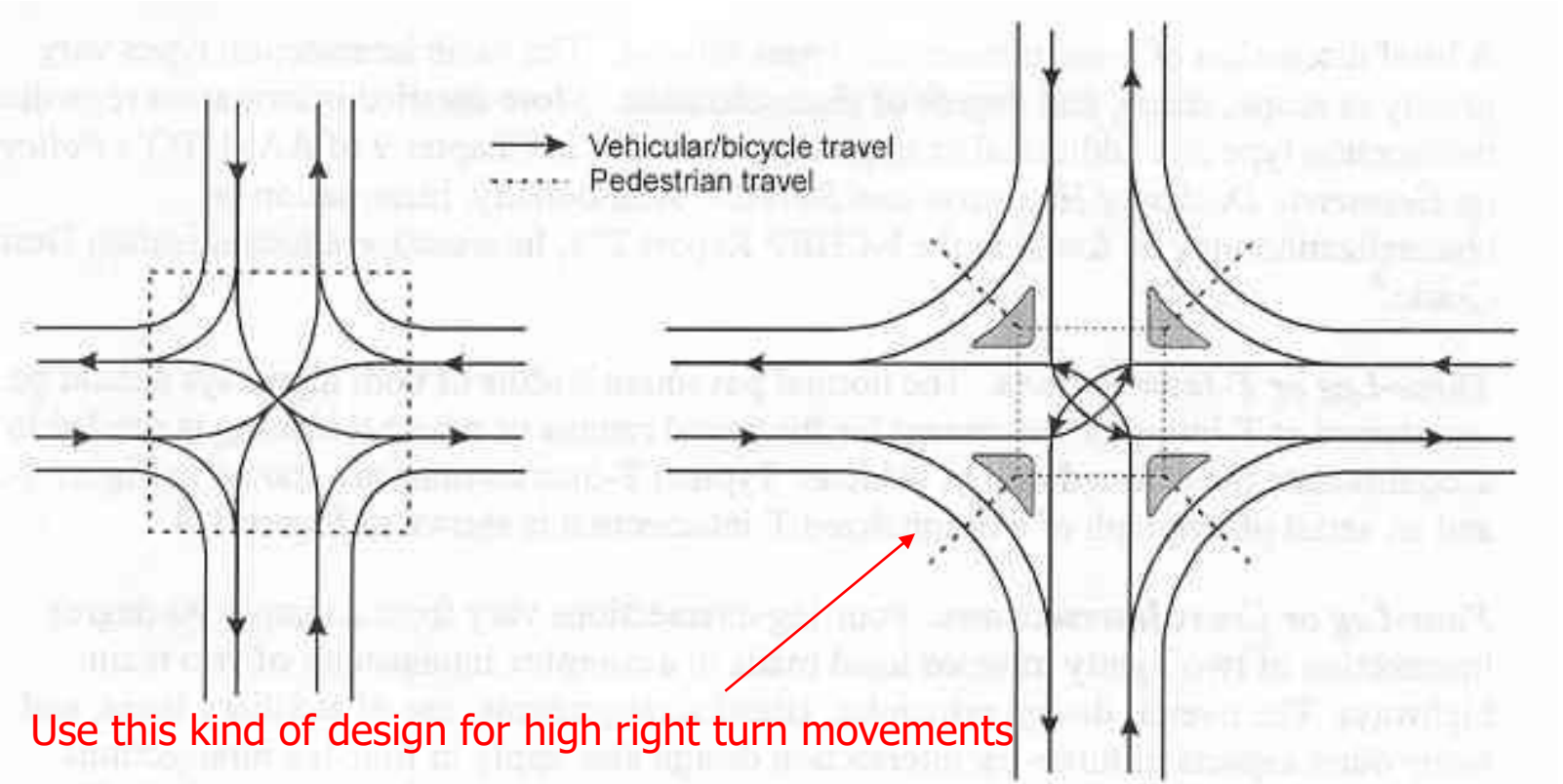
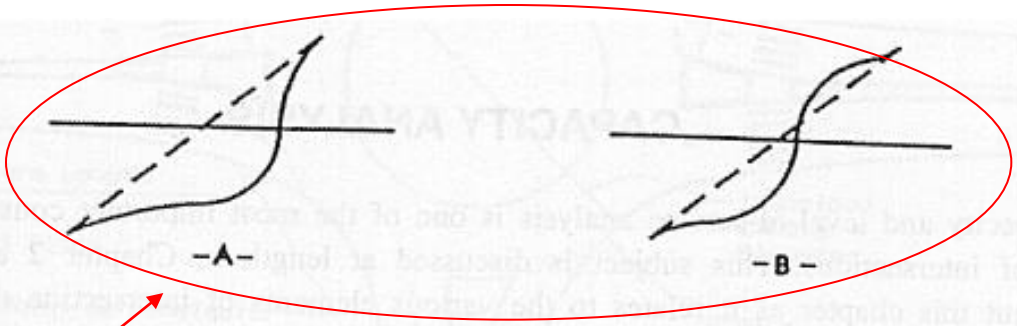


Figure 1-5. Typical Four-Leg Intersections.

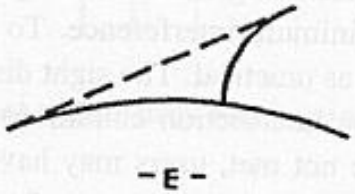
Basic Design

Horizontal Alignment

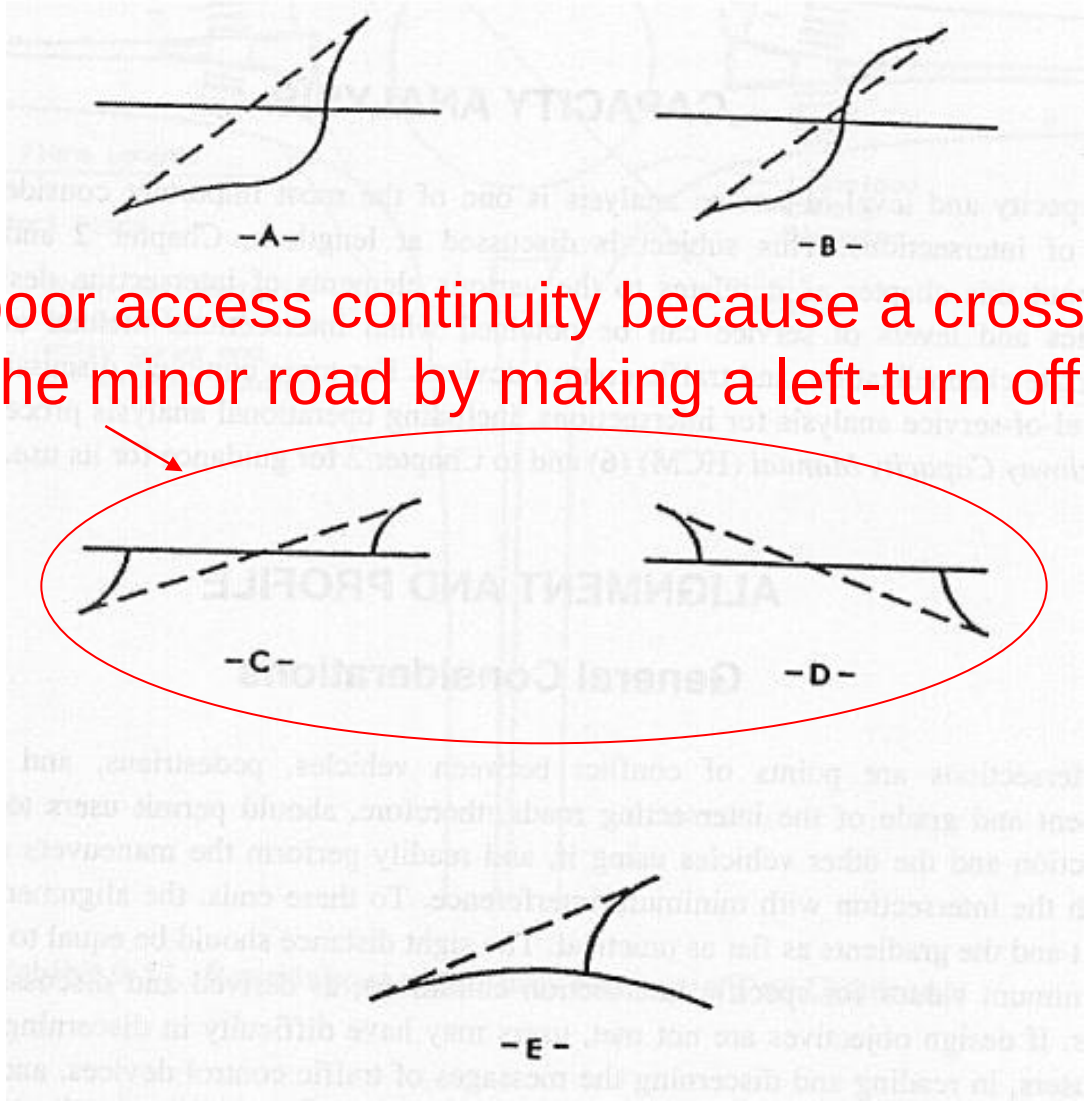


Allows the minor road to have operating speeds nearly equivalent to major-highway approach speeds



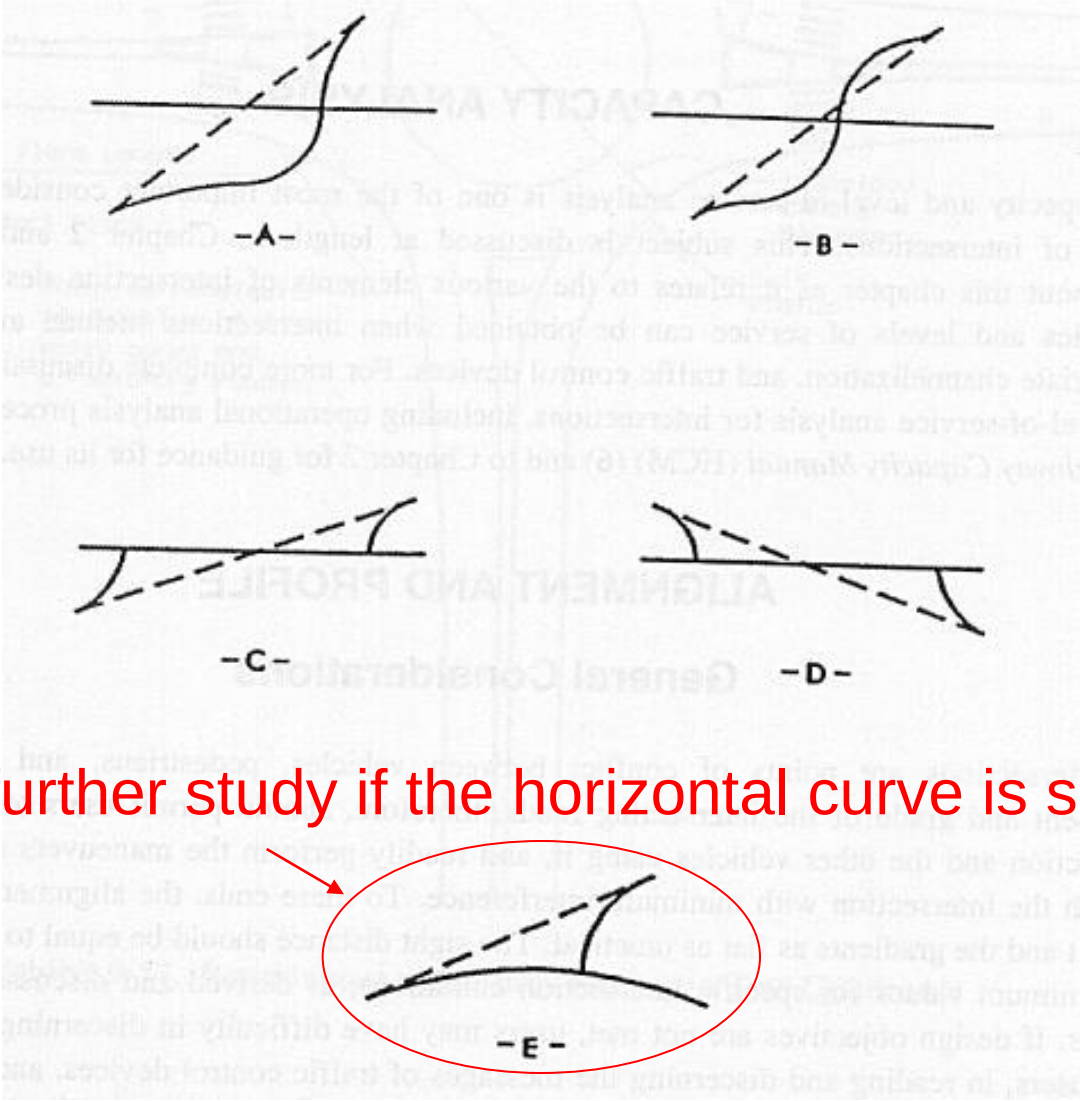


Horizontal Alignment



Can provide poor access continuity because a crossing vehicle must reenter the minor road by making a left-turn off the major highway

Horizontal Alignment



May need further study if the horizontal curve is superelevated

Turning Roadways

- Minimum Edge-of-Traveled-Way (METW)
  - The corner radii should be based on the minimum turning path of the selected design vehicles
  - Design paths of design vehicles illustrated in Exhibits 2-3 to 2-23
  - METW shown in Exhibits 9-19 and 9-20
  - METW dependent upon angle at which the highways meet
  - Three types of design:
    - 1) simple curves
    - 2) simple curves with taper
    - 3) compound curves

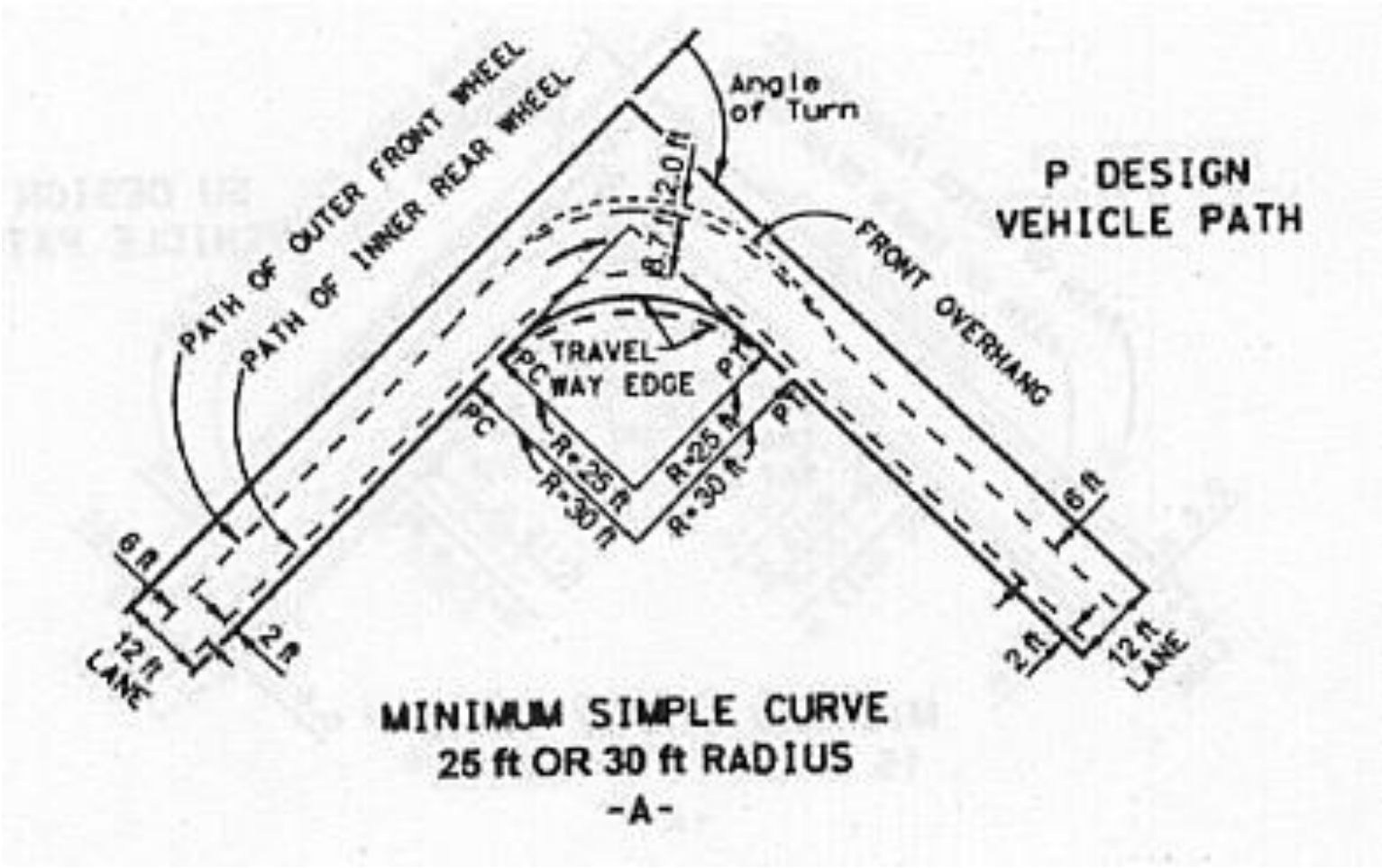
Turning Roadways

US Customary					
Angle of turn (degrees)	Design vehicle	Simple curve radius (ft)	Simple curve radius with taper		
			Radius (ft)	Offset (ft)	Taper H:V
75	P	35	25	2.0	10:1
	SU	55	45	2.0	10:1
	WB-40	–	60	2.0	15:1
	WB-50	–	65	3.0	15:1
	WB-62	–	145	4.0	20:1
	WB-67	–	145	4.5	20:1
	WB-100T	–	85	3.0	15:1
	WB-109D	–	140	5.5	20:1
90	P	30	20	2.5	10:1
	SU	50	40	2.0	10:1
	WB-40	–	45	4.0	10:1
	WB-50	–	60	4.0	15:1
	WB-62	–	120	4.5	30:1
	WB-67	–	125	4.5	30:1
	WB-100T	–	85	2.5	15:1
	WB-109D	–	115	2.9	15:1
105	P	–	20	2.5	–
	SU	–	35	3.0	–
	WB-40	–	40	4.0	–
	WB-50	–	55	4.0	15:1
	WB-62	–	115	3.0	15:1
	WB-67	–	115	3.0	15:1
	WB-100T	–	75	3.0	15:1
	WB-109D	–	90	9.2	20:1

Turning Roadways

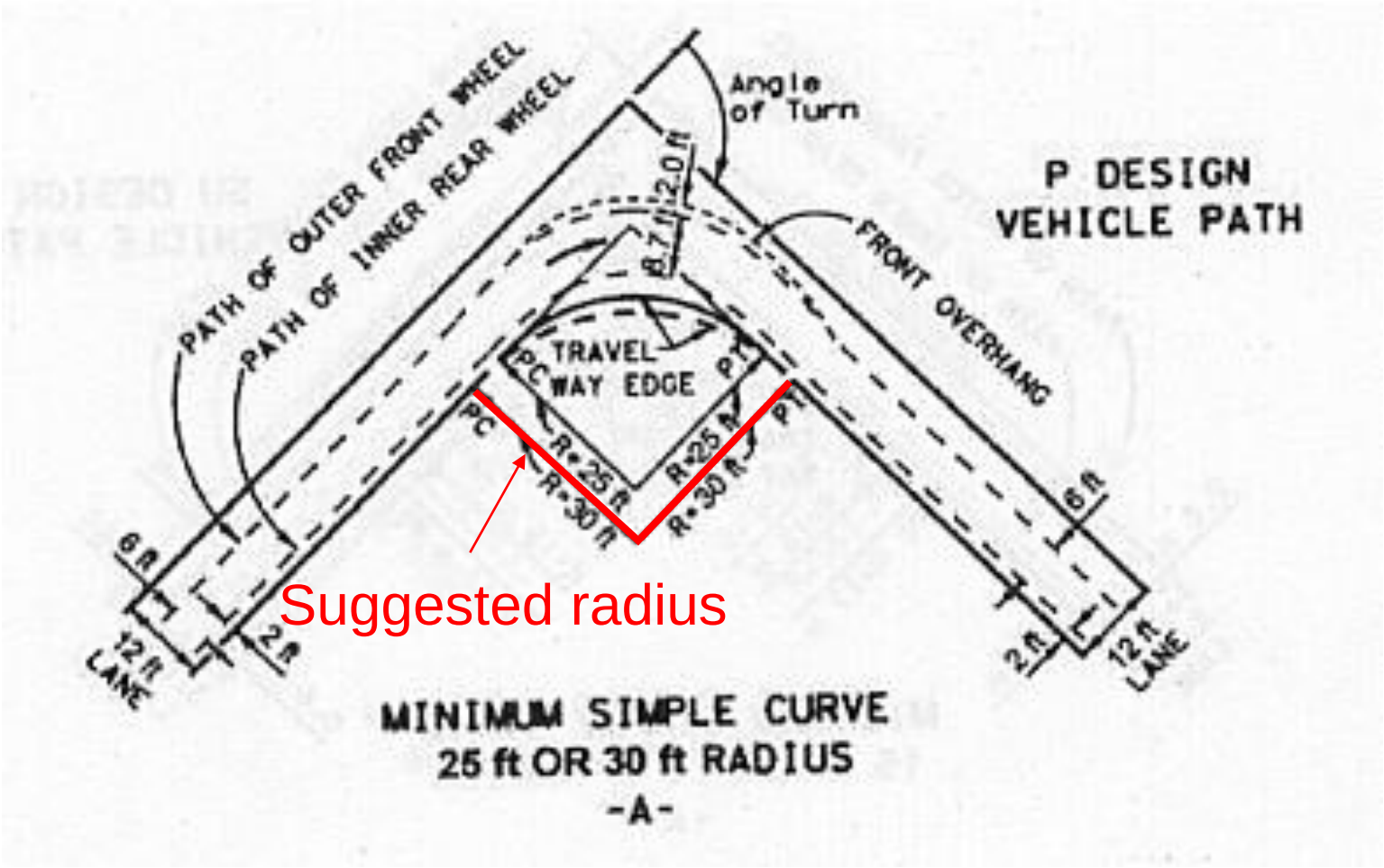
US Customary					
Angle of turn (degrees)	Design vehicle	3-centered compound Curve radii (ft)	3-centered compound Symmetric offset (ft)	3-centered compound Curve radii (ft)	3-centered compound Asymmetric (ft)
75	P	100-75-100	2.0	–	–
	SU	120-45-120	2.0	–	–
	WB-40	120-45-120	5.0	120-45-195	2.0–6.5
	WB-50	150-50-150	6.5	150-50-225	2.0–10.0
	WB-62	440-75-440	15.0	140-100-540	5.0–12.0
	WB-67	420-75-420	10.0	200-80-600	1.0–10.0
	WB-100T	250-80-250	4.5	100-80-300	1.5–5.0
	WB-109D	700-125-700	6.5	150-110-550	1.5-11.5
90	P	100-20-100	2.5	–	–
	SU	120-40-120	2.0	–	–
	WB-40	120-40-120	5.0	120-40-200	2.0–6.5
	WB-50	180-60-180	6.5	120-40-200	2.0–10.0
	WB-62	400-70-400	10.0	160-70-360	6.0–10.0
	WB-67	440-65-440	10.0	200-70-600	1.0–11.0
	WB-100T	250-70-250	4.5	200-70-300	1.0–5.0
	WB-109D	700-110-700	6.5	100-95-550	2.0–11.5
105	P	100-20-100	2.5	–	–
	SU	100-35-100	3.0	–	–
	WB-40	100-35-100	5.0	100-55-200	2.0–8.0
	WB-50	180-45-180	8.0	150-40-210	2.0–10.0
	WB-62	520-50-520	15.0	360-75-600	4.0–10.5
	WB-67	500-50-500	13.0	200-65-600	1.0–11.0
	WB-100T	250-60-250	5.0	100-60-300	1.5–6.0
	WB-109D	700-95-700	8.0	150-80-500	3.0–15.0

Turning Roadways

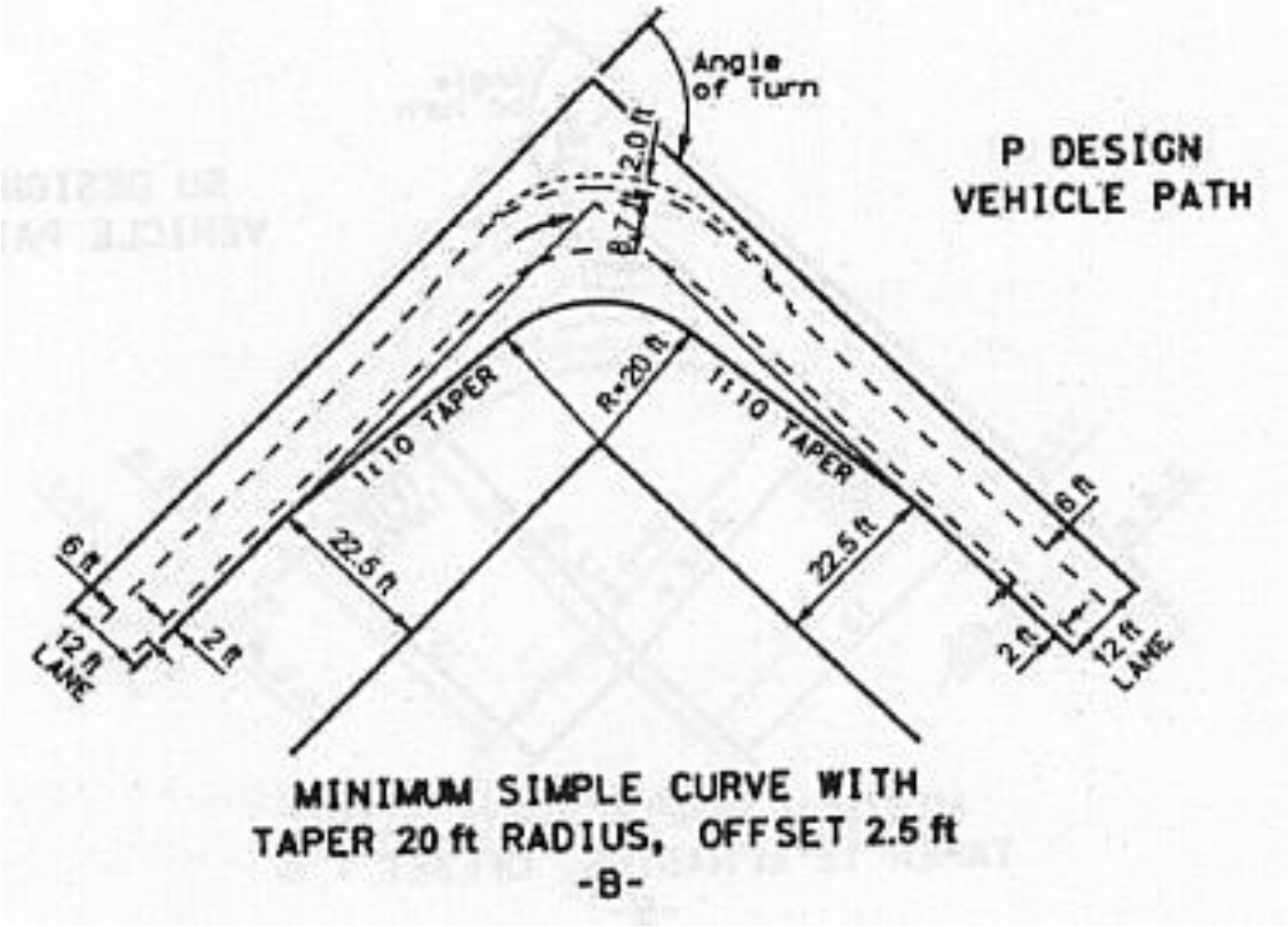


MINIMUM SIMPLE CURVE
25 ft OR 30 ft RADIUS
-A-

Turning Roadways



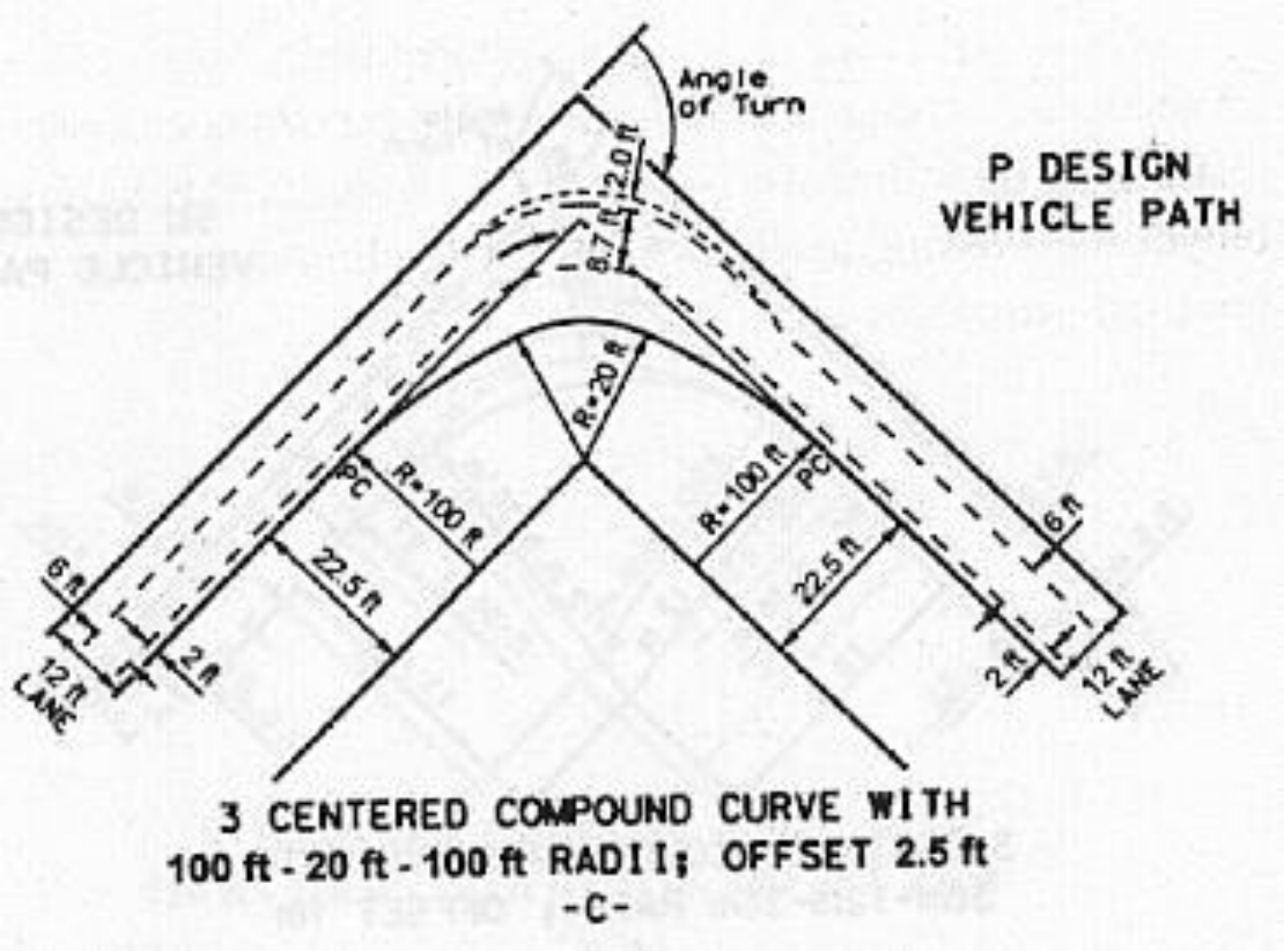
Turning Roadways



MINIMUM SIMPLE CURVE WITH TAPER 20 ft RADIUS, OFFSET 2.5 ft

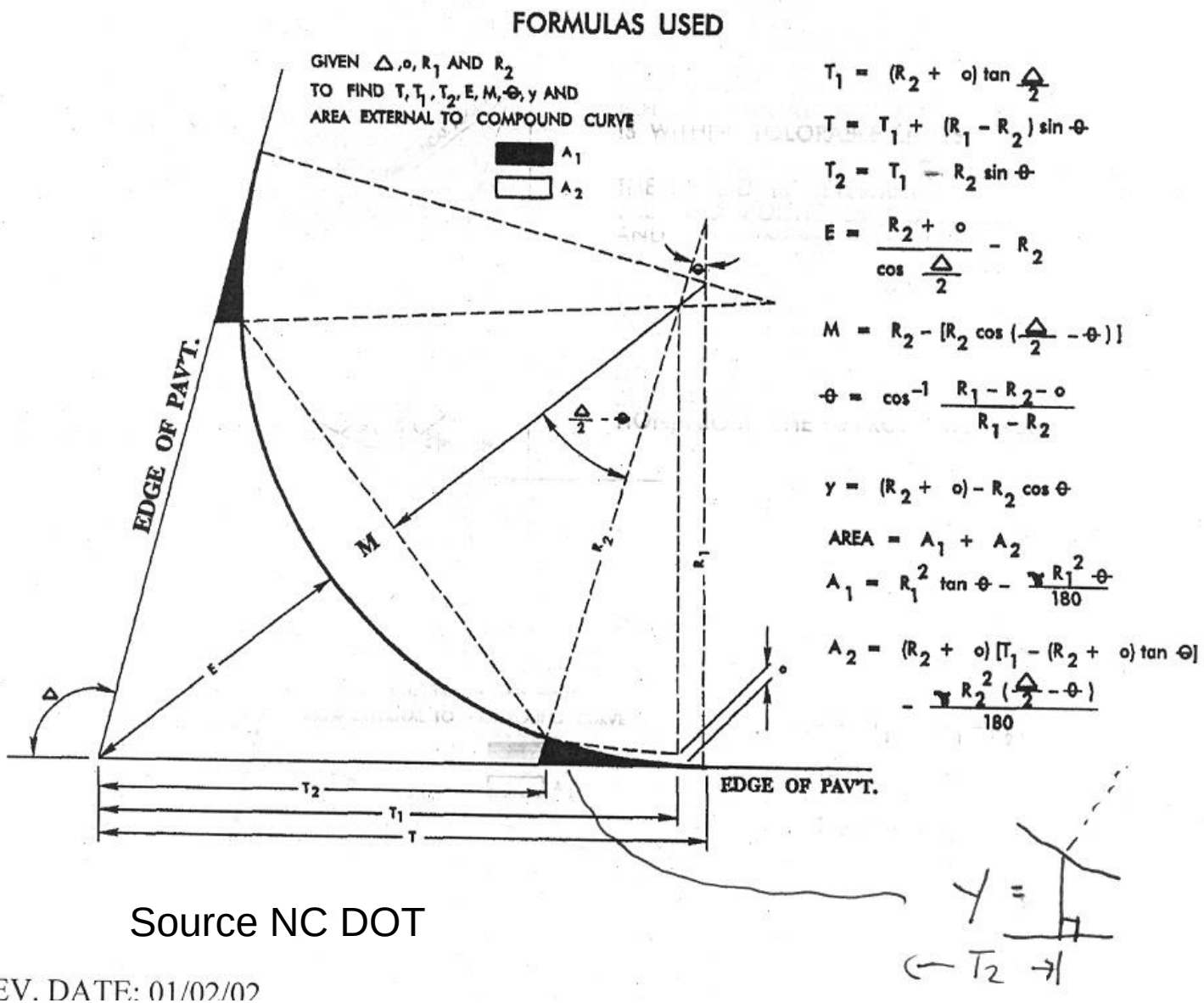
-8-

Turning Roadways



3 CENTERED COMPOUND CURVE WITH
100 ft - 20 ft - 100 ft RADII; OFFSET 2.5 ft
-C-

Turning Roadways

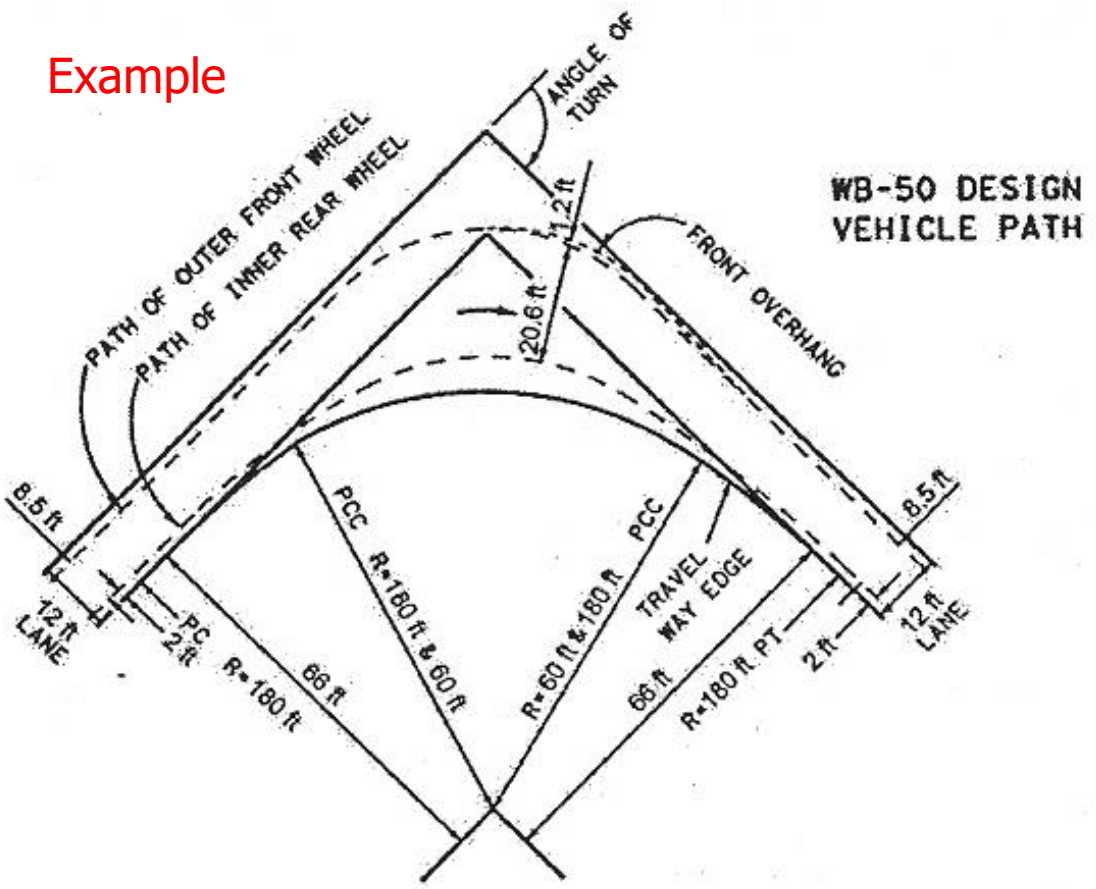


Source NC DOT

REV. DATE: 01/02/02

Turning Roadways

Example



WB-50 SEMITRAILER COMBINATION
3 CENTERED COMPOUND CURVE,
180 ft - 60 ft - 180 ft RADII, OFFSET 6 ft

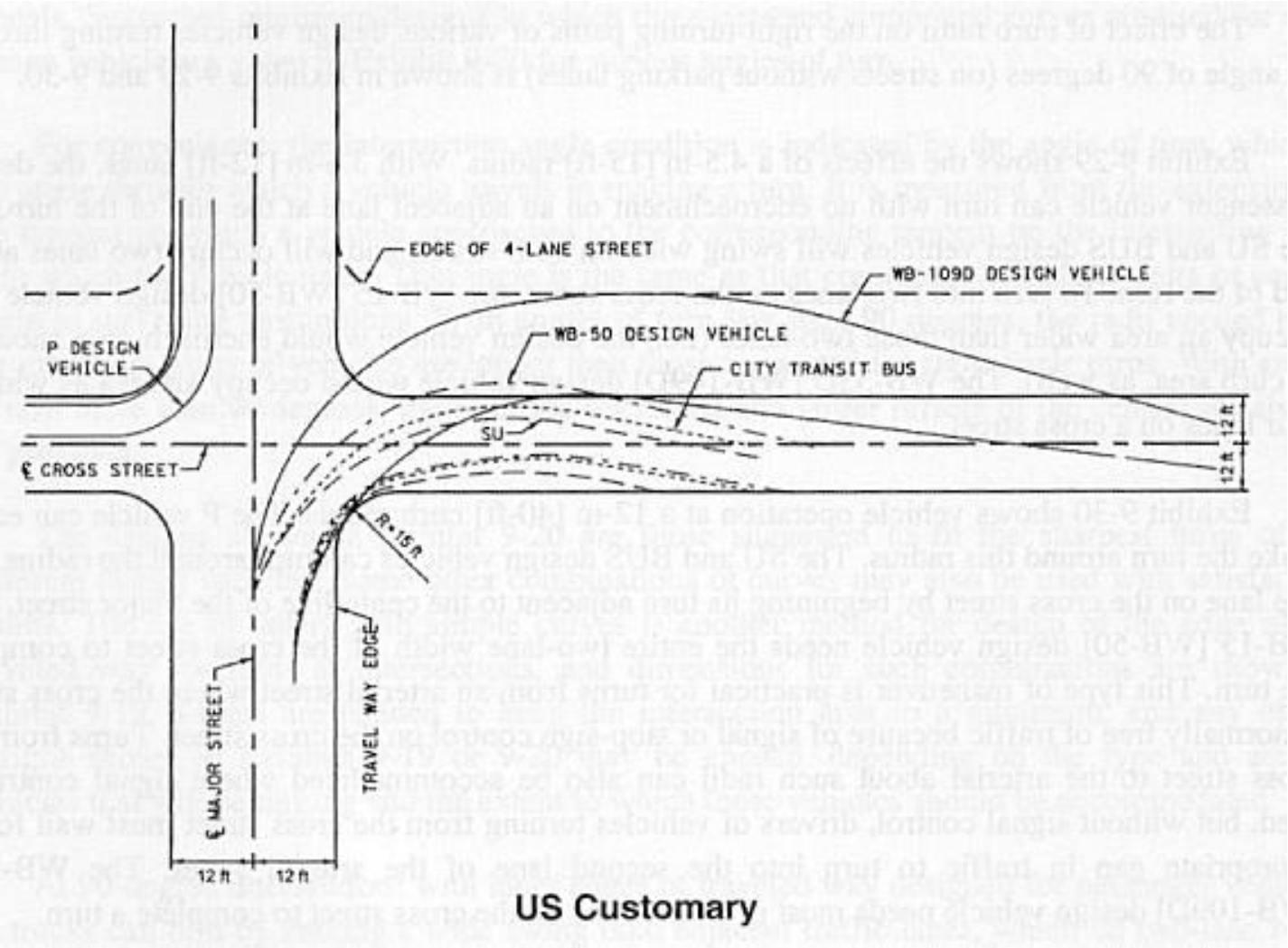
Turning Roadways

- Summary for METW
  - P design vehicle: local road intersections with major roads where turns are made only occasionally
  - SU truck design vehicle: recommended minimum for rural highways
  - Semitrailer combination: used where truck combinations will turn repeatedly; three-centered compound curves may be preferred; may be desirable to build corner triangular island (to minimize asphalt overlay)

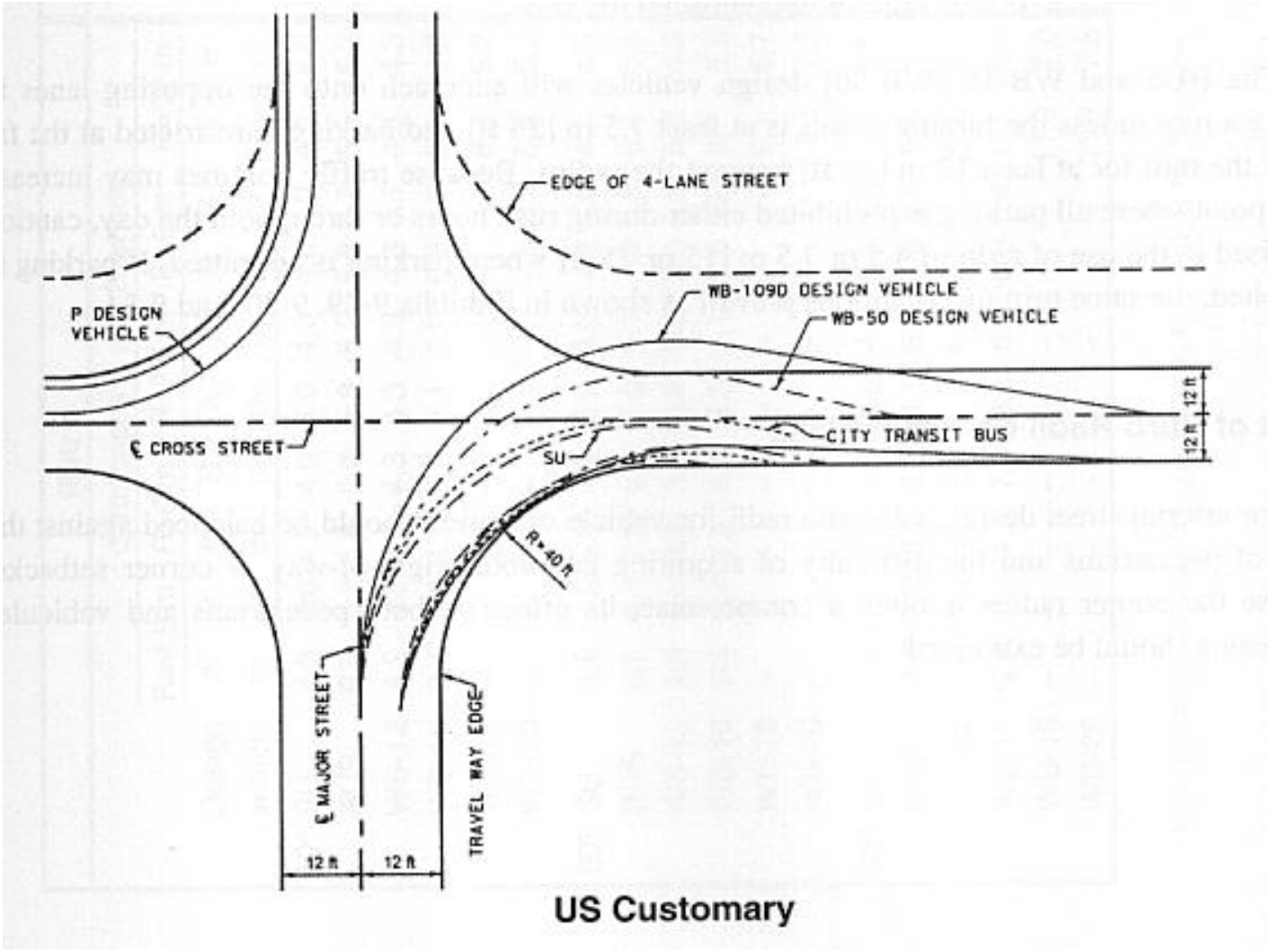
Turning Roadways

- Effects of Curb Radii on Turning Paths
  - 15-ft radii
    - Large vehicles cannot make a right turn with a radii of 15 ft
    - Even with 4 lanes, large vehicles will impede on opposing lanes
    - Passenger vehicles have enough space to turn
  - 40-ft radii
    - City transit bus can turn without impeding on opposing lane
    - Large trucks (WB 50 and WB109D) still need to impede on opposing lane

Turning Roadways



Turning Roadways



Turning Roadways

- Effects of Curb Radii on Pedestrians
  - Adequate radii is often a compromise between pedestrian and vehicular movements
- General guidelines:
  - Radii of 15 to 25 ft is adequate for passenger vehicles
  - Radii of 25 ft or more: provide at minor cross streets for new construction
  - Radii of 30 ft or more: provide at minor cross street so that occasional trucks can turn without too much encroachment
  - Radii of 40 ft or more: used where large trucks or buses turn frequently (use three-centered curves)
  - Heavy pedestrian activity: below 25 ft is better (may create problems with larger vehicles)

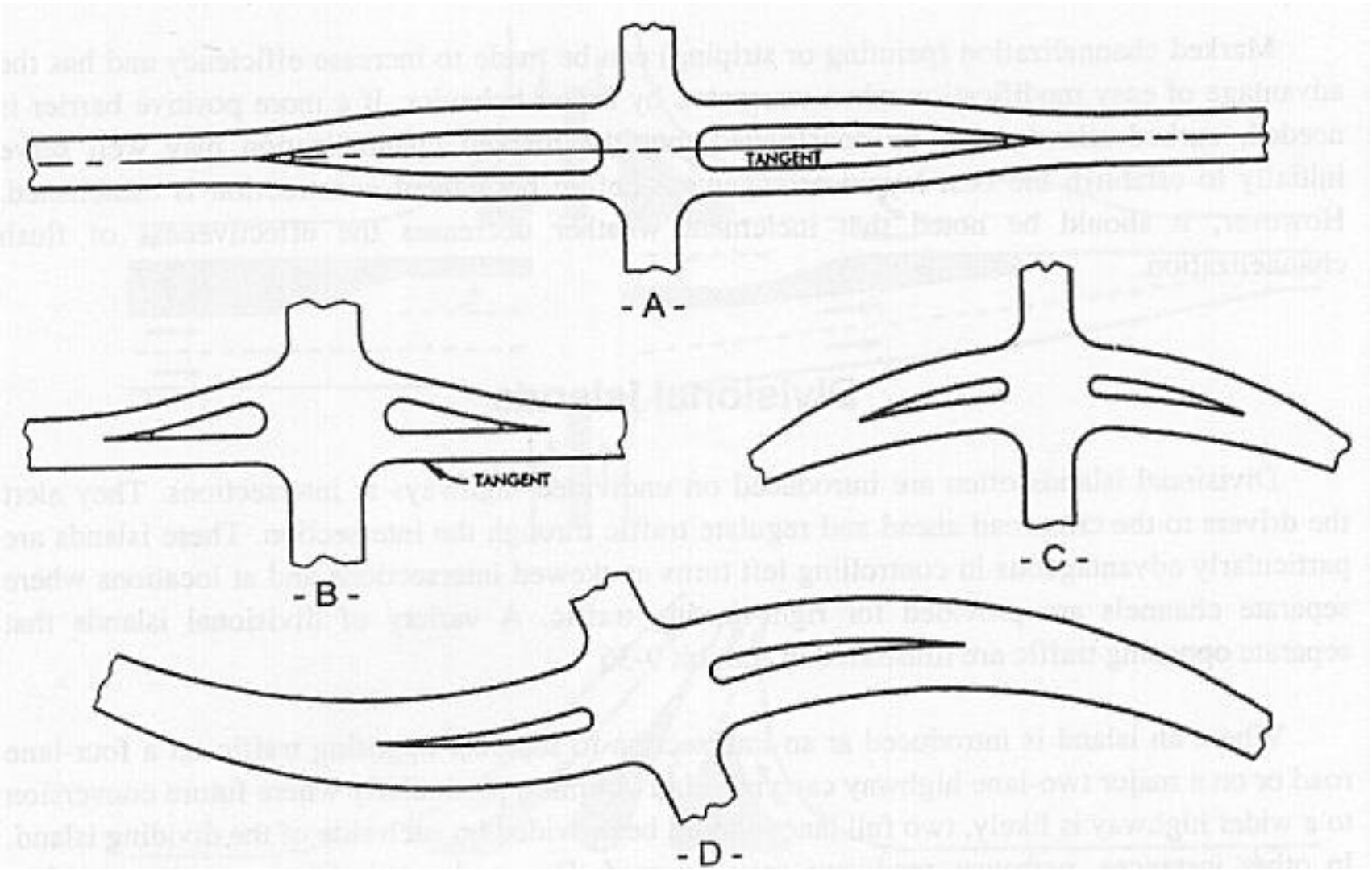
Islands

- Islands
  - Area between traffic lanes used for controlling vehicle movements
  - Purposes:
    - Separate conflicts
    - Control angle of conflict
    - Reduce excessive pavement area
    - Regulate traffic
    - Favor a predominant turning movement
    - Protect pedestrians
    - Provide storage for vehicles
    - Allow the use of traffic control devices
  - Drivers are not meant to drive over them

Islands

- Channelizing Islands
  - Use to control and direct movement traffic at intersections
  - The path should be obvious to the driver
  - Avoid the use of multiple islands (three or more) to channelize various movements
  - Need to include pavement marking/delineation near the island
- Divisional islands
  - Use to control left turns and provide refuge for pedestrians at intersections
  - Usually built on 4-lane highways (2-lane with future expansion)
  - May use taper design

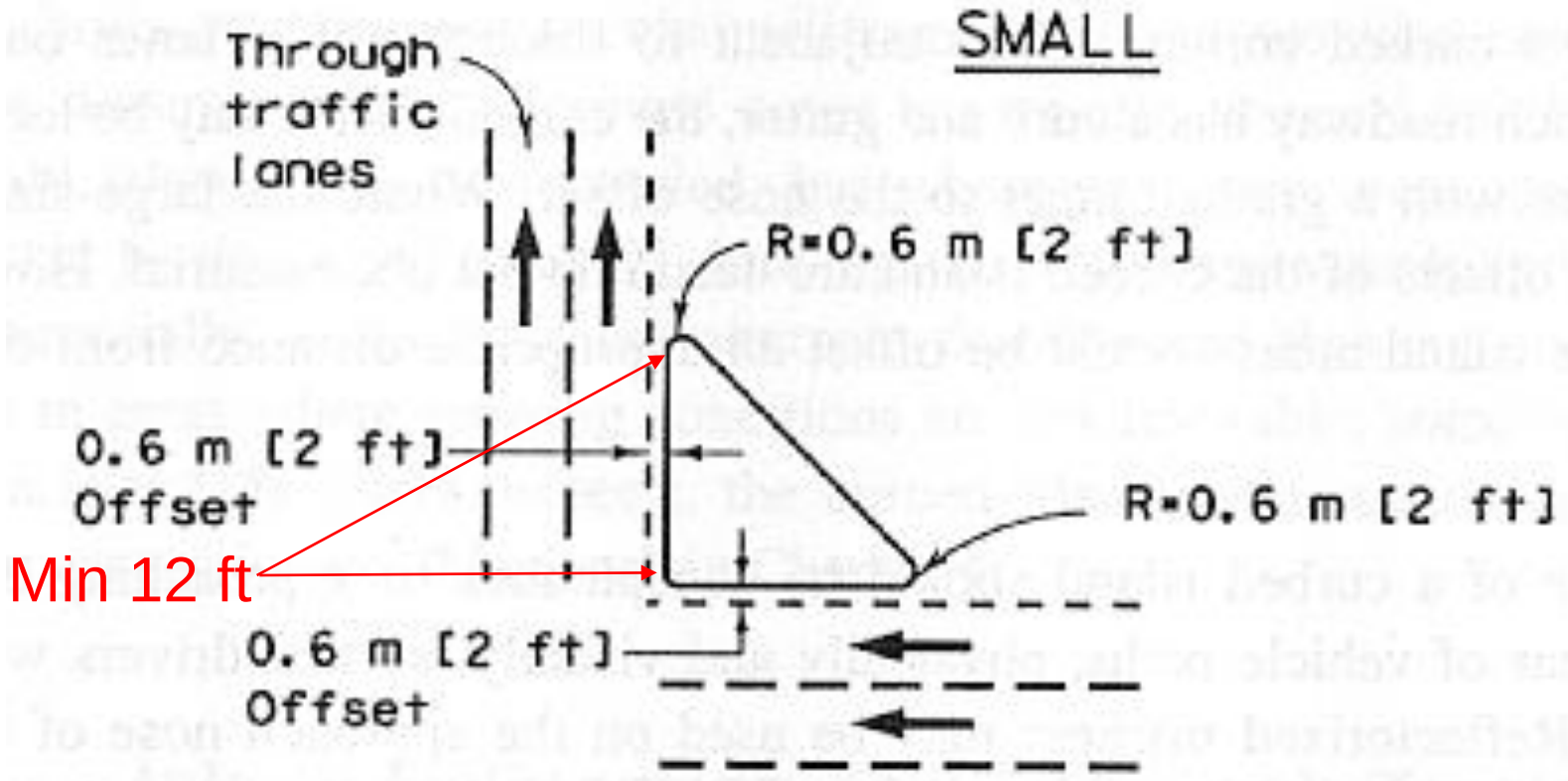
Islands



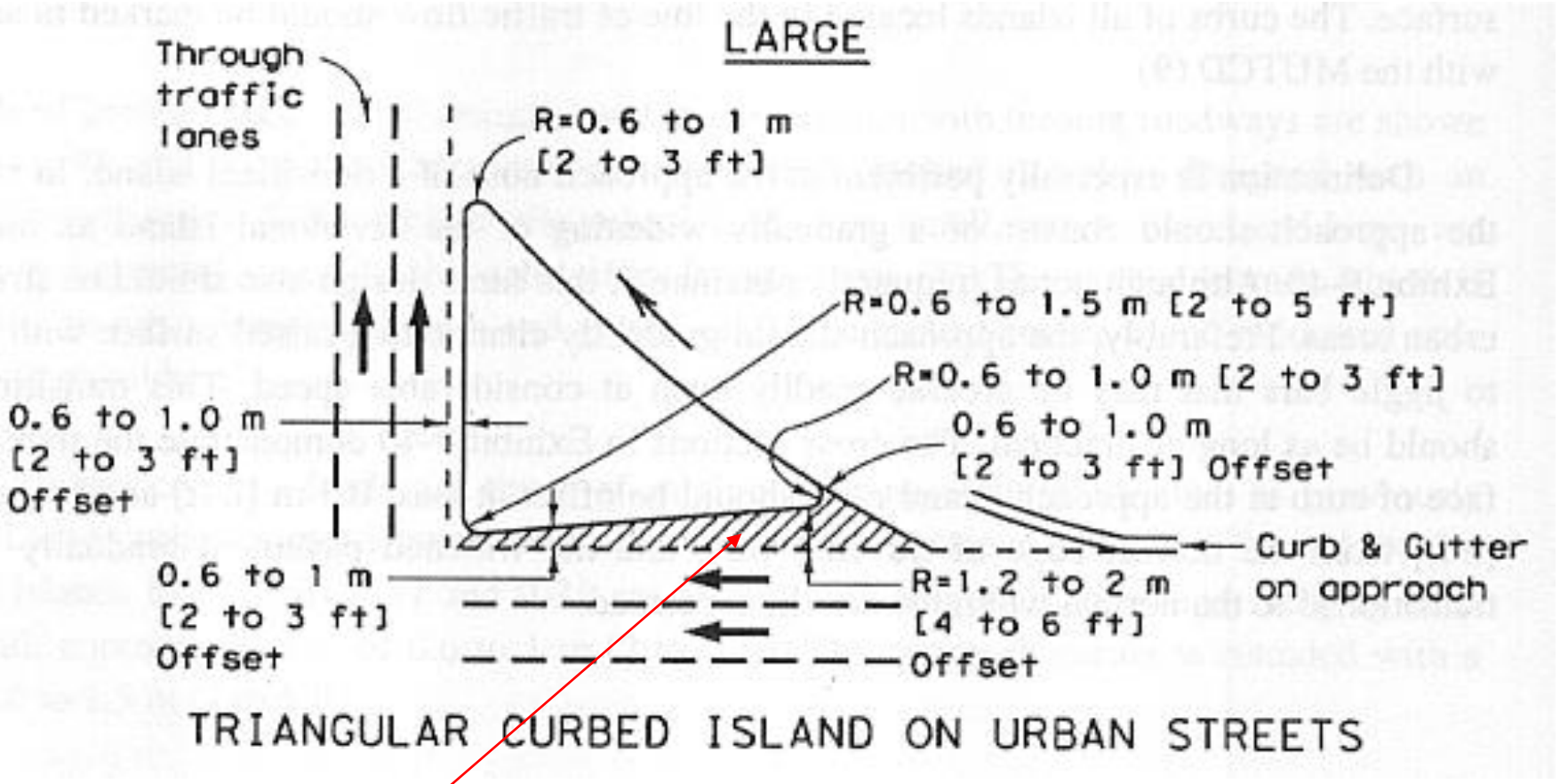
Islands

- Island Size and Designation
  - Corner islands
    - Urban: 50 ft^2
    - Rural: 75 ft^2
    - Length: minimum 12 ft for each side
  - Divisional islands
    - Width: 4 ft (6 ft if designed for pedestrians)
    - Length: 20 to 25 ft (high speed: 100 ft)
- Delineation
  - Curb height: 6 in (low speed)
  - May provide vegetation cover, mounted earth, shrubs for large islands
  - Corner island: offset and corner radii dependent on side length

Islands


SMALL
Through traffic lanes
R=0.6 m [2 ft]
0.6 m [2 ft] Offset
R=0.6 m [2 ft]
Min 12 ft
0.6 m [2 ft] Offset

Islands

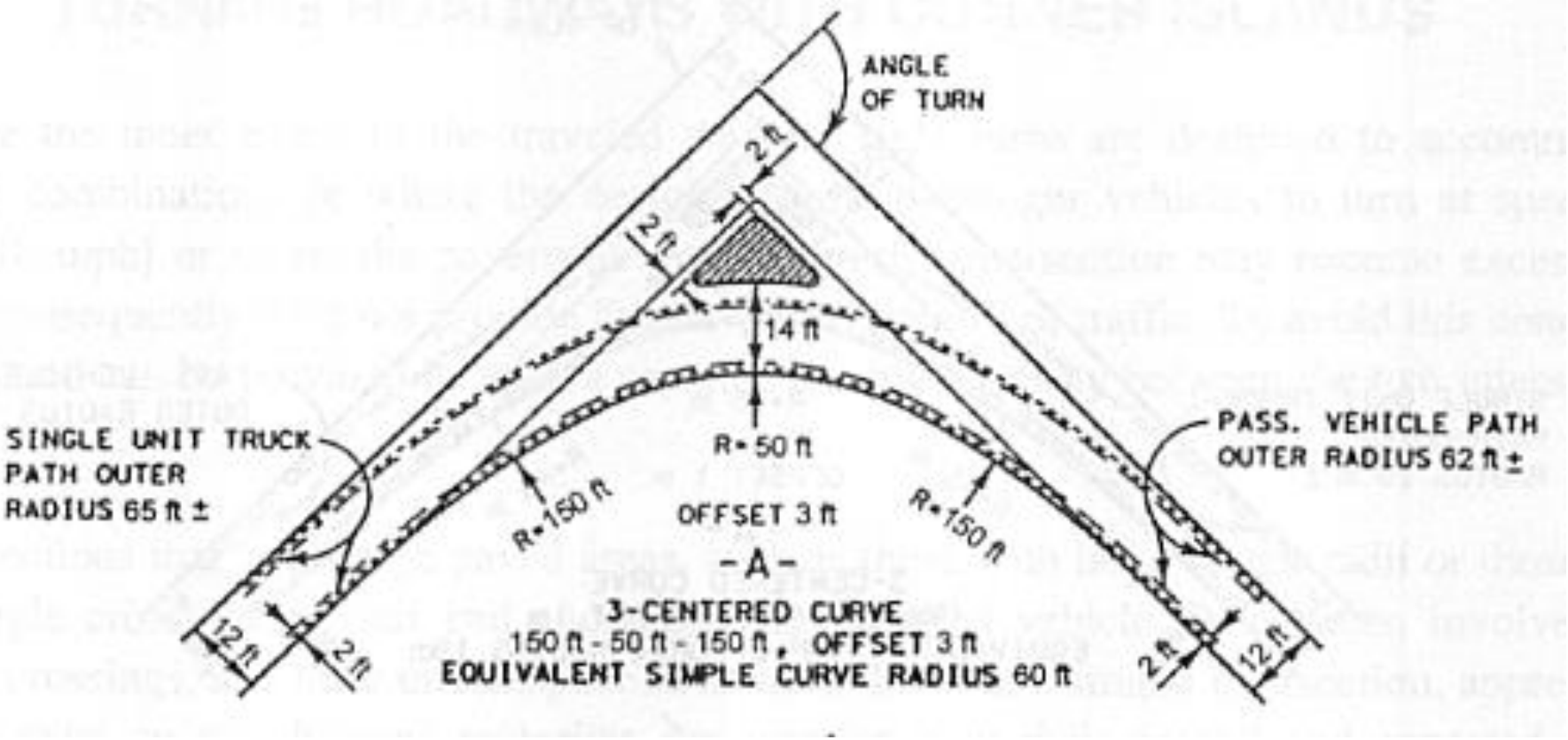


Painted stripes

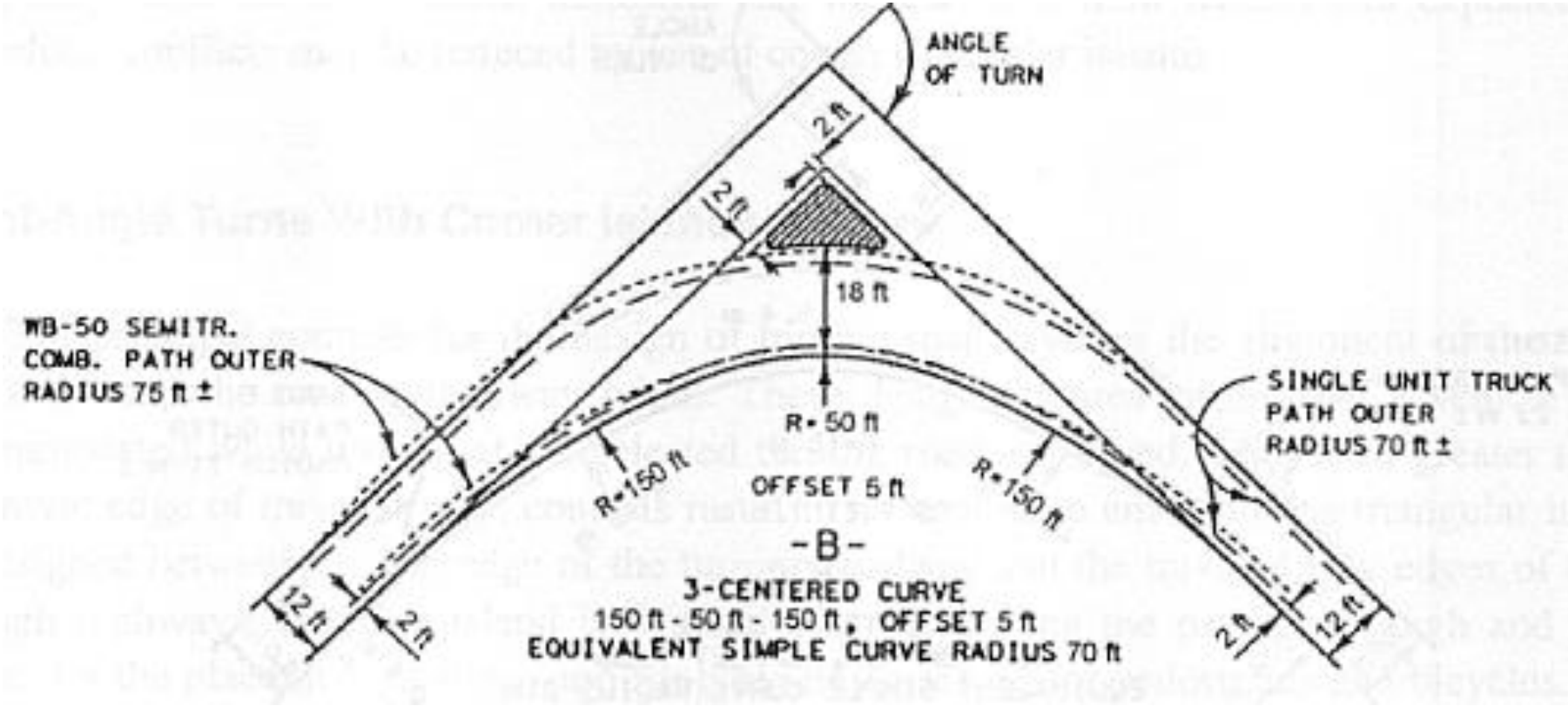
Islands

- Corner islands
  - The turning roadway should be provided with at least the minimum size island and the minimum width of roadway
  - Minimum offset: 2 ft
  - To discourage passenger cars from using a wide roadway, the roadway may be marked with paint or thermoplastic markings

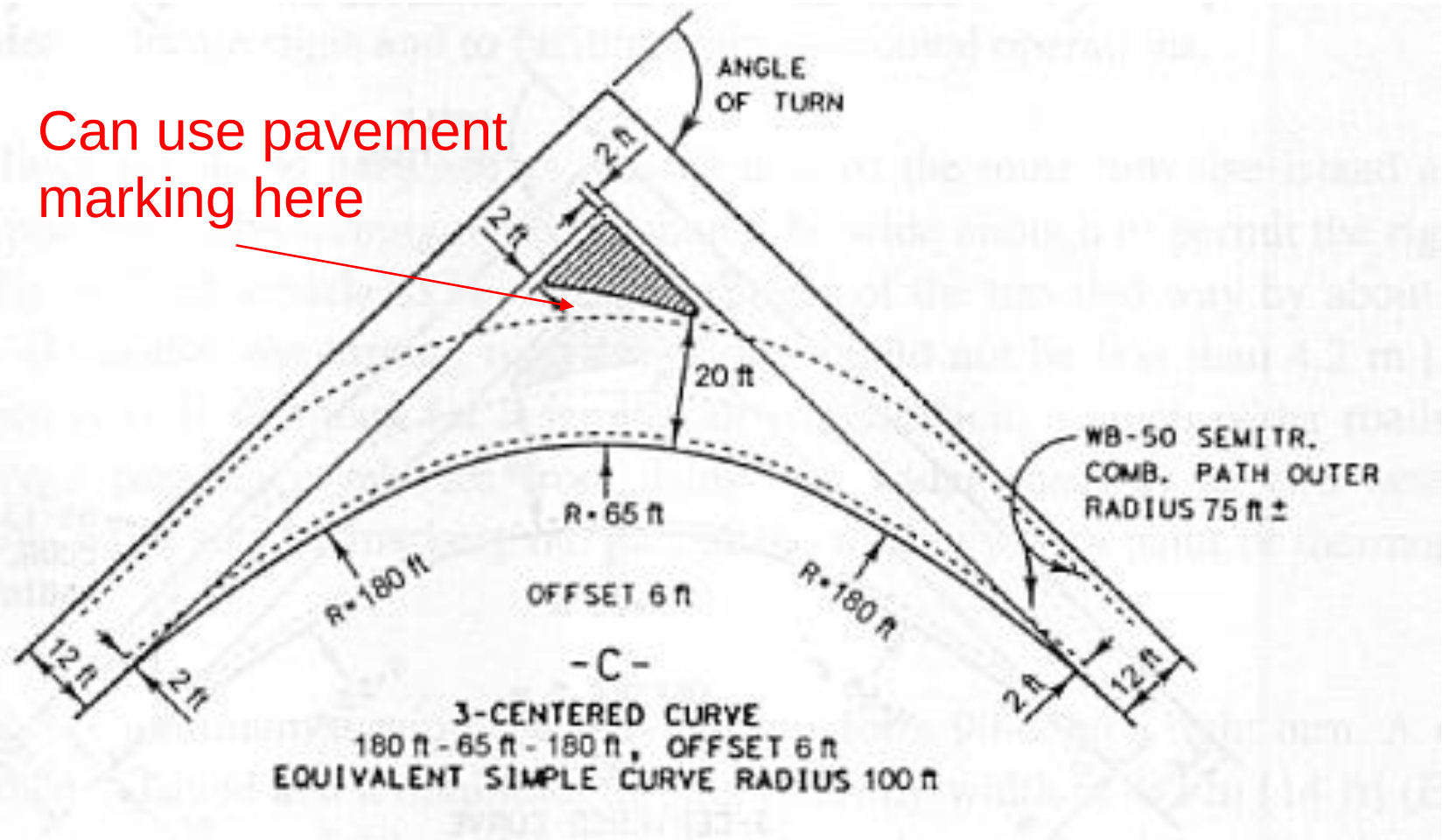
Islands


ANGLE
OF TURN
2 ft
2 ft
14 ft
R = 50 ft
R = 150 ft
R = 150 ft
OFFSET 3 ft
SINGLE UNIT TRUCK
PATH OUTER
RADIUS 65 ft ±
PASS. VEHICLE PATH
OUTER RADIUS 62 ft ±
12 ft
2 ft
2 ft
12 ft
-A-
3-CENTERED CURVE
150 ft - 50 ft - 150 ft, OFFSET 3 ft
EQUIVALENT SIMPLE CURVE RADIUS 60 ft

Islands


ANGLE
OF TURN
2 ft
2 ft
18 ft
WB-50 SEMITR.
COMB. PATH OUTER
RADIUS 75 ft ±
SINGLE UNIT TRUCK
PATH OUTER
RADIUS 70 ft ±
R=50 ft
R=150 ft
R=150 ft
OFFSET 5 ft
-B-
3-CENTERED CURVE
150 ft - 50 ft - 150 ft, OFFSET 5 ft
EQUIVALENT SIMPLE CURVE RADIUS 70 ft
12 ft
2 ft
2 ft
12 ft

Islands


Can use pavement marking here
ANGLE OF TURN
2 ft
2 ft
20 ft
WB-50 SEMITR. COMB. PATH OUTER RADIUS 75 ft ±
R=65 ft
R=180 ft
R=180 ft
OFFSET 6 ft
12 ft
2 ft
2 ft
12 ft
-C-
3-CENTERED CURVE
180 ft - 65 ft - 180 ft, OFFSET 6 ft
EQUIVALENT SIMPLE CURVE RADIUS 100 ft

Islands

US Customary					
Angle of turn (degrees)	Design classification	Three-centered compound curve		Width of lane (ft)	Approx. island size (ft^2)
		Radii (ft)	Offset (ft)		
75	A	150-75-150	3.5	14	60
	B	150-75-150	5.0	18	50
	C	180-90-180	3.5	20	50
90[a]	A	150-50-150	3.0	14	50
	B	150-50-150	5.0	18	80
	C	180-65-180	6.0	20	125
105	A	120-40-120	2.0	15	70
	B	100-35-100	5.0	22	50
	C	180-45-180	8.0	30	60
120	A	100-30-100	2.5	16	120
	B	100-30-100	5.0	24	90
	C	180-40-180	8.5	34	220
135	A	100-30-100	2.5	16	460
	B	100-30-100	5.0	26	370
	C	160-35-160	9.0	35	640
150	A	100-30-100	2.5	16	1400
	B	100-30-100	6.0	30	1170
	C	160-35-160	7.1	38	1720

A: Passenger cars + occasional single-unit truck

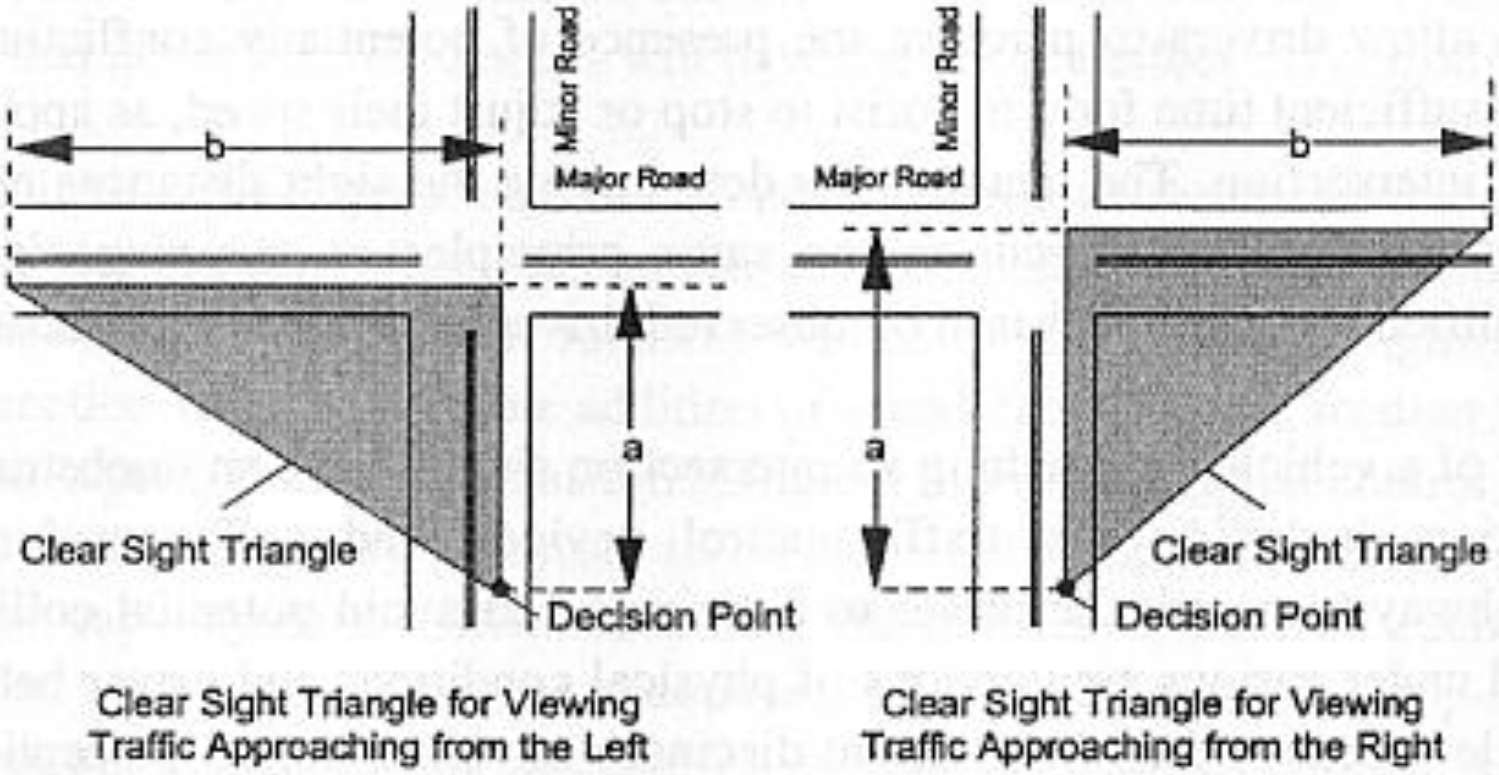
B: SU trucks + occasional semi-trailers (WB-50) (slight encroachment)

C: Full access to WB-50

Intersection Sight Distance

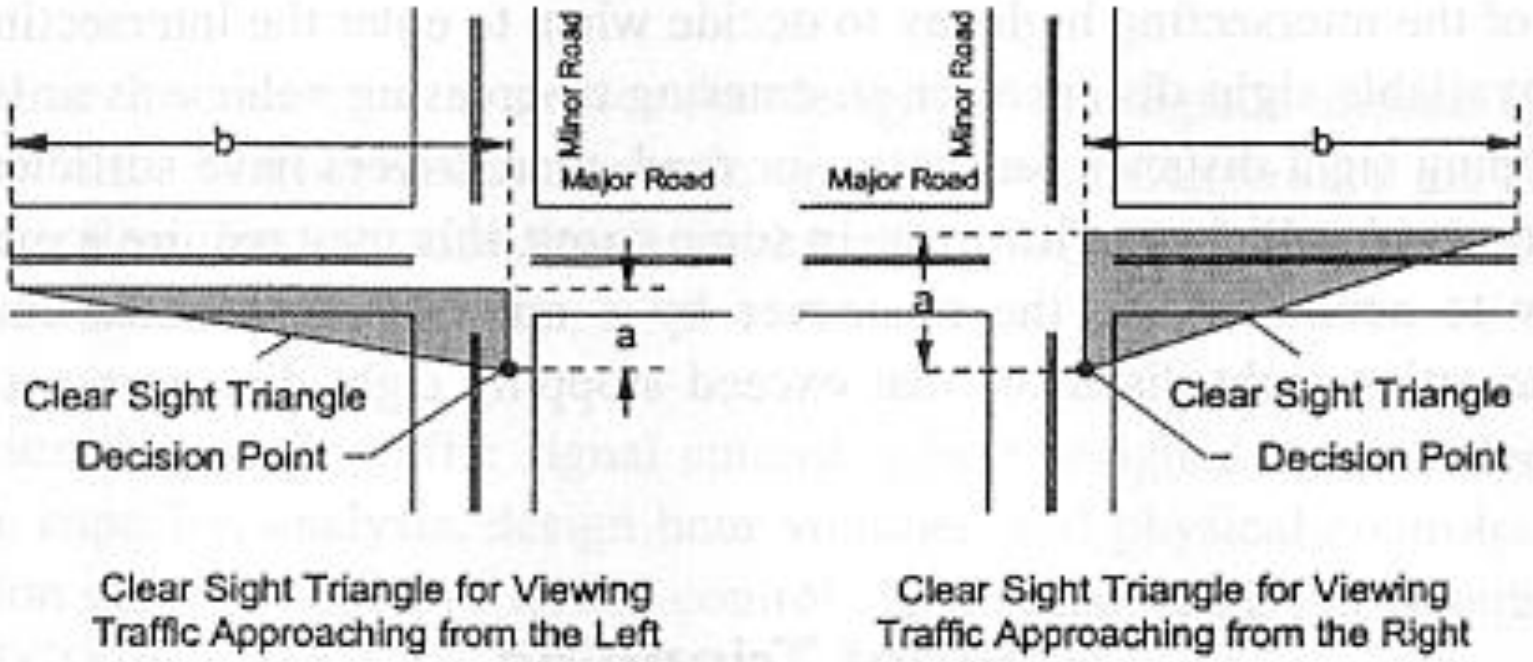
- The stopping sight distance needs to be provided at intersections
- Sight distance is provided to perceive the presence of potentially conflicting vehicles
- Thus, the driver need to have an unobstructed view of the entire intersection
- Rationale: a driver has enough distance to stop if a conflicting vehicle enters the intersection

Intersection Sight Distance



A – Approach Sight Triangles

Intersection Sight Distance



B – Departure Sight Triangles

Intersection Sight Distance

- Characteristics:
  - Within the sight triangles, all obstructions should be removed: buildings, parked vehicles, tress, hedges, tall grass, etc.
  - Eye height: 3.5 ft
  - Object height: 3.5 ft (4.35 ft less 10 inches allowance) (vehicle height)
  - Sometimes, can use eye height for trucks (7.6 ft)

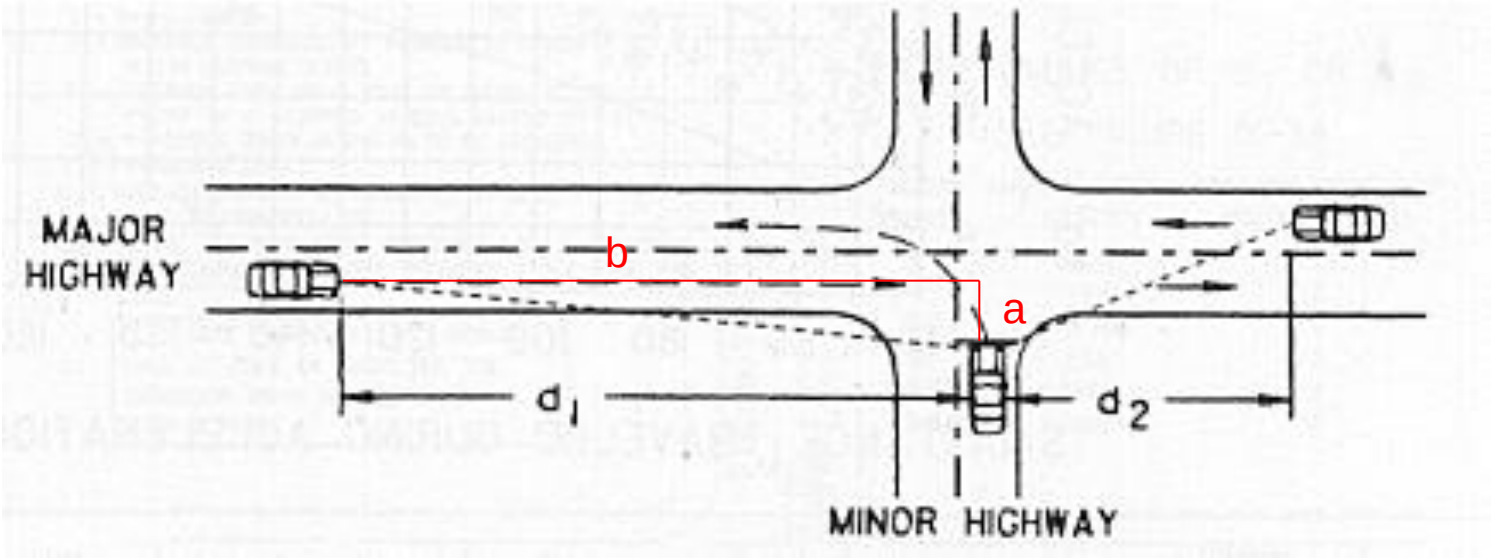
Intersection Sight Distance

- Sight distance determine for different types of traffic control:
  - Case A: no control
  - Case B: Stop controlled (2 stop signs)
  - Case C: Yield control
  - Case D: traffic signals
  - Case E: All-way stop controlled
  - Case F: left-turns from the major road

Intersection Sight Distance

- Intersections with Stop Control (Case B)
  - Case B1: left turns from minor road
  - Case B2: Right turns from minor road
  - Case B3: Crossing major road

Intersection Sight Distance
Case B1



Assumptions:

Position of vehicle: 14.5 ft from edge of traveled way

Left: position of vehicle + ½ lane (dimension "*a*" above)

Right: position of vehicle + 1 ½ lane (dimension "*a*" above)

Intersection Sight Distance
Case B1

Dimension "*b*" in figure above

US Customary		
$ISD = 1.47\, V_{major}\, t_g$ (9-1)		
where:		
ISD	=	intersection sight distance (length of the leg of sight triangle along the major road) (ft)
V_{major}	=	design speed of major road (mph)
t_g	=	time gap for minor road vehicle to enter the major road (s)

Intersection Sight Distance
Case B1

Design vehicle	Time gap (s) at design speed of major road (t_g)
Passenger car	7.5
Single-unit truck	9.5
Combination truck	11.5

Note: Time gaps are for a stopped vehicle to turn right or left onto a two-lane highway with no median and grades 3 percent or less. The table values require adjustment as follows:

For multilane highways:

For left turns onto two-way highways with more than two lanes, add 0.5 seconds for passenger cars or 0.7 seconds for trucks for each additional lane, from the left, in excess of one, to be crossed by the turning vehicle.

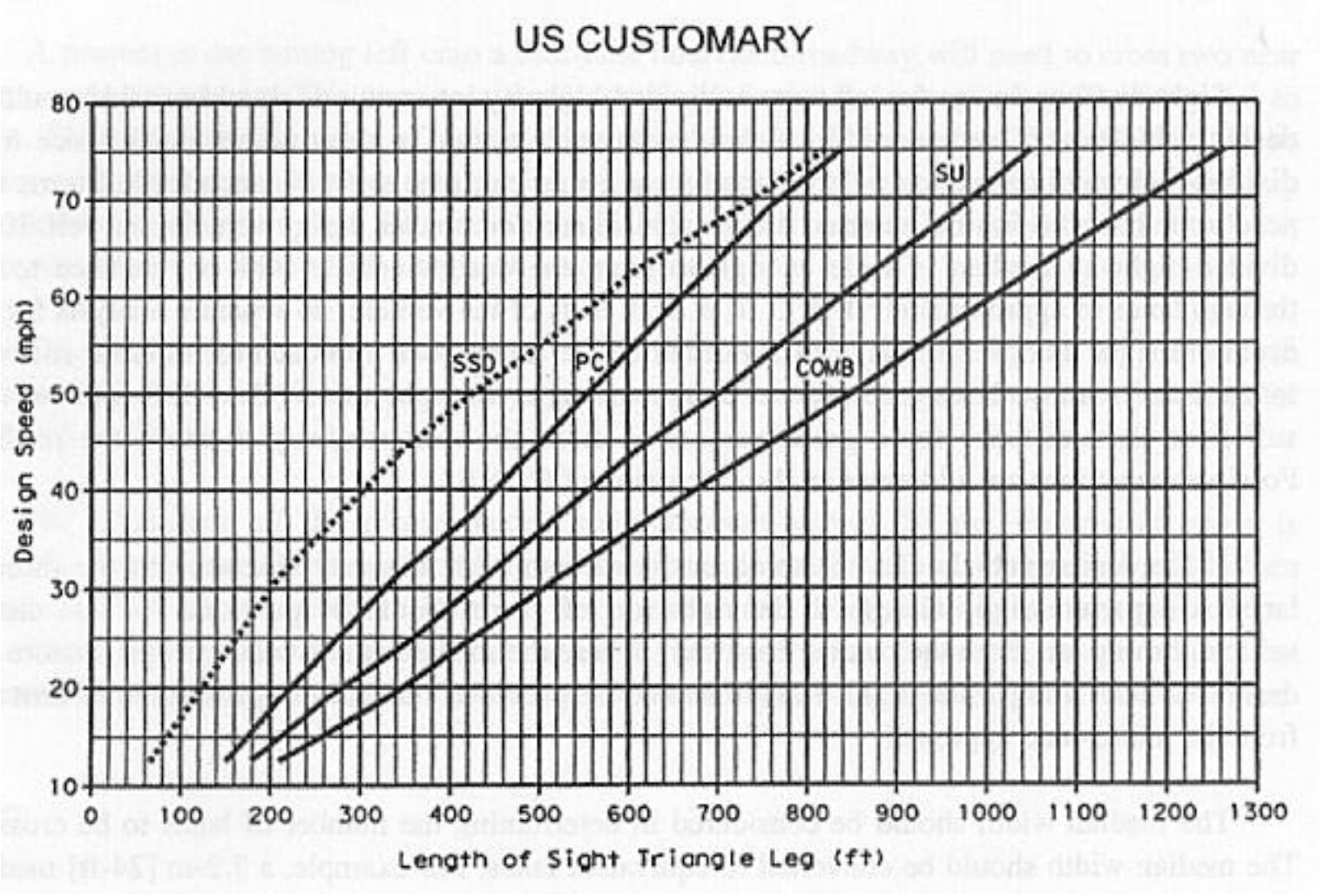
For minor road approach grades:

If the approach grade is an upgrade that exceeds 3 percent; add 0.2 seconds for each percent grade for left turns

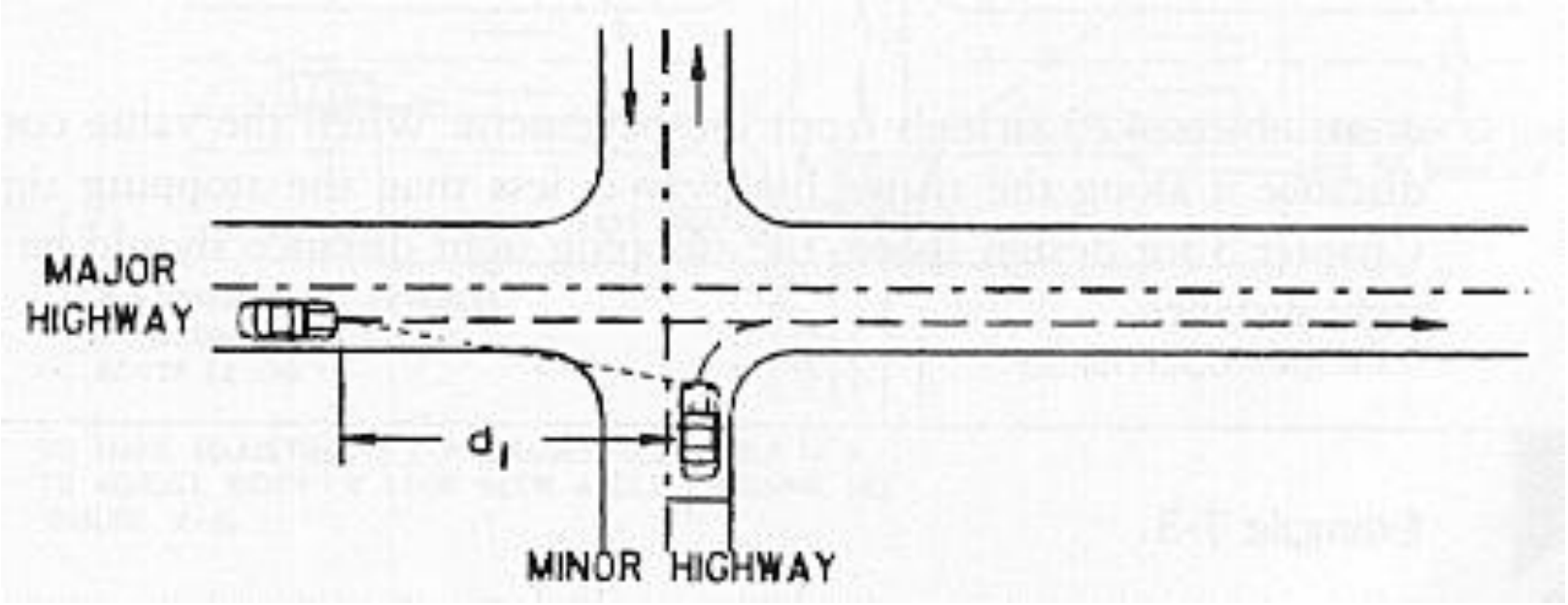
Intersection Sight Distance
Case B1

US Customary			
Design speed (mph)	Stopping sight distance (ft)	Intersection sight distance for passenger cars	
		Calculated (ft)	Design (ft)
15	80	165.4	170
20	115	220.5	225
25	155	275.6	280
30	200	330.8	335
35	250	385.9	390
40	305	441.0	445
45	360	496.1	500
50	425	551.3	555
55	495	606.4	610
60	570	661.5	665
65	645	716.6	720
70	730	771.8	775
75	820	826.9	830
80	910	882.0	885

Intersection Sight Distance
Case B1



Intersection Sight Distance
Case B2



Intersection Sight Distance
Case B2

- Right Turn from the Minor Road
  - Use same approach as for left turn
  - However, need to adjust for t_g
  - The time gaps can be reduced by 1 sec

Intersection Sight Distance
Case B2

Design vehicle	Time gap (s) at design speed of major road (t_g)
Passenger car	6.5
Single-unit truck	8.5
Combination truck	10.5

Note: Time gaps are for a stopped vehicle to turn right onto or cross a two-lane highway with no median and grades 3 percent or less. The table values require adjustment as follows:

For multilane highways:
For crossing a major road with more than two lanes, add 0.5 seconds for passenger cars and 0.7 seconds for trucks for each additional lane to be crossed and for narrow medians that cannot store the design vehicle.

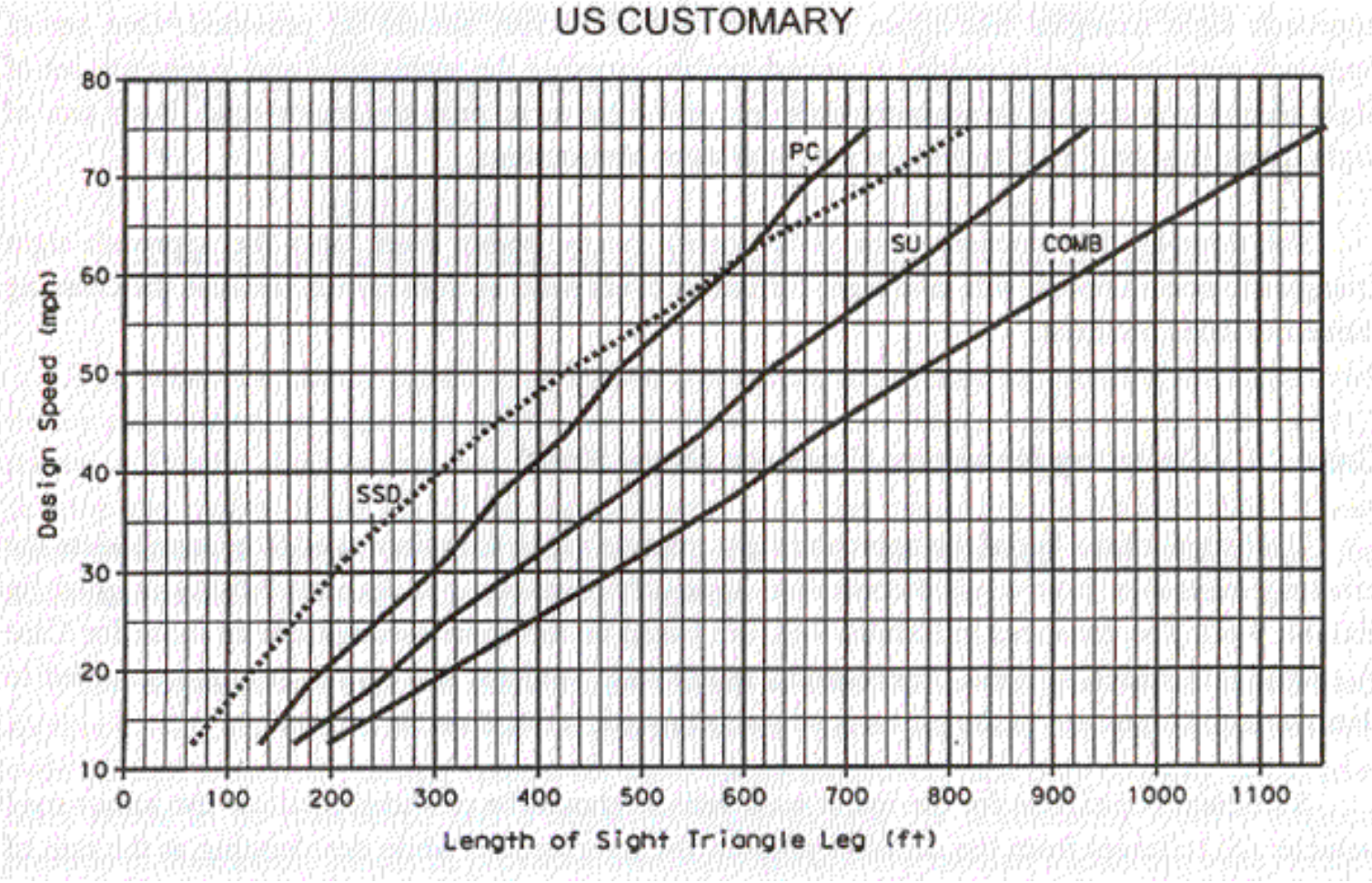
For minor road approach grades:
If the approach grade is an upgrade that exceeds 3 percent, add 0.1 seconds for each percent grade.

Intersection Sight Distance
Case B2

US Customary			
Design speed (mph)	Stopping sight distance (ft)	Intersection sight distance for passenger cars	
		Calculated (ft)	Design (ft)
15	80	143.3	145
20	115	191.1	195
25	155	238.9	240
30	200	286.7	290
35	250	334.4	335
40	305	382.2	385
45	360	430.0	430
50	425	477.8	480
55	495	525.5	530
60	570	573.3	575
65	645	621.1	625
70	730	668.9	670
75	820	716.6	720
80	910	764.4	765

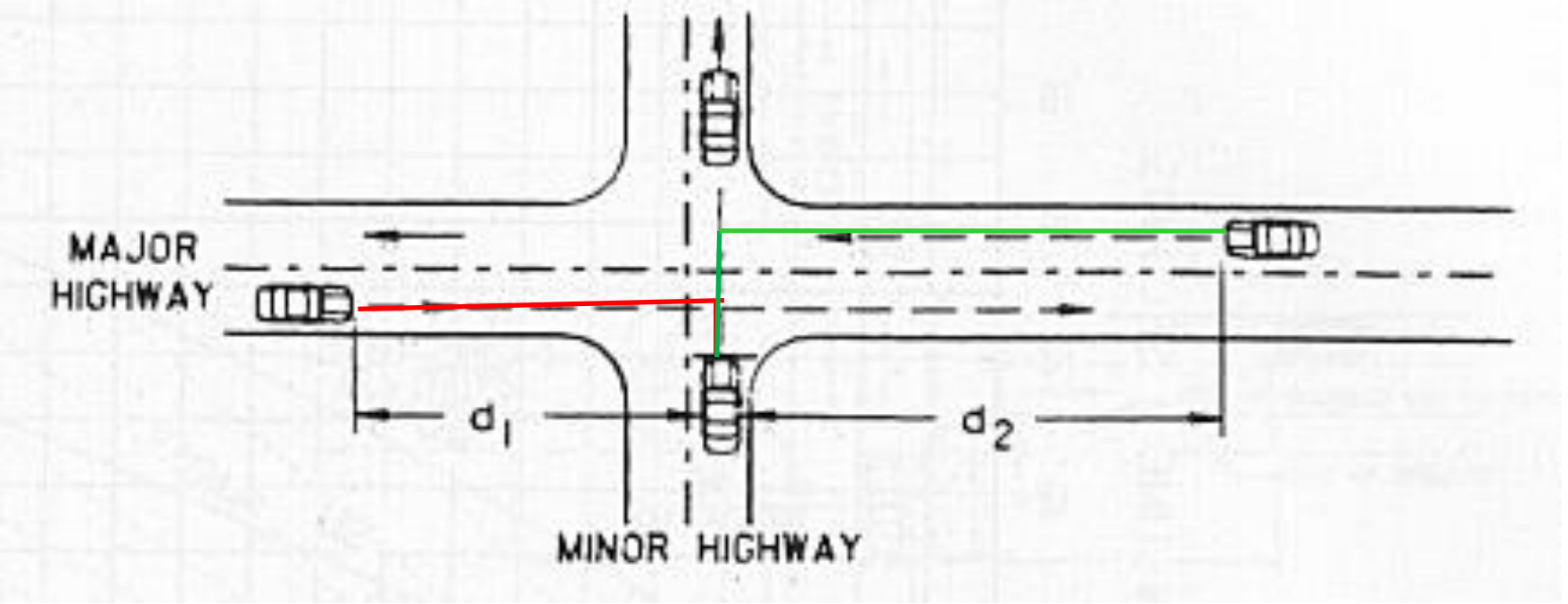
Intersection Sight Distance

Case B2



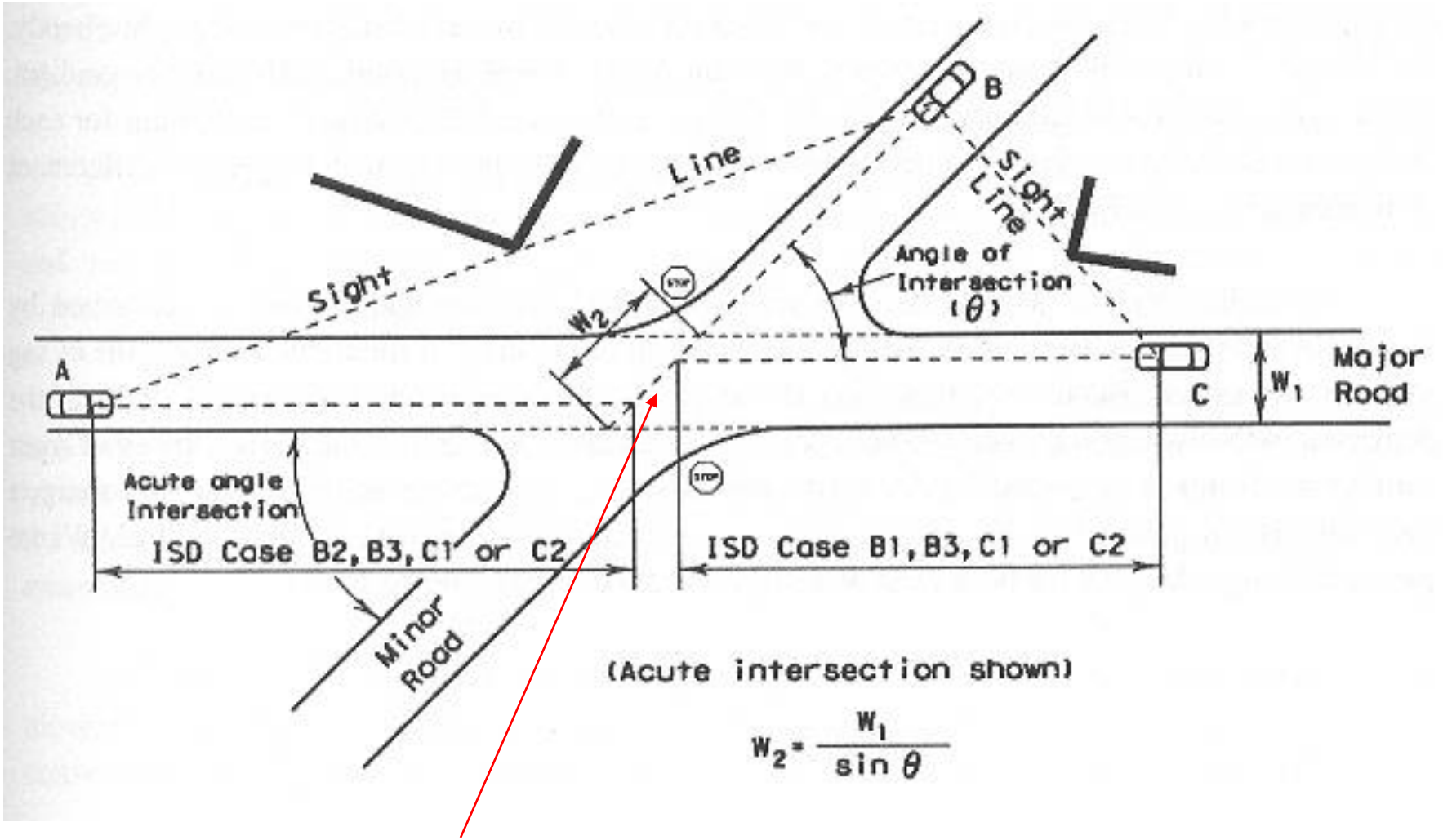
Intersection Sight Distance

Case B3



Intersection Sight Distance
Case B3

- Crossing Maneuver from minor road
  - Sight triangles defined for left-turn and right-turn should be adequate
  - Need to compute if:
    - Right and/or left turn is prohibited
    - If more than 6 lanes
    - If steep grades might slow vehicles on the minor road



The length needs to be adjusted by dividing the total width of the lanes (+ median width) to be crossed by the sine of the intersection angle.

If the difference is higher than 12 ft, need to adjust the computation of the sight distance by adding an additional lane (e.g., exhibits 9-54 & 9-57).