Modern Roundabouts
Training Workshop

Presented by:

CH2MHILL

The Modern Roundabout

What is a Modern Roundabout?

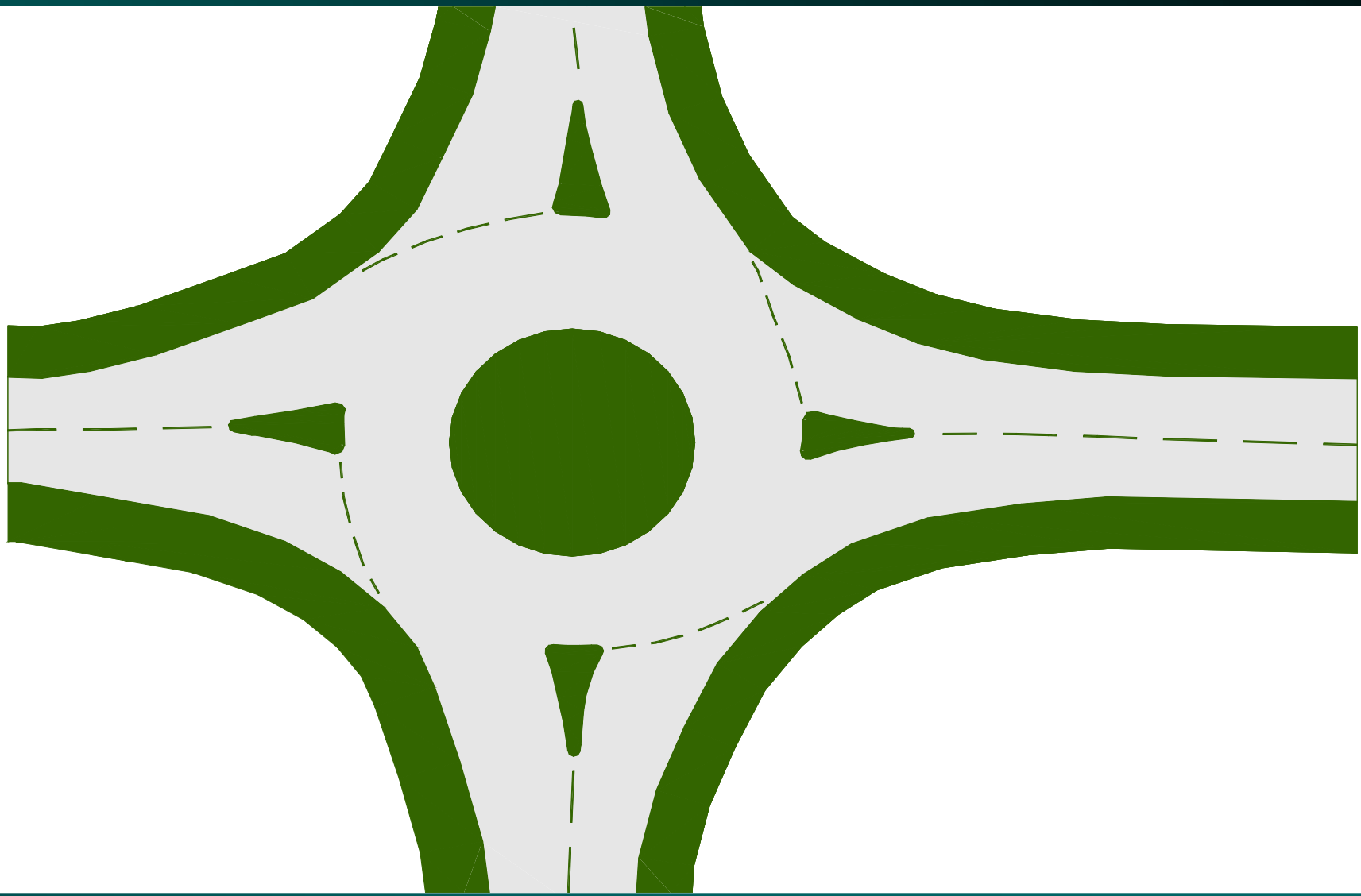
- Is a type of intersection layout
  - traffic moves in one direction around a central island
  - priority to the circulating traffic flow
  - yield control at entry points
- A series of interconnected priority-type (“T”) intersections

What is a Modern Roundabout?

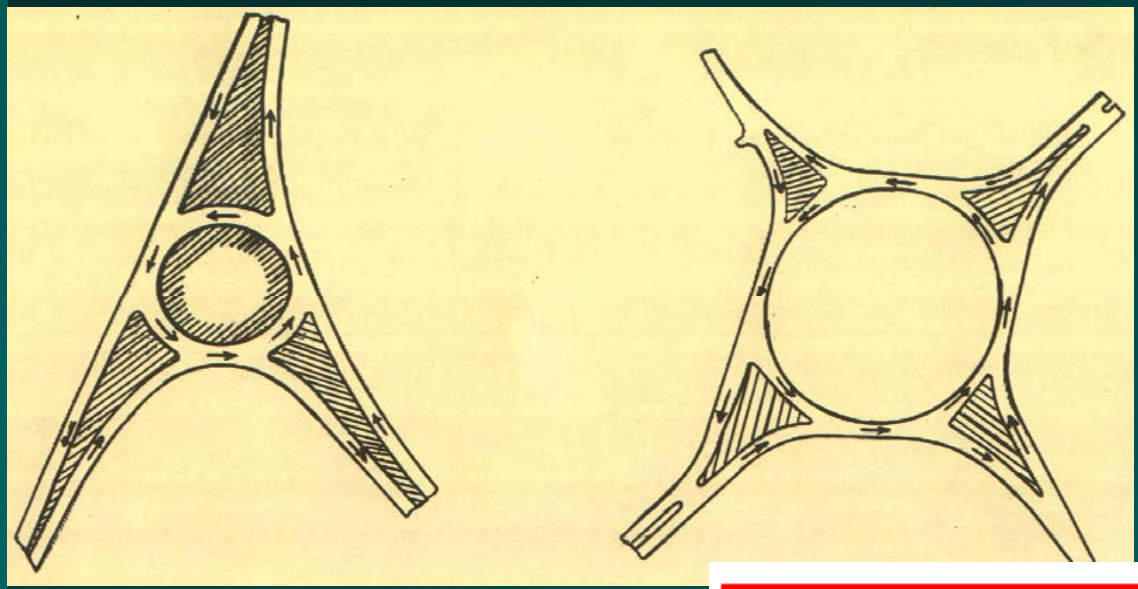
- Roundabouts are circular intersections with specific design and traffic control features
  - Yield Control of all entering traffic
  - Channelized approaches
  - Appropriate geometric curvature to ensure travel speeds of less than 30 mph

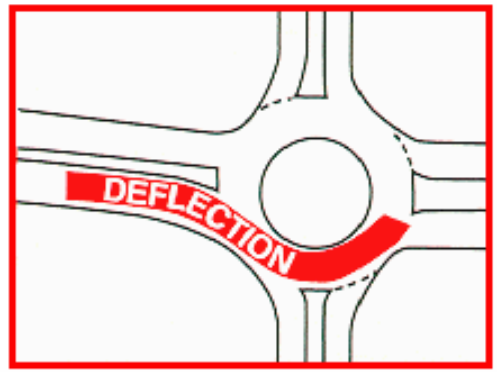
FHWA “Roundabouts: An informational Guide”

The Modern Roundabout

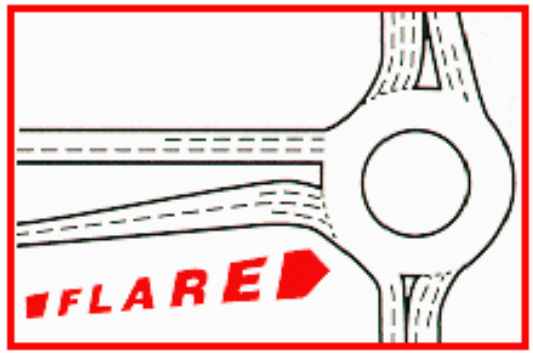


Roundabouts are NOT Traffic Circles





Deflection



Flare

Yield-at-Entry

Why Modern Roundabouts?

- Safety
- Very high capacity
- Overall reduced delay
- Low operating and maintenance costs
- Aesthetics (community enhancement)
- Traffic calming (slow down all traffic)
- Simple for traffic to use. Yield-at-entry
- Simple for pedestrian to use
- Self-regulatory (yield-at-entry rule and “No” traffic lights)
- Flexibility in geometry design

Reasons Why Agencies Have Not Yet Built Roundabouts

- Number Not sure drivers will get used to them 37.0%
- Number Not sure they work efficiently 34.3%
- Number Not sure they are safe 7.1%
- Number Not part of AASHTO Guides 14.3%
- Number Concerned about liability 14.3%

NCHRP Synthesis 264

Public Attitude Toward Roundabouts Before And After Construction

Attitude	Before Construction	After Construction
Very Negative	23%	00%
Negative	45%	00%
Neutral	18%	27%
Positive	14%	41%
Very Positive	0%	32%

Types of Modern Roundabouts

- Various variations throughout the world
  - Normal Roundabouts
  - Mini/Small Roundabouts
  - Double Roundabouts
  - Grade Separated
  - Signalized

Normal Roundabout

Mini/Small Roundabout

Categories of Roundabouts

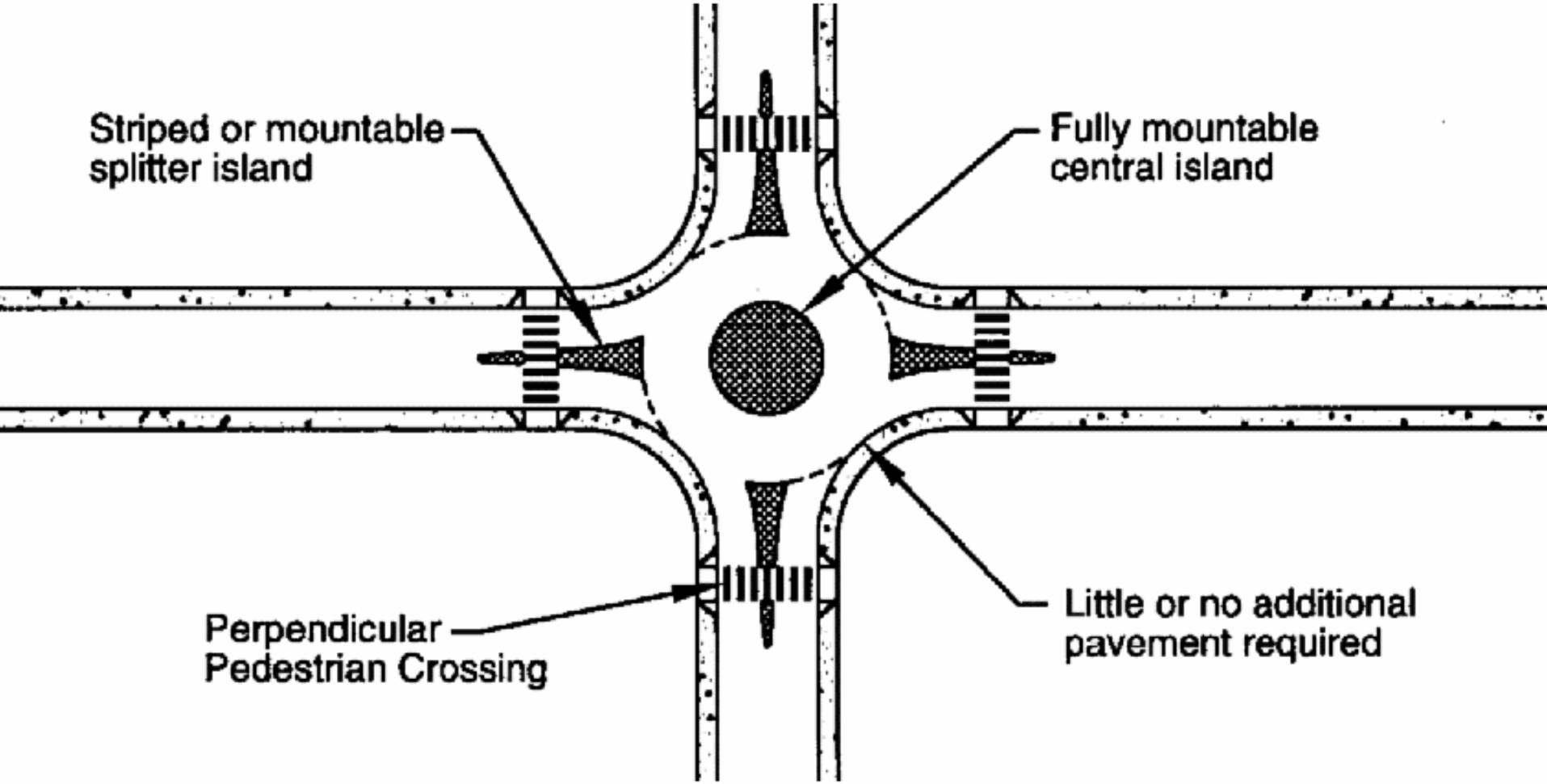
- Based on:
  - Environment
  - Number of Lanes
  - Size

- Mini-Roundabouts
- Urban Compact
- Urban Single-Lane
- Urban Double-Lane
- Rural Single-Lane
- Rural Double-Lane

Design Characteristics of the Roundabout Categories

Design Elements	Mini-Roundabout	Urban Compact	Urban Single- Lane	Urban Double-Lane	Rural Single-Lane	Rural Double-lane
Recommended maximum entry design speed	25 km/h (15 mph)	25 km/h (15 mph)	35 km/h (20 mph)	40 km/h (25 mph)	40 km/h (25 mph)	50 km/h (30 mph)
Maximum number of entering lanes per approach	1	1	1	2	1	2
Typical inscribed circle diameter	13 to 25 m (45 - 80 ft)	25 to 30 m (80-100 ft)	30 to 40 m (100-130 ft)	45 to 55 m (150-180 ft)	35 to 40 m (115-130 ft)	55 to 60 m (180-200 ft)
Splitter island treatment	Raised if possible crosswalk cut if raised	Raised with crosswalk cut	Raised, with crosswalk cut	Raised, with crosswalk cut	Raised and extended, with crosswalk cut	Raised and extended with crosswalk cut
Typical daily service volume on 4-leg roundabout (veh/day)	10,000	15,000	20,000	Refer to chapter 4 procedures	20,000	Refer to chapter 4 procedure

Mini-Roundabout

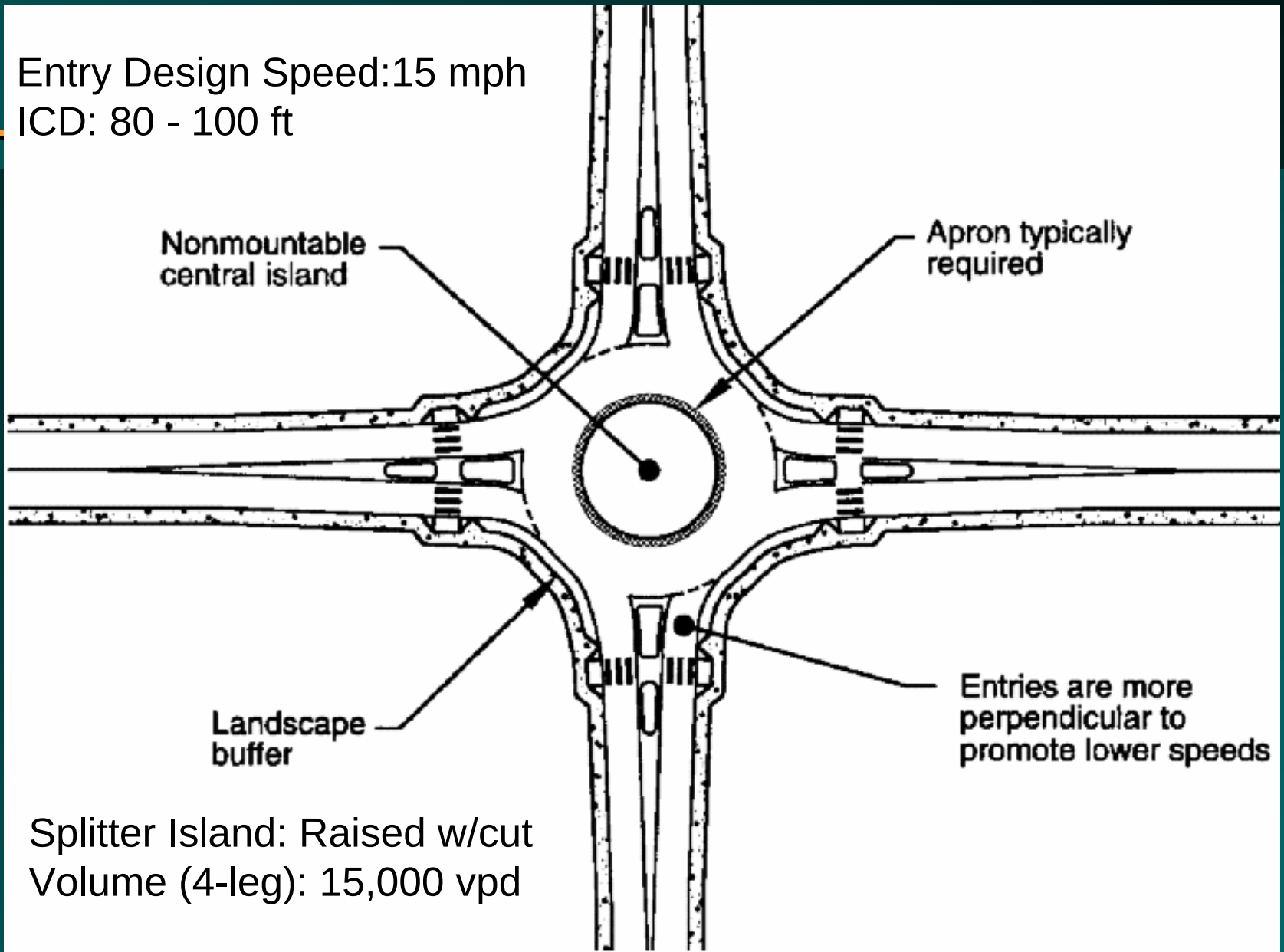


Max Entry Design Speed:15 MPH
ICD: 45 – 80 ft

Splitter Island: Raised if possible
Volume (4-leg): 10,000 vpd

Urban Compact Design

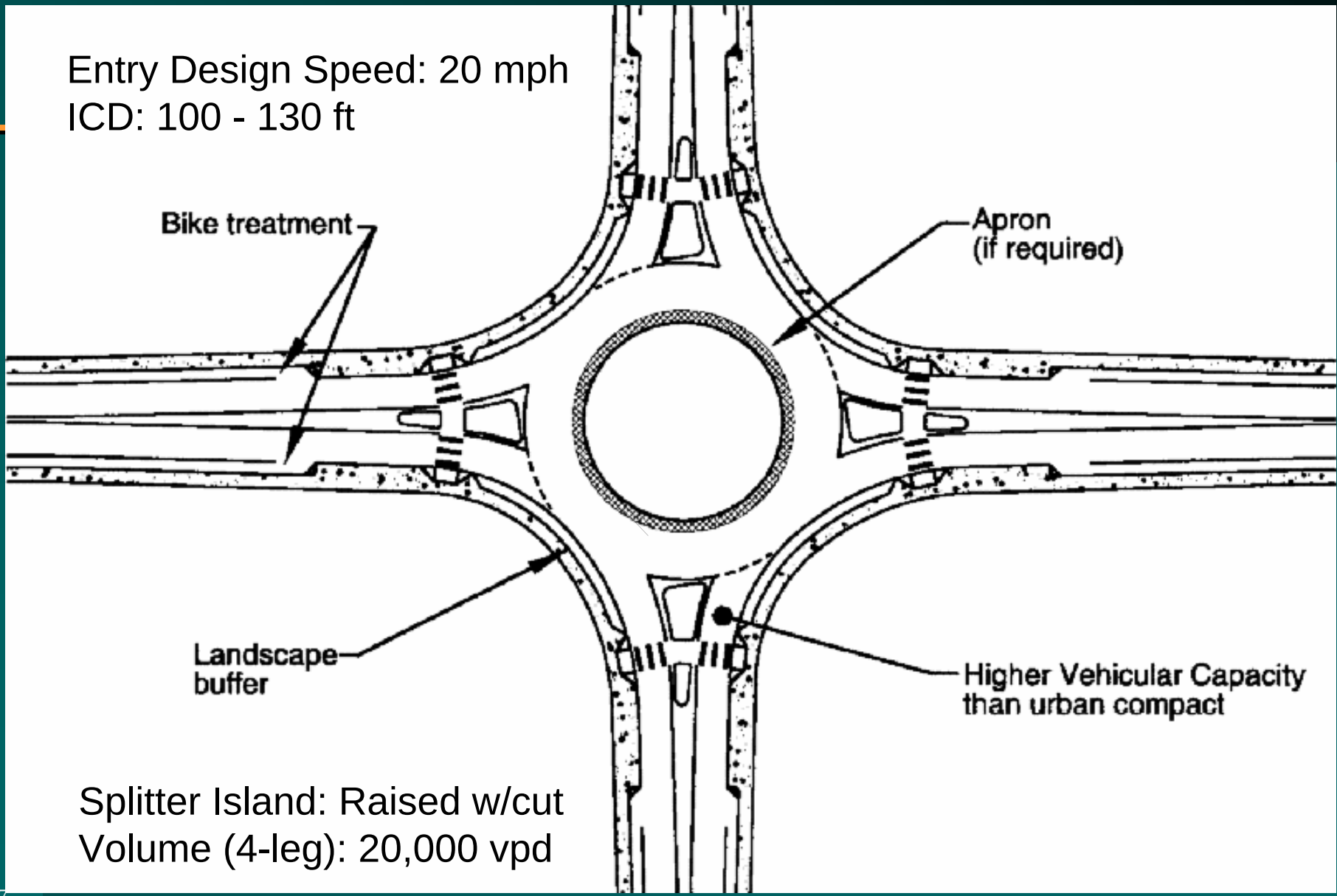
Entry Design Speed:15 mph
ICD: 80 - 100 ft



Splitter Island: Raised w/cut
Volume (4-leg): 15,000 vpd

Urban Moderate-Capacity

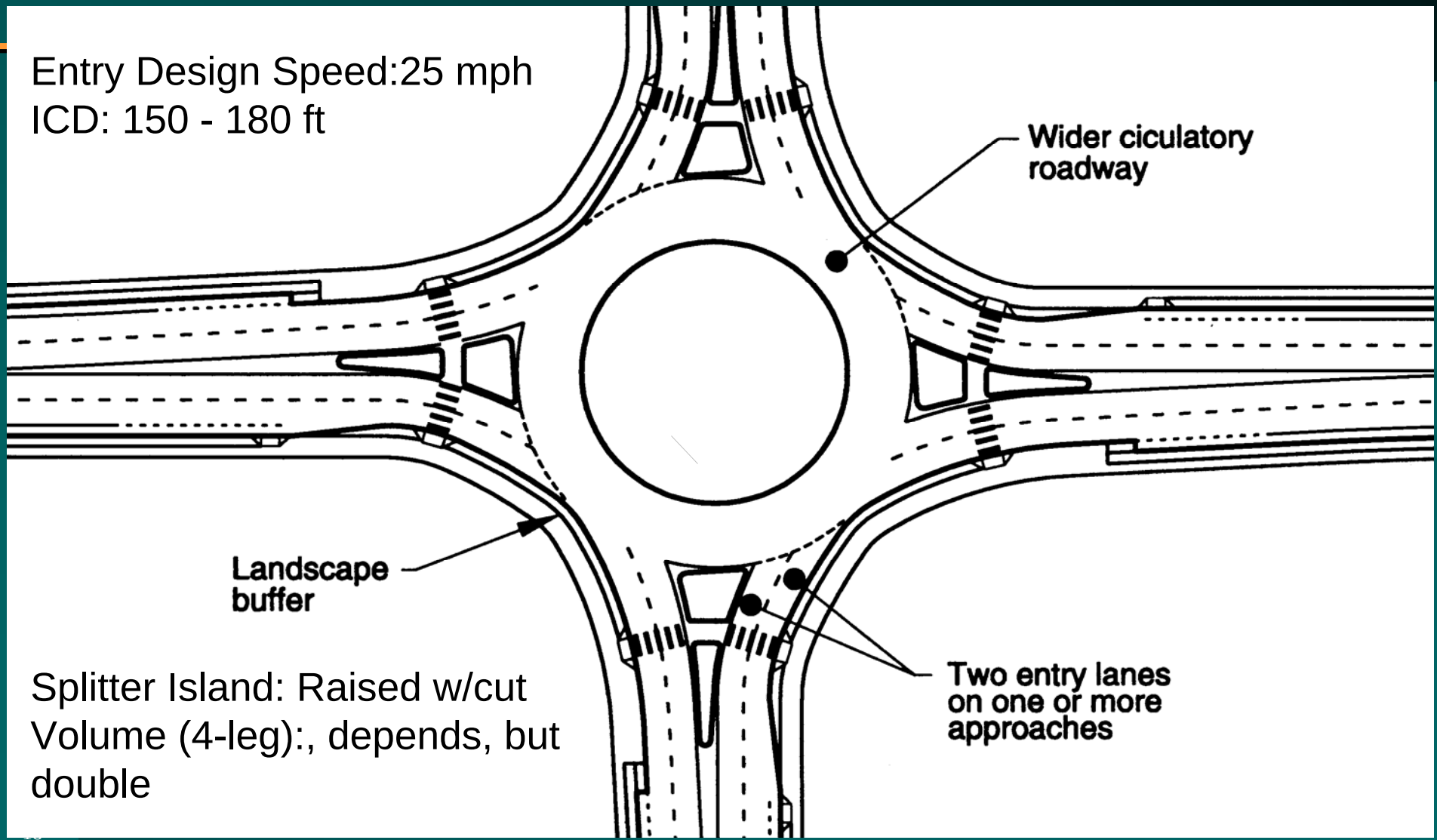
Entry Design Speed: 20 mph
ICD: 100 - 130 ft



Splitter Island: Raised w/cut
Volume (4-leg): 20,000 vpd

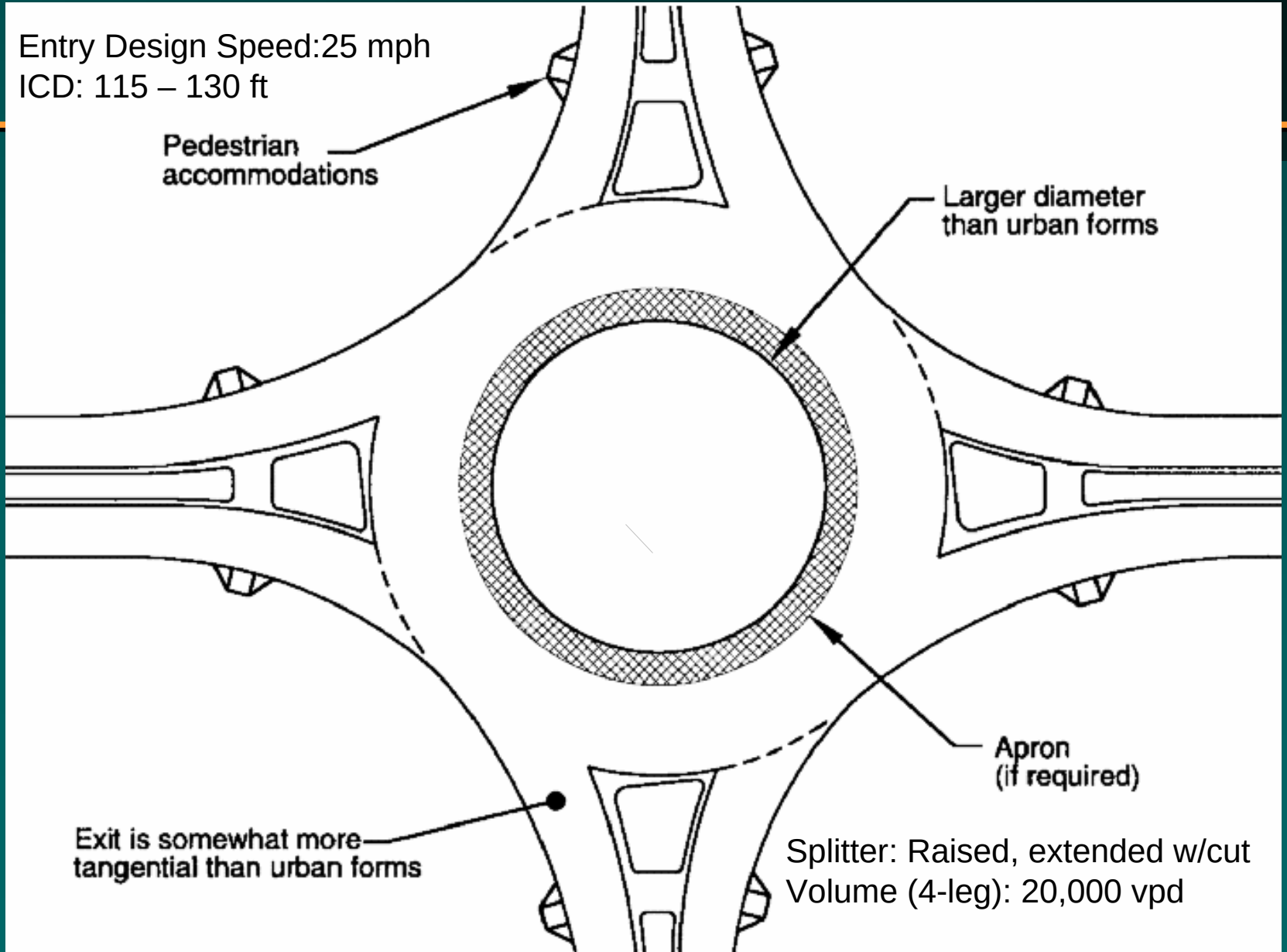
Urban Double-Lane Design

Entry Design Speed:25 mph
ICD: 150 - 180 ft

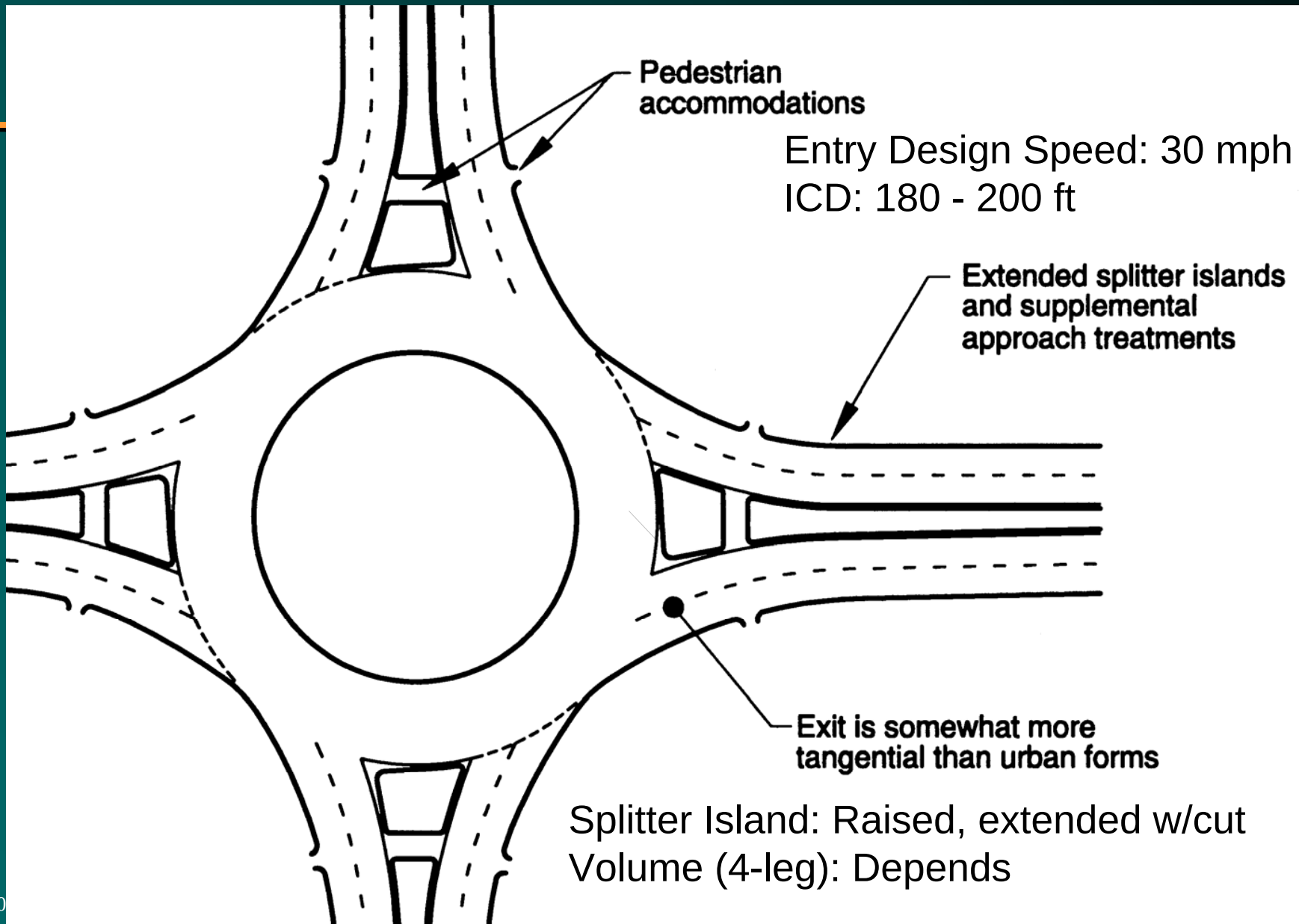


Splitter Island: Raised w/cut
Volume (4-leg):, depends, but double

Rural Single-Lane



Rural Multi-Lane



Entry Design Speed: 30 mph
ICD: 180 - 200 ft

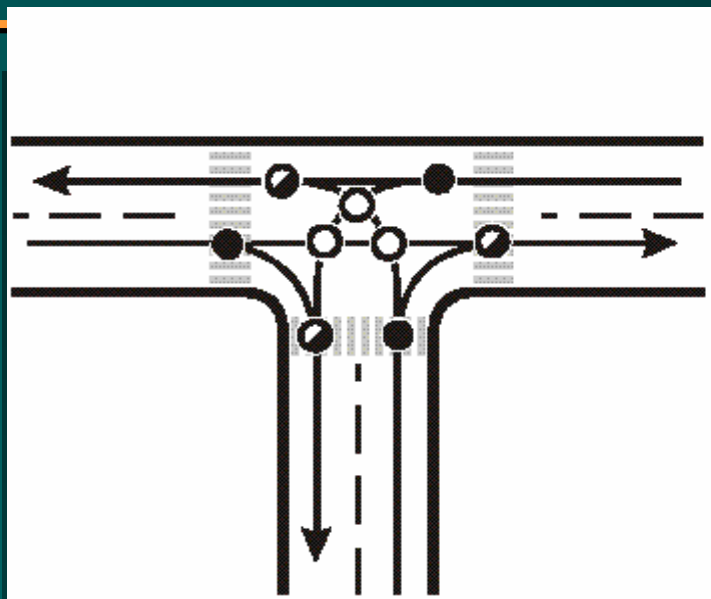
Splitter Island: Raised, extended w/cut
Volume (4-leg): Depends

Examples of Modern Roundabouts

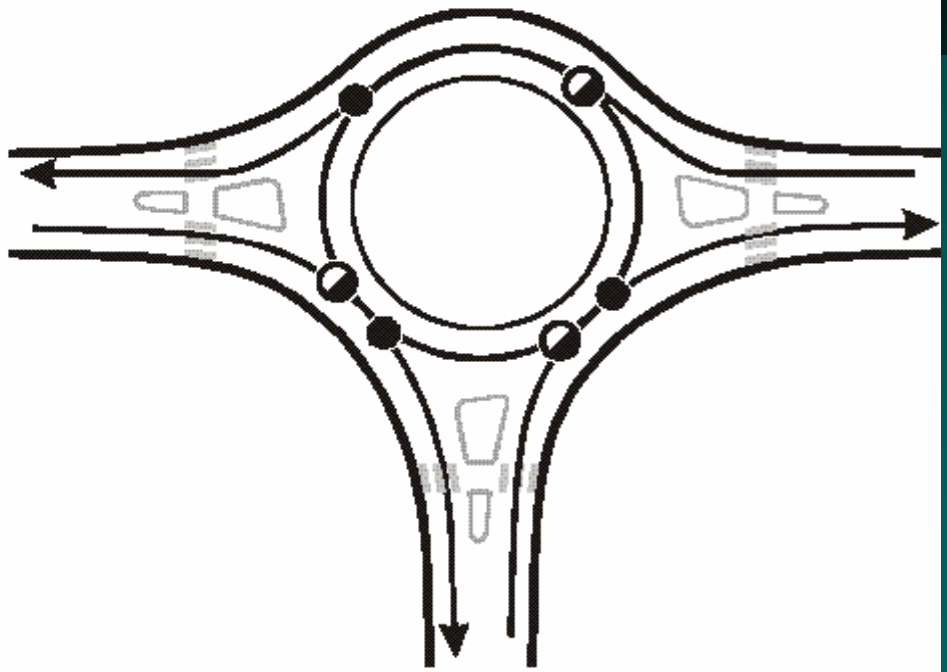
- Overseas
  - United Kingdom
  - Germany
  - Australia
  - Norway
  - France
  - Netherlands
  - Switzerland
  - Ghana
- U.S.
  - Maryland
  - California
  - Florida
  - Colorado
  - Nevada
  - Vermont
  - Oregon

Safety of Roundabouts

Comparison of vehicular Conflict Point

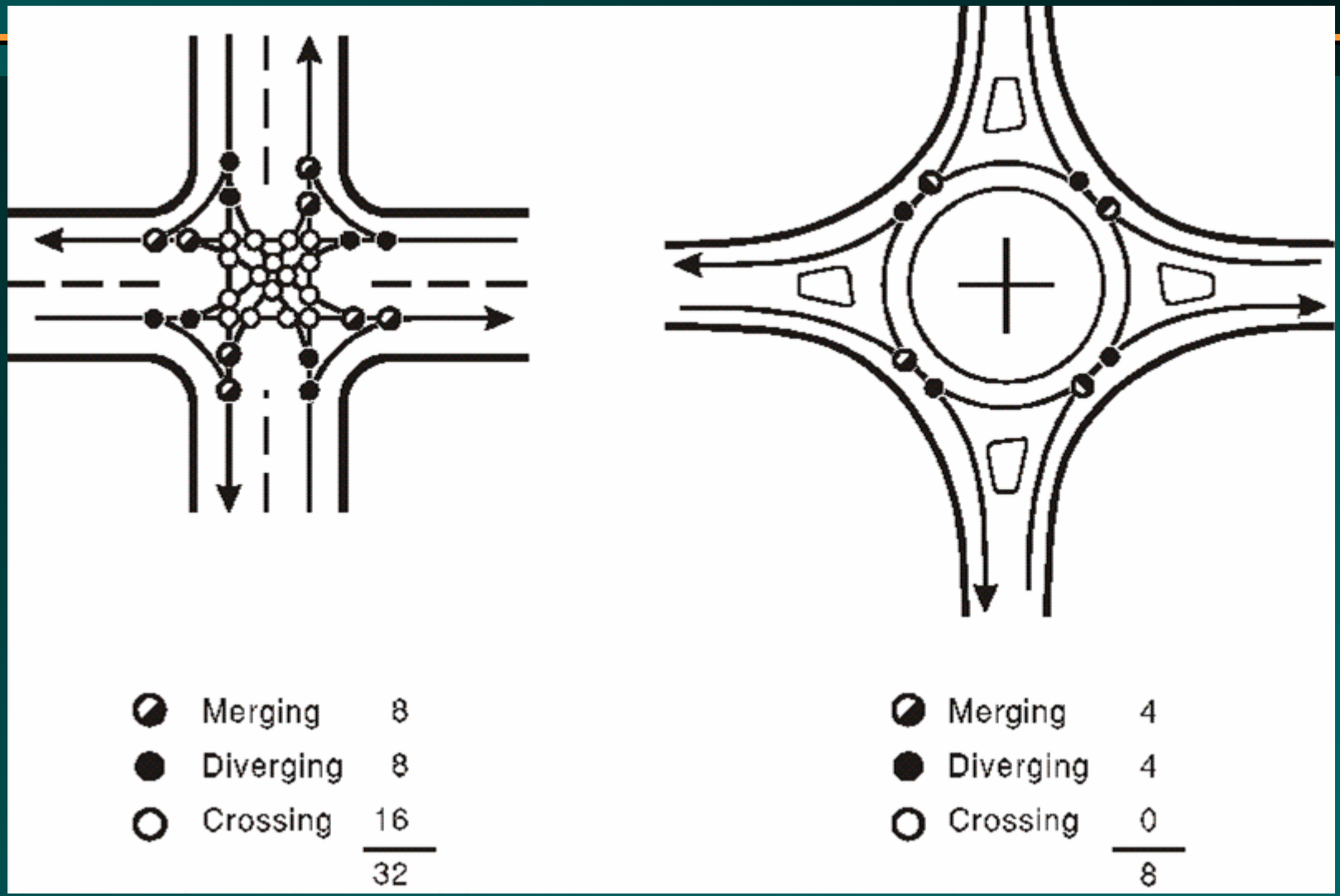


Merging	3
Diverging	3
Crossing	3
	9

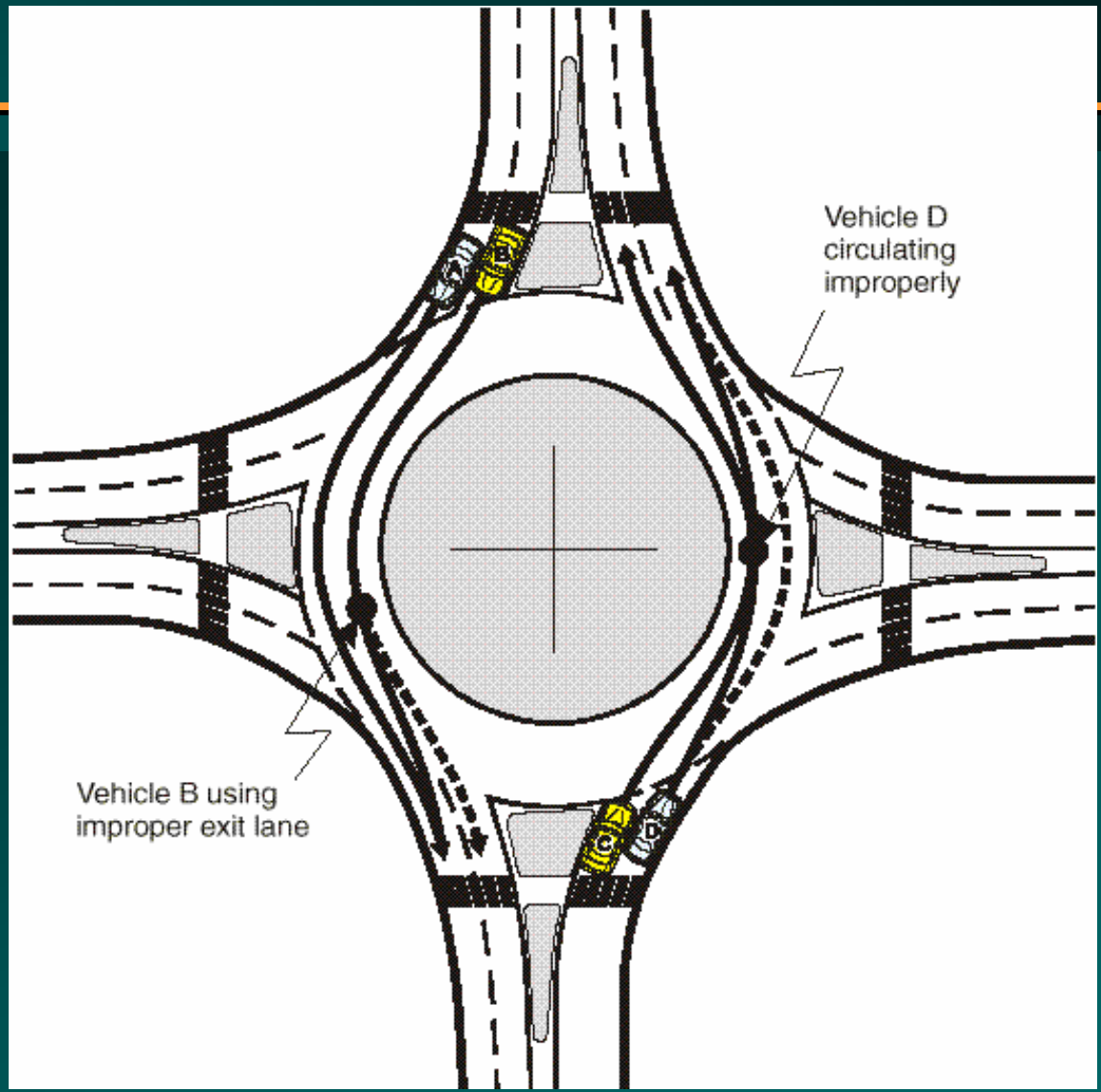


Merging	3
Diverging	3
Crossing	0
	6

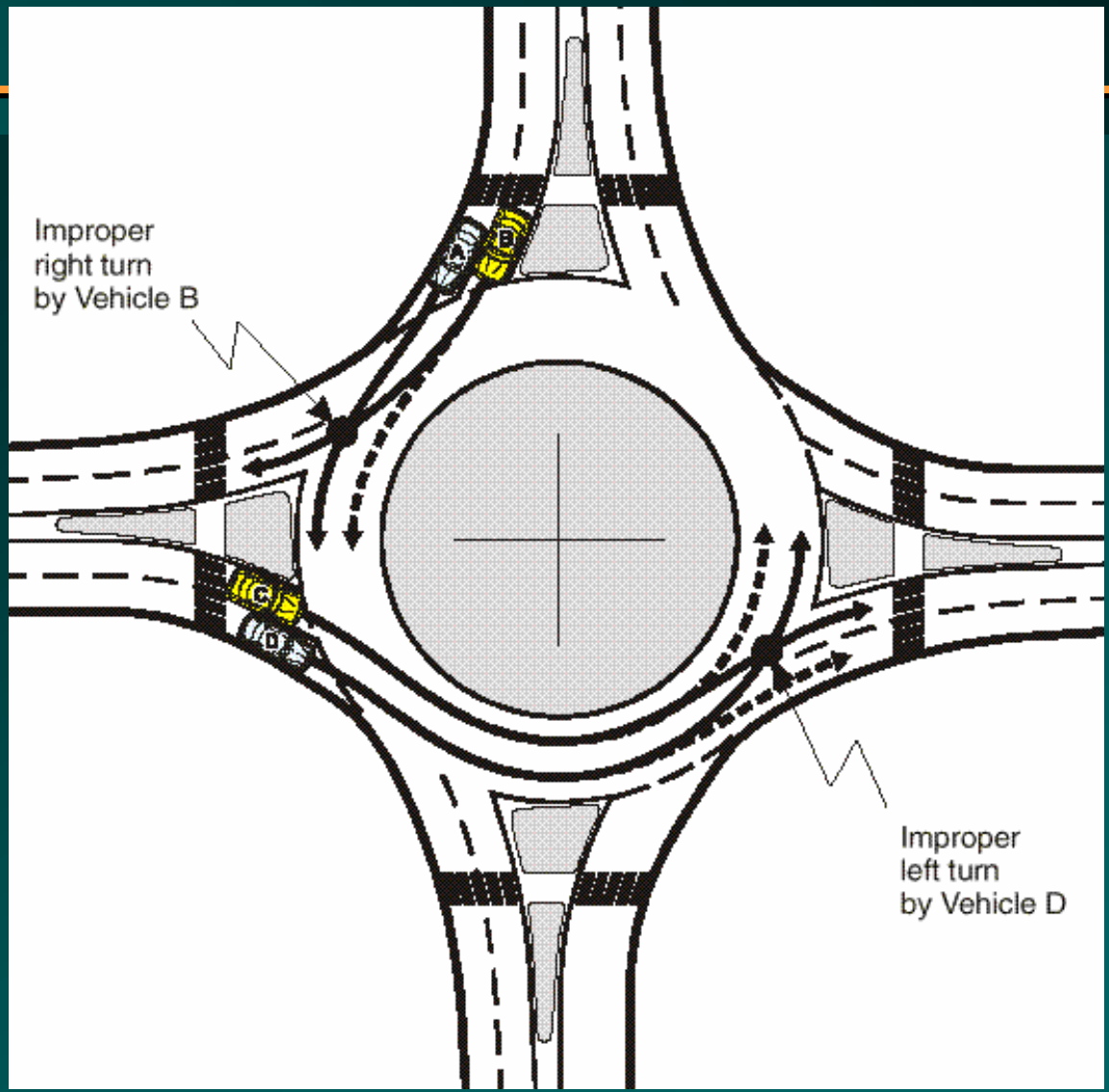
Comparison of vehicular Conflict Point



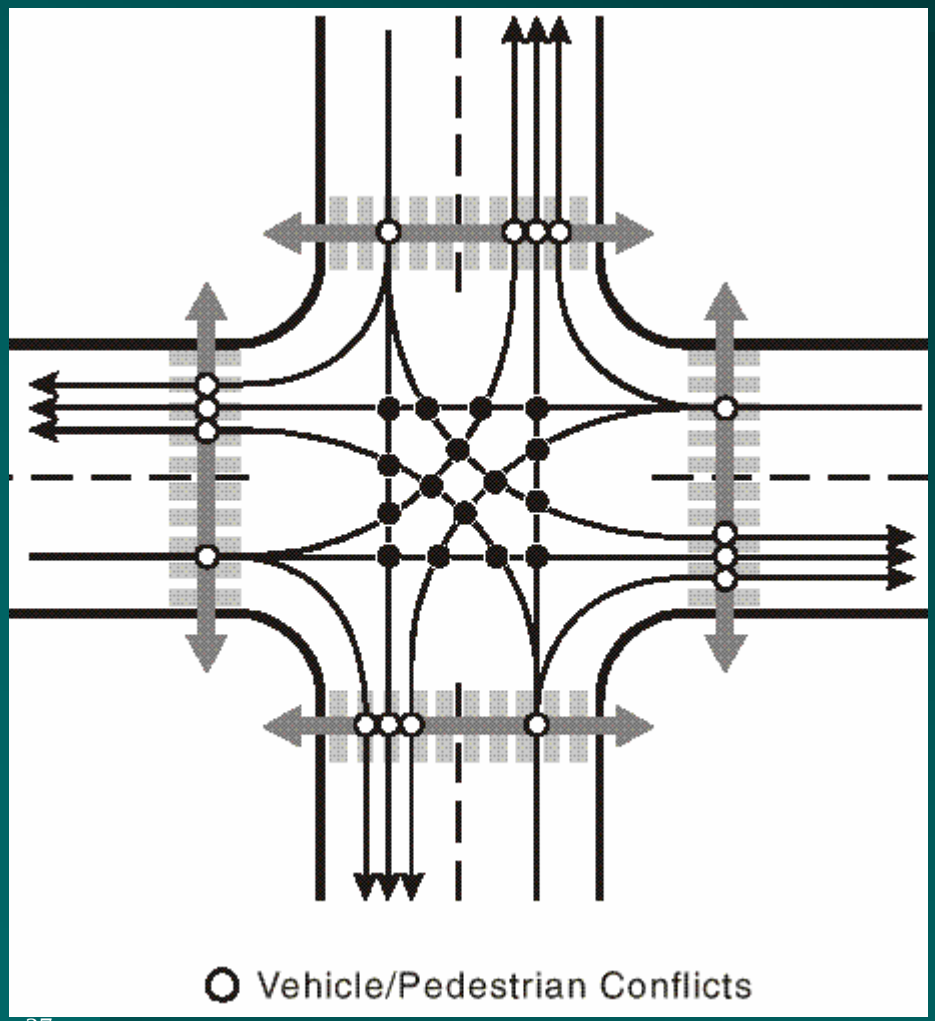
Conflicts at Double Lane Roundabouts

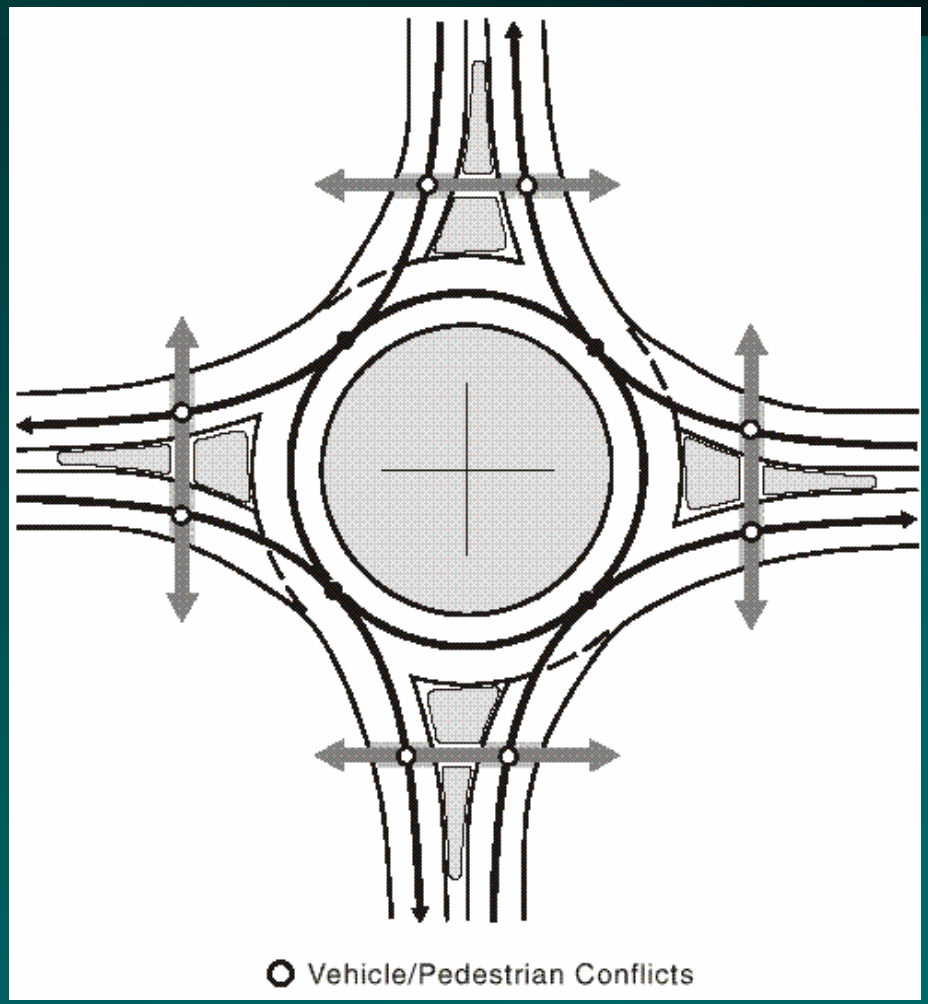


Turn Conflicts at Double Lane Roundabouts

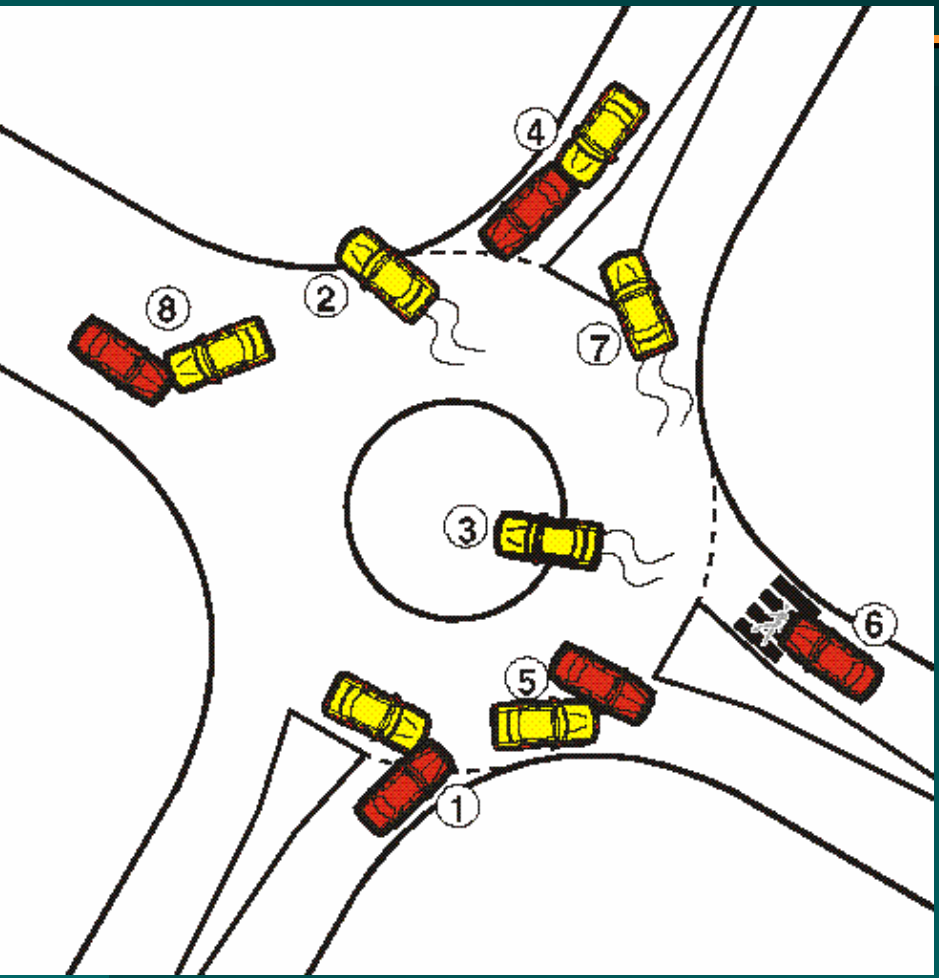


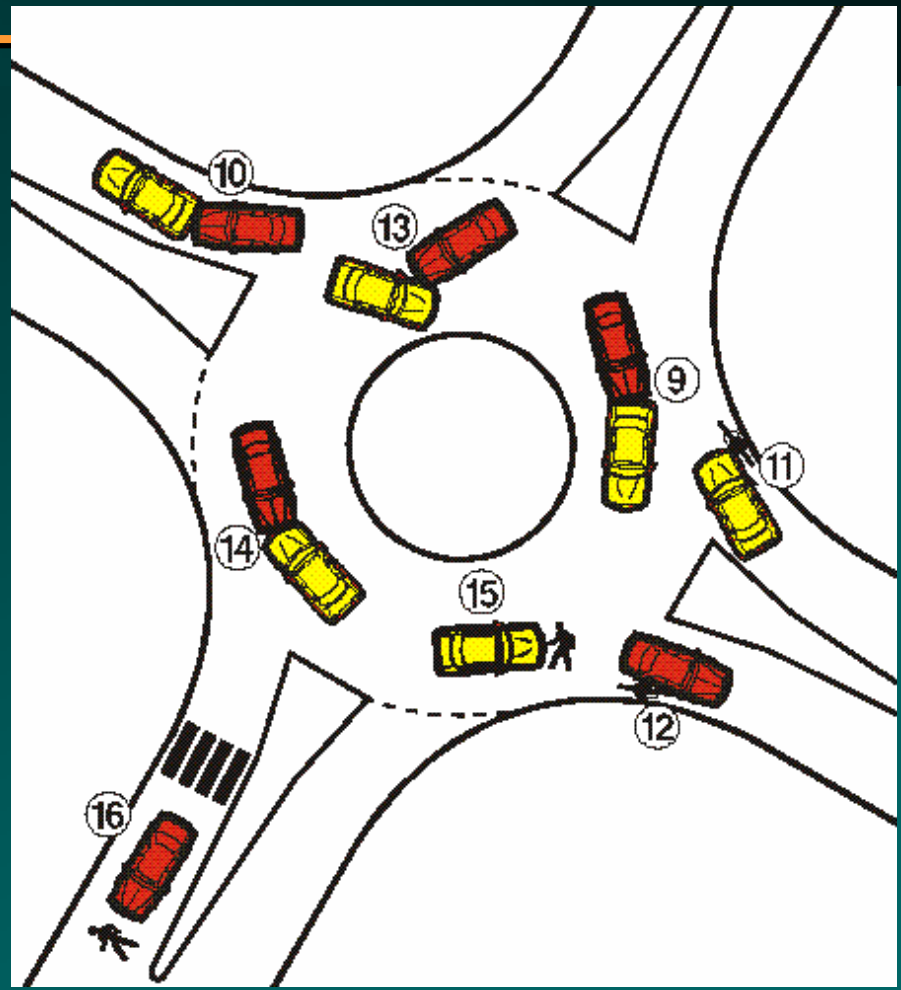
Comparison of Vehicle Pedestrian Conflicts



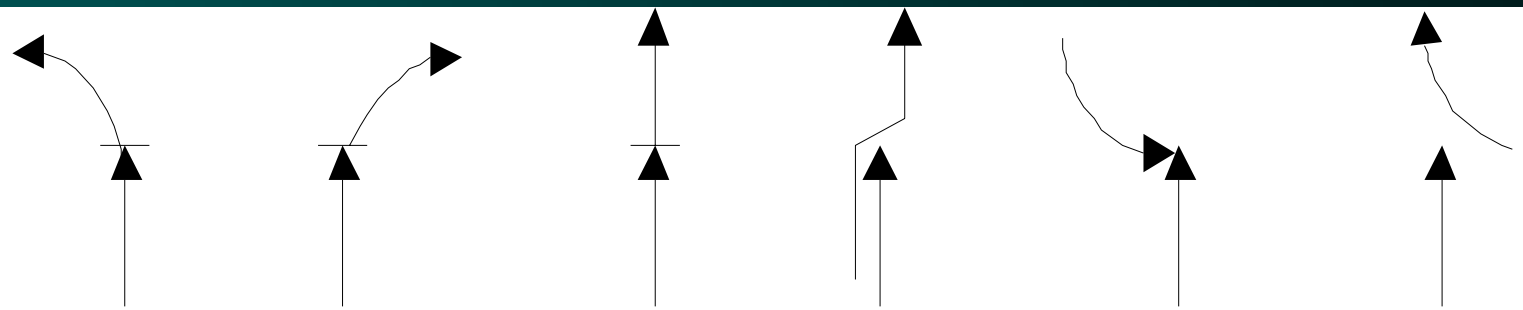


Collision Types in Urban Areas of France

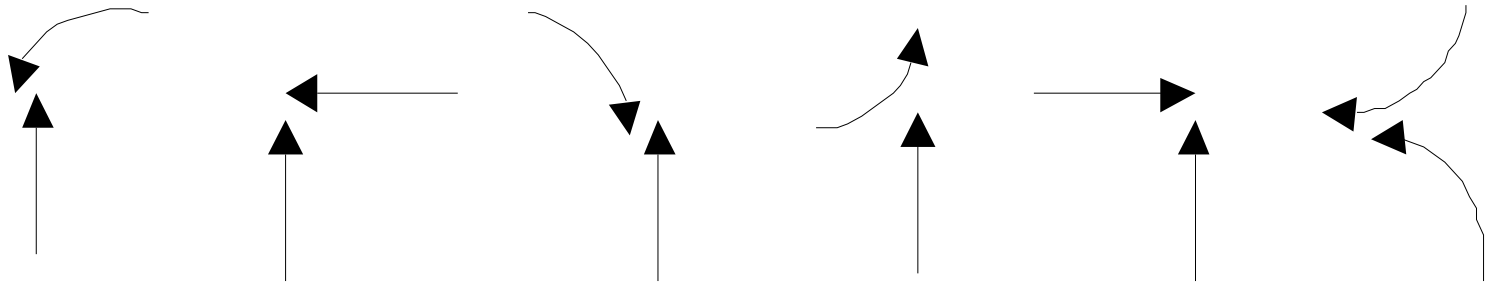




Collision Types at Intersections



Left turn, same direction | Right turn, same direction | Slow vehicle | Lane change | Opposing left turn | Right turn from right



Left turn from right | Through from right | Right turn from left | Left turn from left | Through from left | Right turn on red

Average Annual Crash Frequencies at 11 U.S. Intersections Converted to Roundabouts.

Type of roundabout	Sites	Before Roundabout			Roundabout			Percent change[5]		
		Total	Inj.[3]	PDO[4]	Total	Inj.	PDO	Total	Inj.	PDO
Small/ Moderate[1]	8	4.8	2.0	2.4	2.4	0.5	1.6	-51%	-73%	-32%
Large[2]	3	21.5	5.8	15.7	15.3	4.0	11.3	-29%	-31%	-10%
Total	11	9.3	3.0	6.0	5.9	1.5	4.2	-37%	-51%	-29%

NCHRP Synthesis 264

MARYLAND ROUNDABOUTS

TRUCK CRASH SUMMARY

LOCATION	BEFORE					AFTER		
	YEARS	TOTAL ACCIDENTS	Accidents per Year	TRUCKS	Truck % of Total	YEARS	TOTAL ACCIDENTS	Accidents per Year
MD 94/MD 144 - LISBON	1989-1992	33	8.3	3	9%	1994-1998	14	2.8
MD 63/MD 58 - CEARFOSS	1991-1994	15	3.8	1	7%	1996-1998	2	0.7
MD 213 @ LEEDS ROAD	1991-1994	15	3.8	0	0%	1996-1998	9	3.0
MD 2 @ MD 408/MD 422 - LOTHIAN	1991-1994	27	6.8	3	11%	1996-1998	12	4.0
MD 140 @ MD 832 - TANEYTOWN	1992-1995	24	6.0	2	8%	1997-1998	3	1.5
TOTALS		114		9	8%		40	

Accident Proportion by Type of Users from 15 Towns in Western France

User	All crossroads	Roundabouts
Pedestrians	**6.3**	**5.6**
Bicycles	**3.7**	**7.3**
Mopeds	**11.7**	**16.9**
Motor cycles	**7.4**	**4.8**
Cars	**65.7**	**61.2**
Utility vehicles	**2.0**	**0.6**
Heavy goods vehicles	**2.0**	**3.0**
Bus/coach	**0.8**	**0.6**
Miscellaneous	**0.4**	**0.0**
TOTAL	**100.0**	**100.0**

Percent Reduction of Accidents by Mode at 181 Converted Dutch Rdbts

Mode	All Crashes	Injury Crashes
Passenger car	**63**	**95**
Moped	**34**	**63**
Bicycle	**8**	**30**
Pedestrian	**73**	**89**
Total	**51**	**72**

The Latest U.S. Safety Report
(The Insurance Institute for Highway Safety)

- Before-after studies at 24 intersections
- 39% overall decrease in crashes
- 76% decrease in injury crashes
- 90% decrease in fatal/incapacitating crashes
- 75% reduction in traffic delays

Safety Effects of Design Elements

- Less safe when:
  - the entry is very wide
  - the circulatory roadway is very wide
  - the entry path radius is very large
  - the inscribed diameter is very large
  - the angle between entries is tight

Effects of Design Elements on Traffic Operations

- Higher capacity when:
  - the entry is wider
  - the flare length is longer
  - the inscribed diameter is larger
  - the entry radius is larger
  - the entry angle is smaller

Policy Considerations

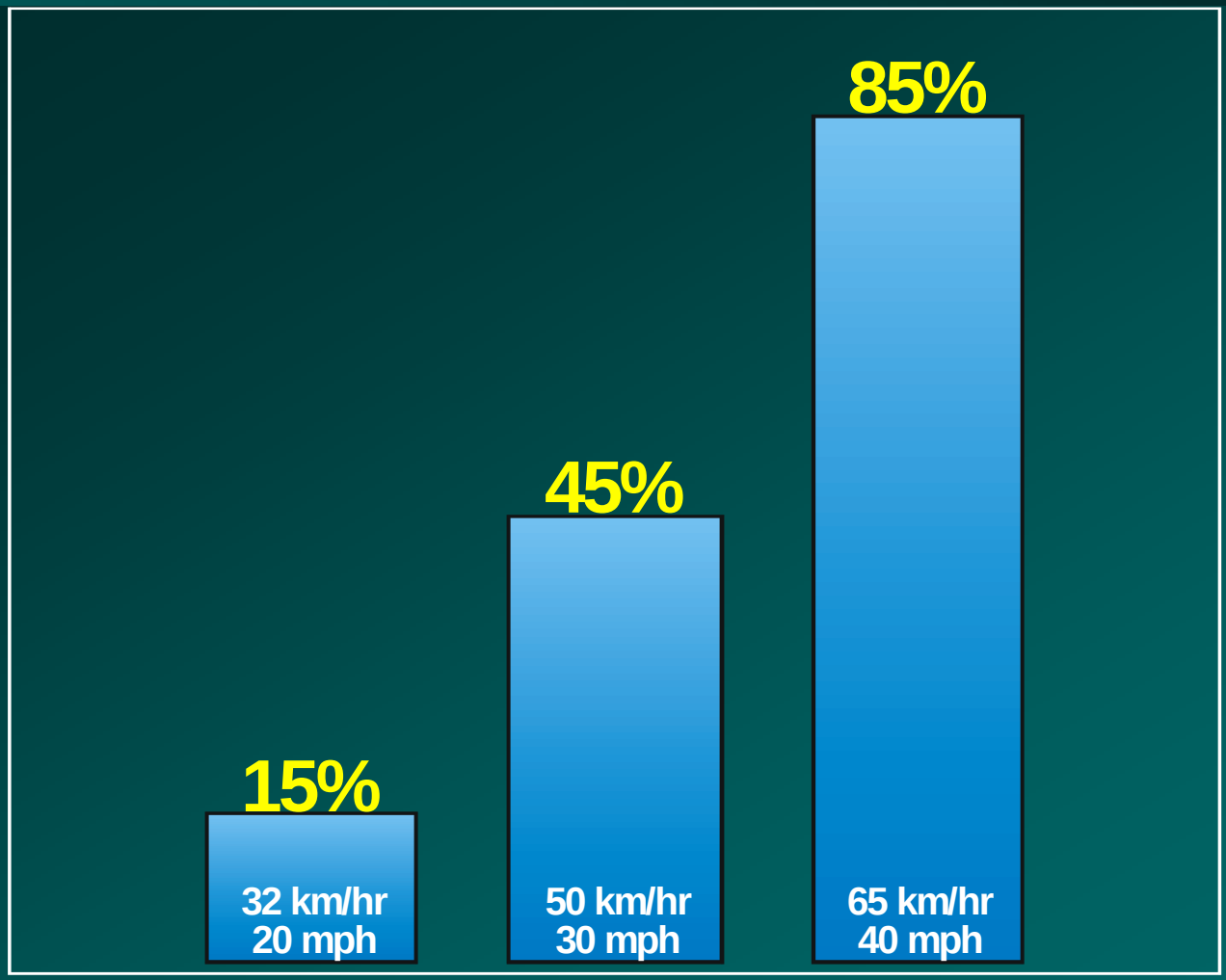
Policy Considerations

- Multimodal Considerations
- Legal Considerations
- Public Involvement
- Education

Multimodal Considerations

- Pedestrian Considerations
  - Simplify Decision Making for pedestrians
  - Provide special attention for the visually impaired, the elderly, and children
  - Provide shorter travel distance
  - Splitter Islands
  - Discourage crossing to central island
  - Reduce speeds at approaches/exits
  - Design to meet prevailing policies/laws including ADA

Pedestrians Probability of Death if Struck by vehicles



Source: U.K.

Multimodal Considerations

- Bicyclists Considerations
  - Avoid dedicated bike lanes in roundabouts circulatory width
  - Possible to mix/share with vehicles at one-lane roundabouts
  - Speeds (15-22 mph) comparable to vehicles entry/circulatory speeds
  - At double lane roundabouts, safer to provide a shared pedestrian/cyclists path away from circulatory road

Multimodal Considerations

- Large Vehicles
  - Design to accommodate the largest vehicle anticipated (Design Vehicle)
  - Transit (Buses)
  - Emergency Vehicles

Multimodal Considerations

- Legal Considerations
  - Uniform Vehicle Code (UVC) does not provide clear directions on roundabouts
  - Pedestrian Accessibility
  - Prohibit overtaking within circulatory roadway
  - Prohibit parking at or near roundabout intersection area

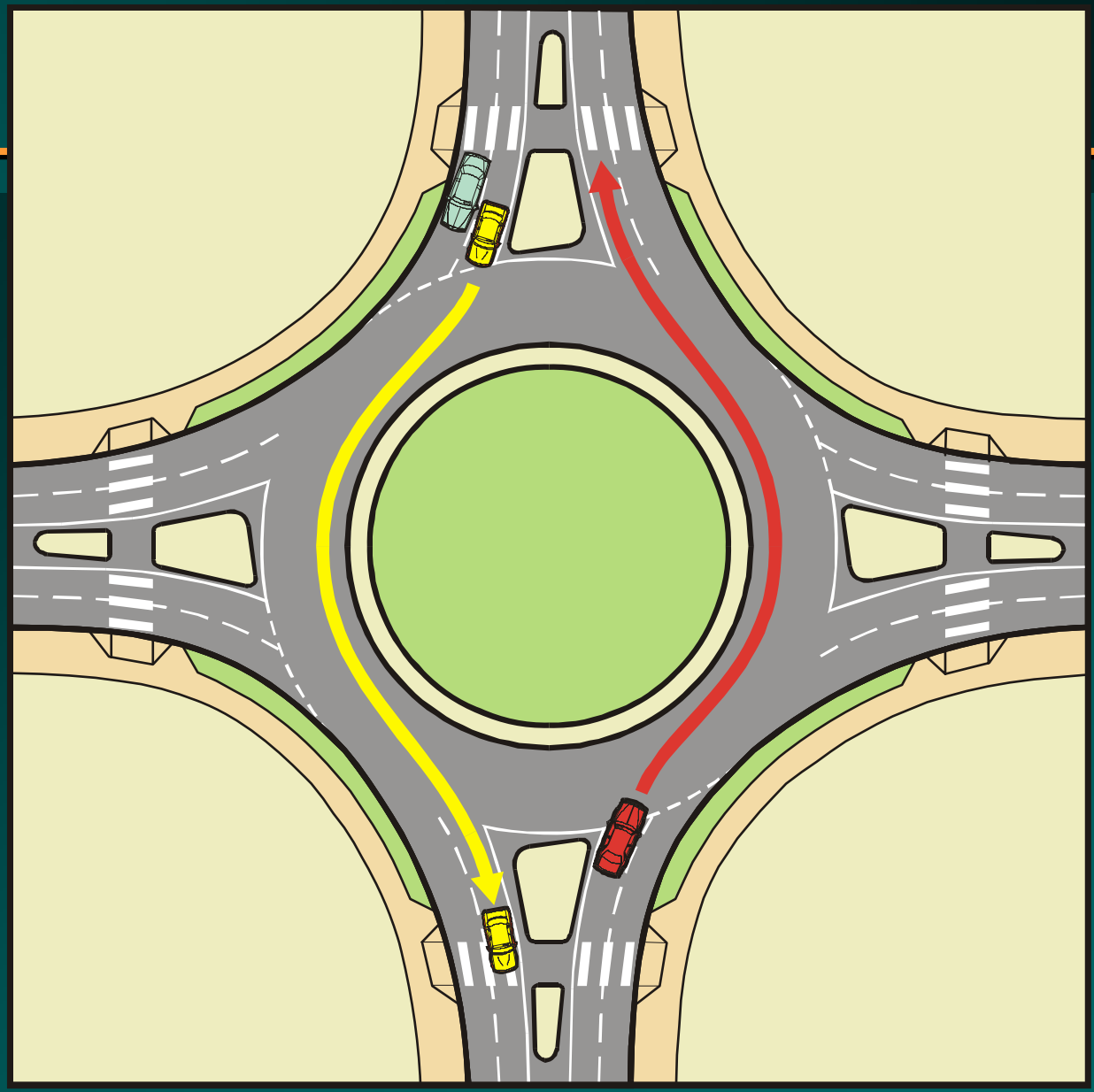
Multimodal Considerations

- Public Involvement
  - Engage the public very early in the process
  - Public Meetings
  - Informational Brochures
  - Videos
  - Media Announcements

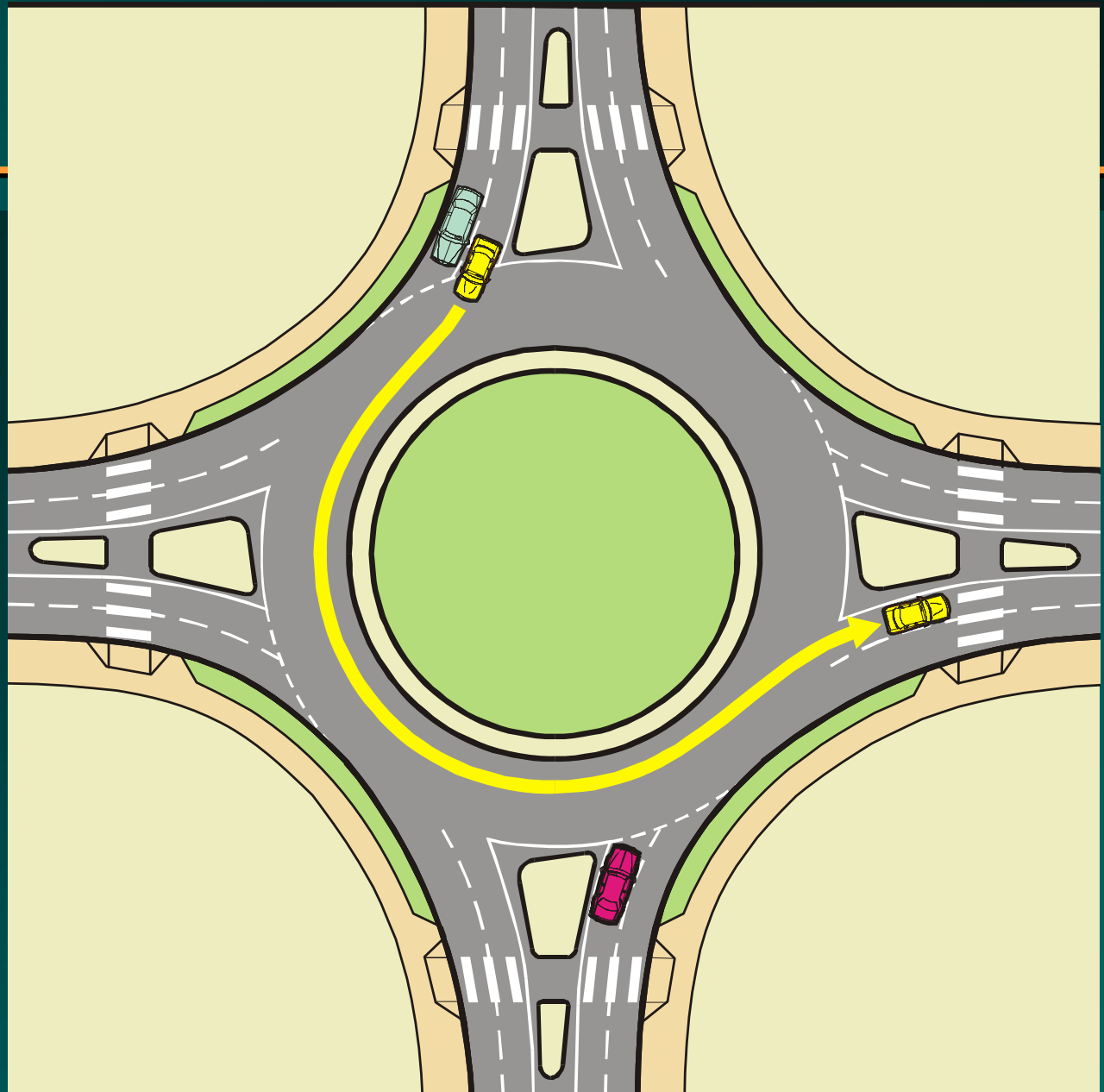
Multimodal Considerations

- Education
  - Continuing education of motorists, pedestrians and cyclists

Driving Straight Through a Roundabout



Turning Left at a Roundabout



Planning of Roundabouts

Planning of Roundabouts

- Planning Context
- Preliminary Lane Configuration
- Selection Criteria
- Perform Analysis
- Space Requirements
- Economic Analysis

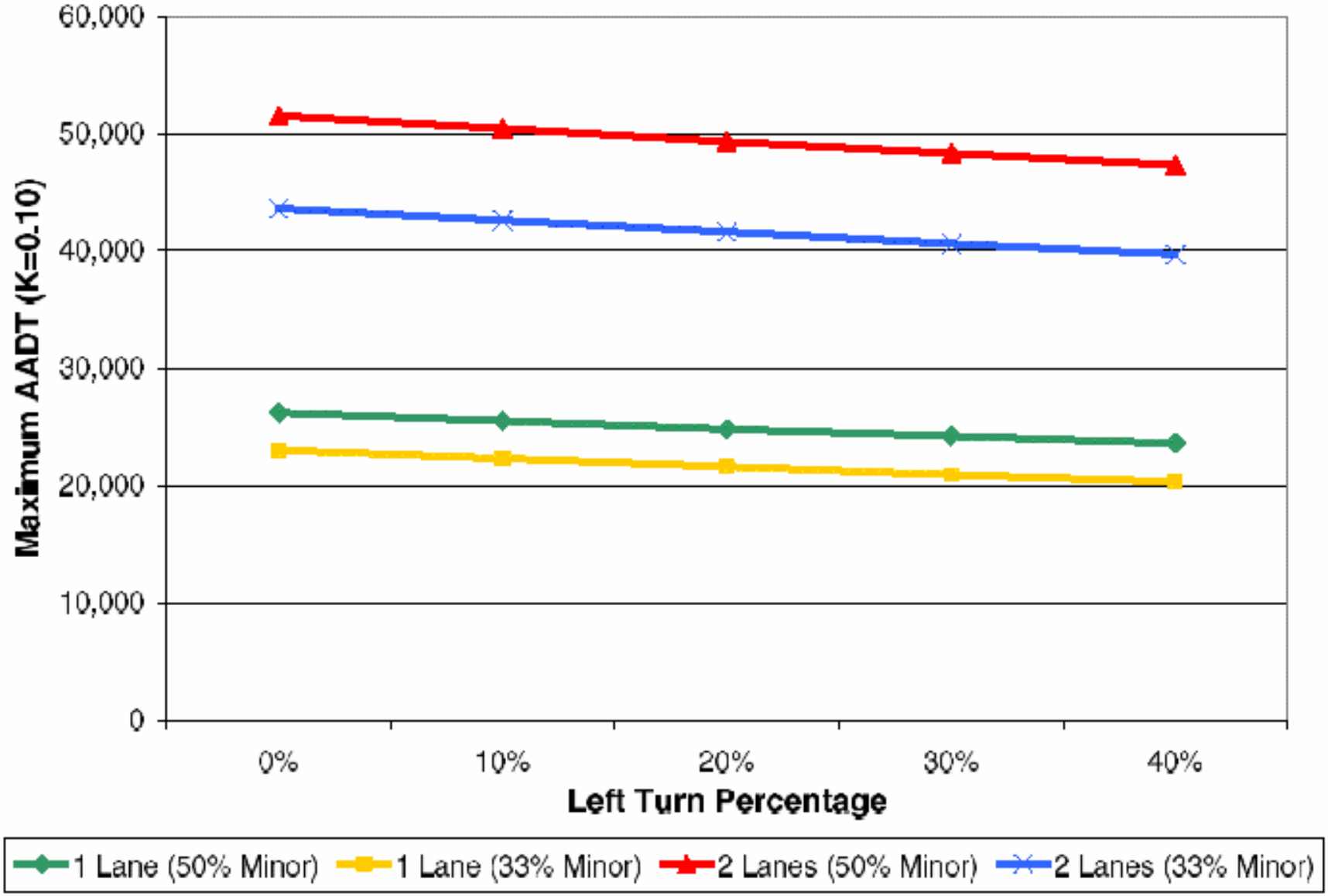
Planning Context

- Consider the context
  - Policies to be considered
    - Federal, State, Local?
  - Why Roundabout?
    - Urban or Rural Setting?
    - First in location?
  - New or Reconstruction?
    - Is it a good choice?

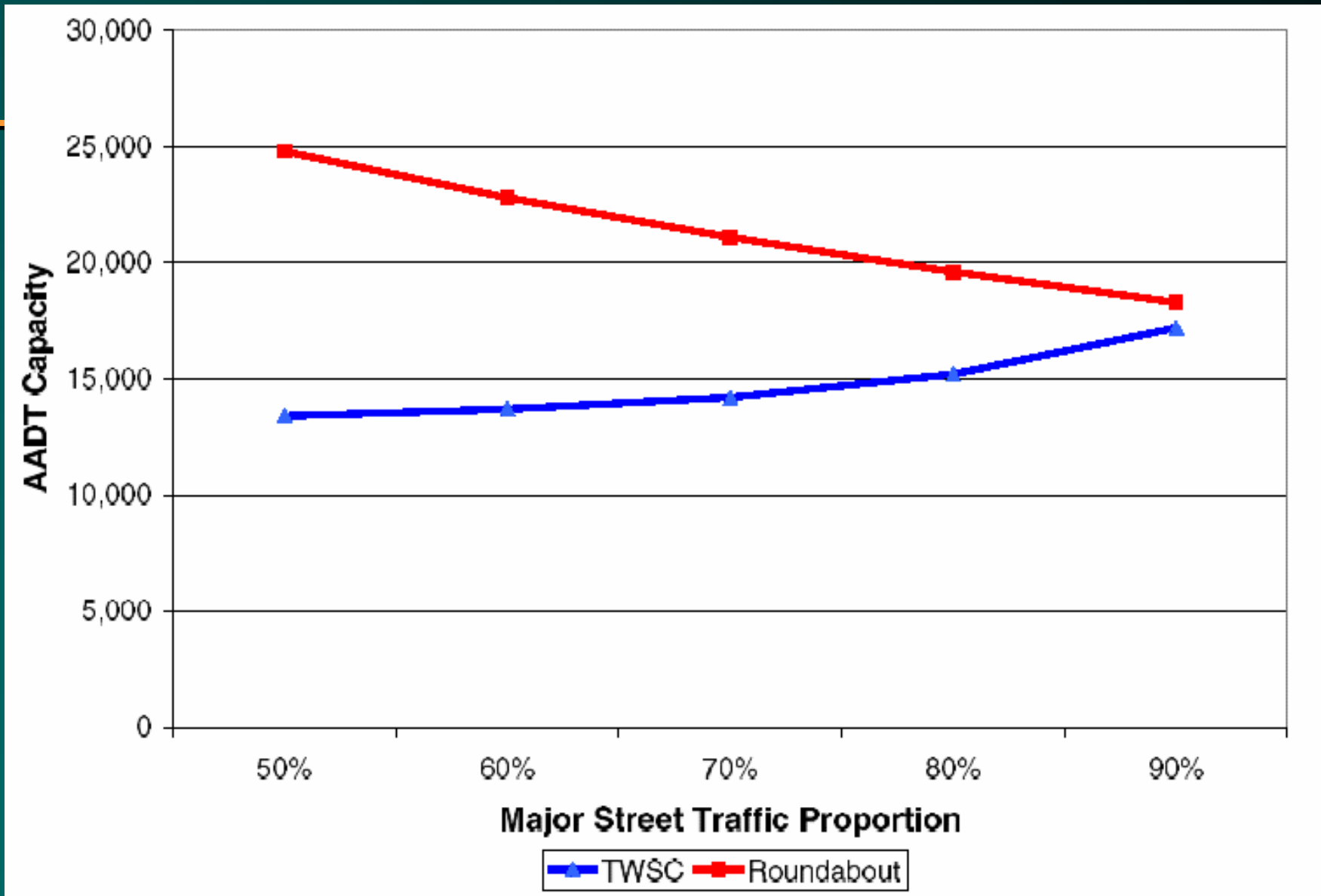
Preliminary Lane Configuration

- Number of Lanes required
  - Entry lanes to meet traffic demand
    - Limit volume to capacity ratio to 0.85
  - Single lane roundabout?
  - Double (multi) lane roundabouts?

Maximum Daily Volumes for a 4-leg Roundabout



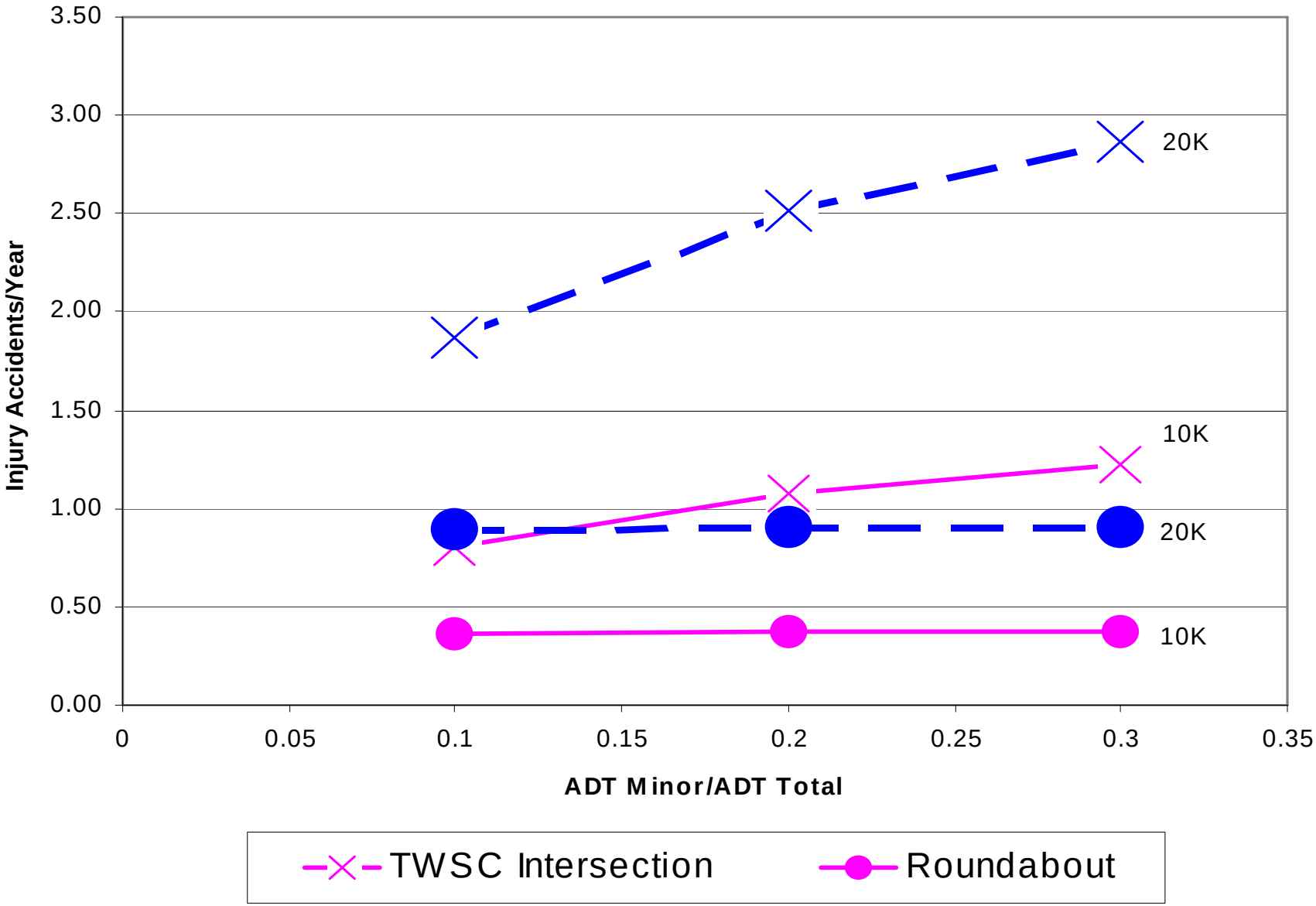
Capacity Comparison with TWSC



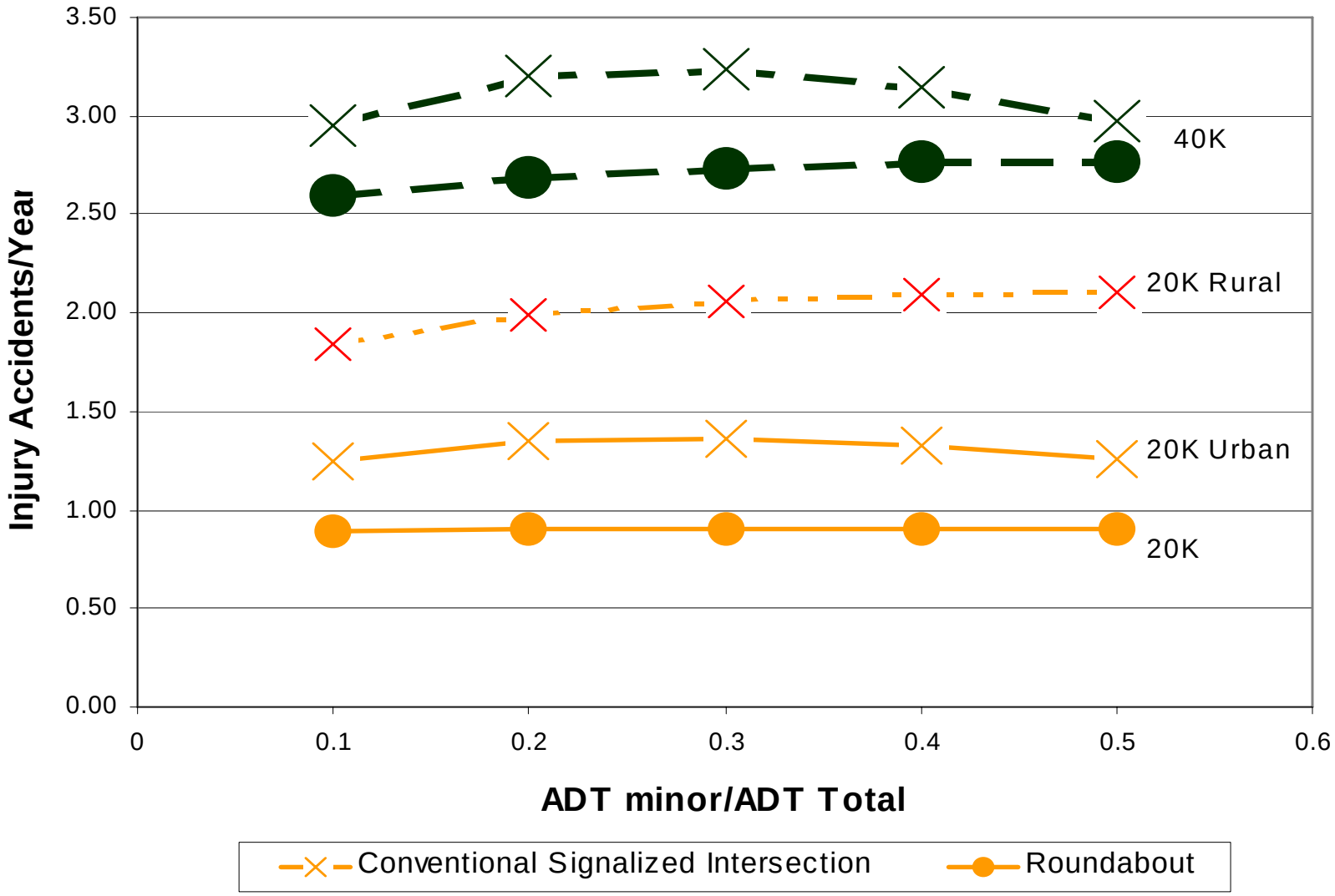
Selection Criteria

- Identify selection criteria
  - Community Enhancement
  - Traffic Calming
  - Safety Improvements
  - Operational Improvements
    - Delay and Capacity
  - Special Conditions

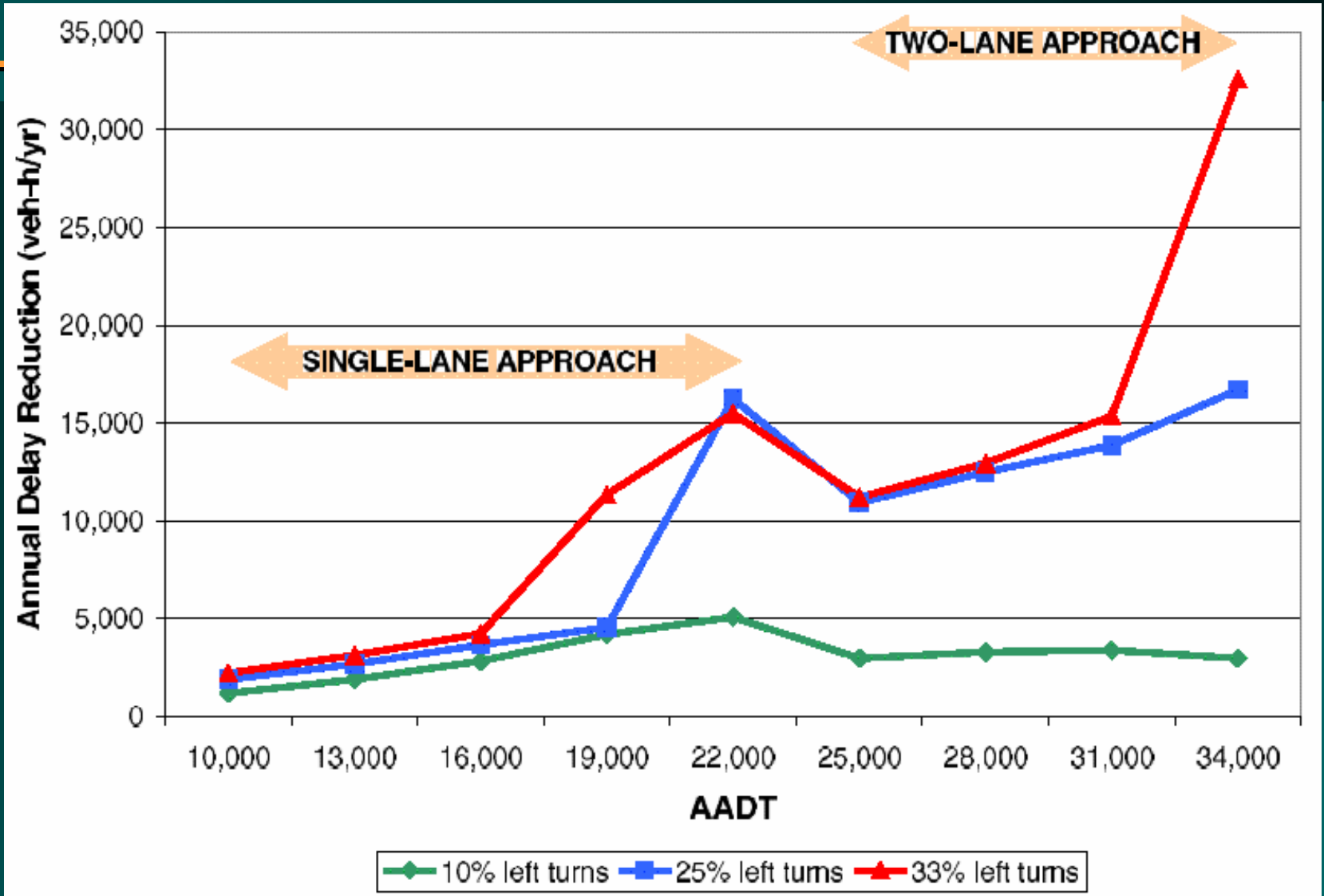
Comparison of Roundabout Crash Models with rural TWSC



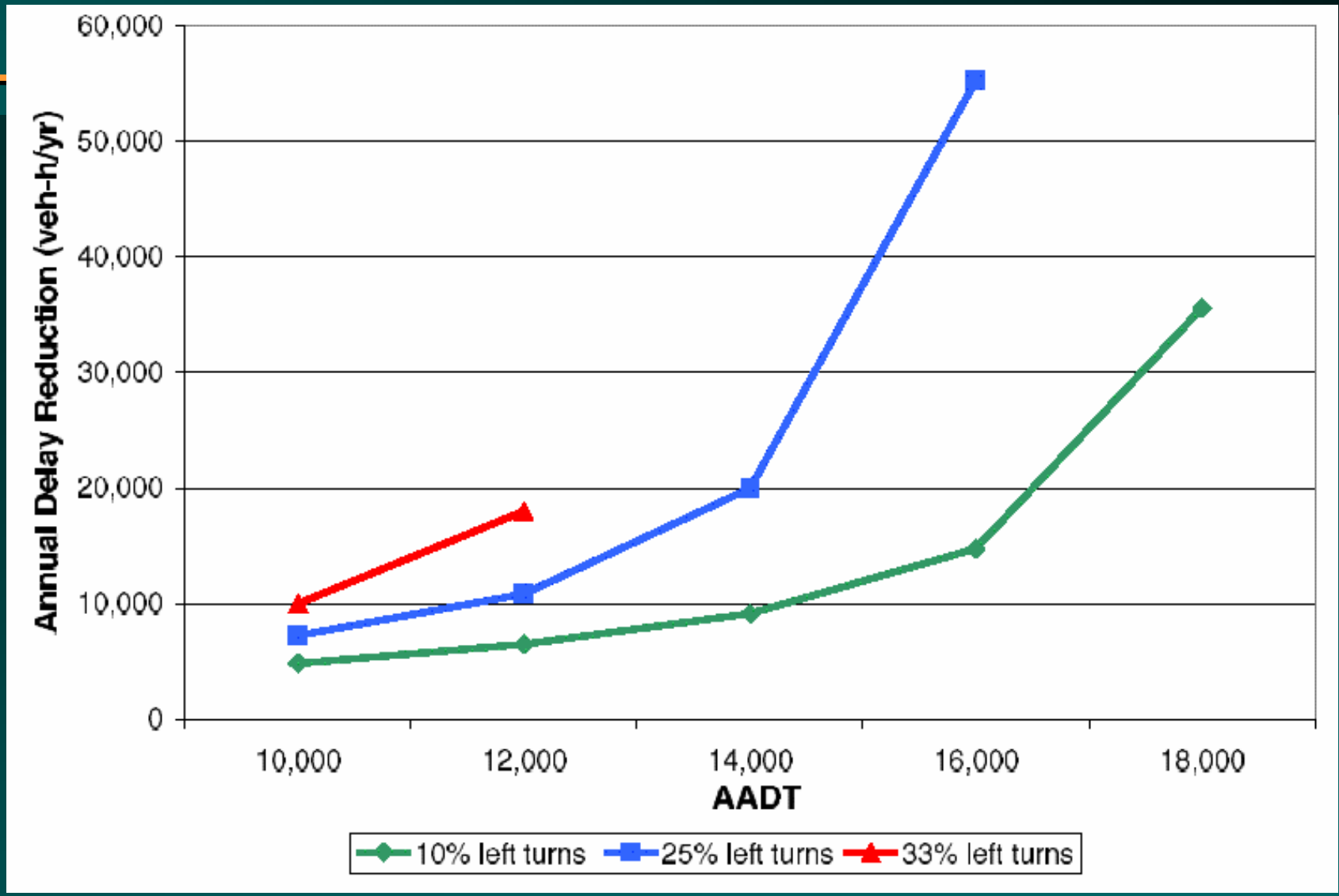
Comparison of Roundabout Crash Models with SIGNALS



Annual Savings in Delay for Roundabout versus Signal, 65% volume on Major Road



Annual Savings in Delay for Single-Lane Roundabouts versus AWSC, 65% of volume on Major Road



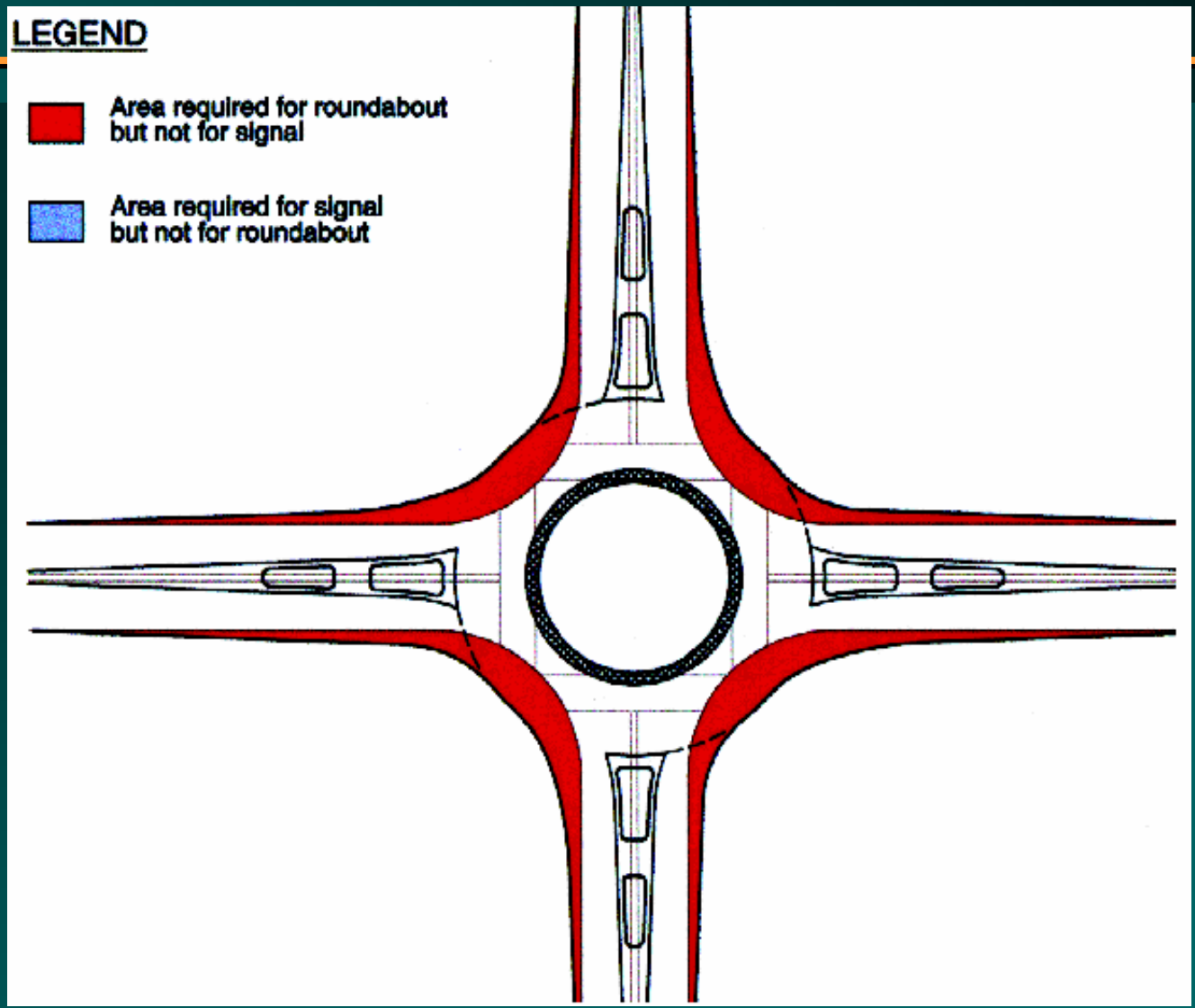
Roundabouts Traffic Operation

- Capacity
  - Geometric Elements
  - Circulating Flow
- Performance
  - Delay ~ “best” indicator of roundabout performance
  - Degree of saturation
  - Queue length

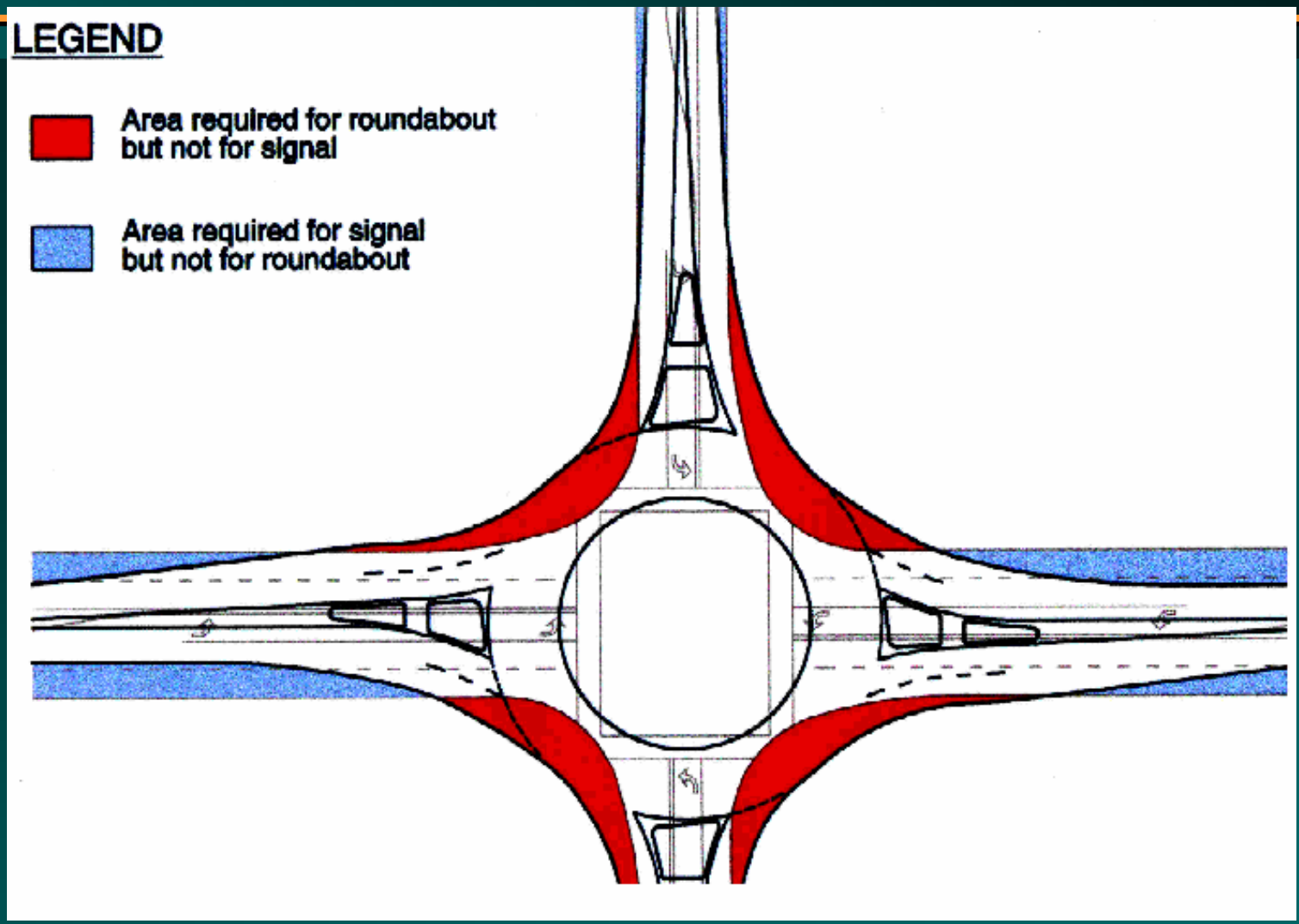
Space Requirements

- Roundabouts generally require more space than conventional roundabouts
- Consider Right-of-Way limitations

Area Comparison: Urban Compact Roundabout versus Signalized Intersection



Area Comparison: Urban Flared Roundabout versus Signalized Intersection



Economic Analysis

- Perform Cost/Benefit analysis in comparison with other forms of intersections

- Benefits
  - Safety Benefits
  - Operational Benefits
  - Environmental Benefits

- Costs
  - Construction Costs
  - Operation and Maintenance Costs

Benefits of Modern Roundabouts

- Safety Benefits
  - Traffic Calming Device
    - reduced speed into and through intersection
    - low and similar speed through the roundabout
    - improve overall safety

Benefits of Roundabouts

- Operational Benefits
  - Circulatory traffic will have priority
  - Entry traffic will yield to circulatory traffic
  - Left turning conflicts will be eliminated
  - Expected to simplify decision process of driver
    - one-way traffic
    - yield at entry
    - absence of left-turning conflicts

Benefits of Roundabouts

- Environmental Benefits
  - Aesthetically appealing

Benefits of Roundabouts

- Costs
  - Construction Costs
  - Self-Regulating with expected lower operating and maintenance costs

Disadvantages of Modern Roundabouts

- Safety concerns for cyclists
- Very difficult to design for high traffic flows
- Unsuitable for unbalanced traffic flows
- “New concept” in the U.S.

Modern Roundabouts vs. Other Intersection Control Alternatives

- Depends……
  - Benefit/Cost analysis
  - Road users' specific requirements
- Enhance Safety => Roundabouts
- Higher Capacity => Roundabouts
- High left turn flows => Roundabouts
- Low turning flows => Traffic Signals

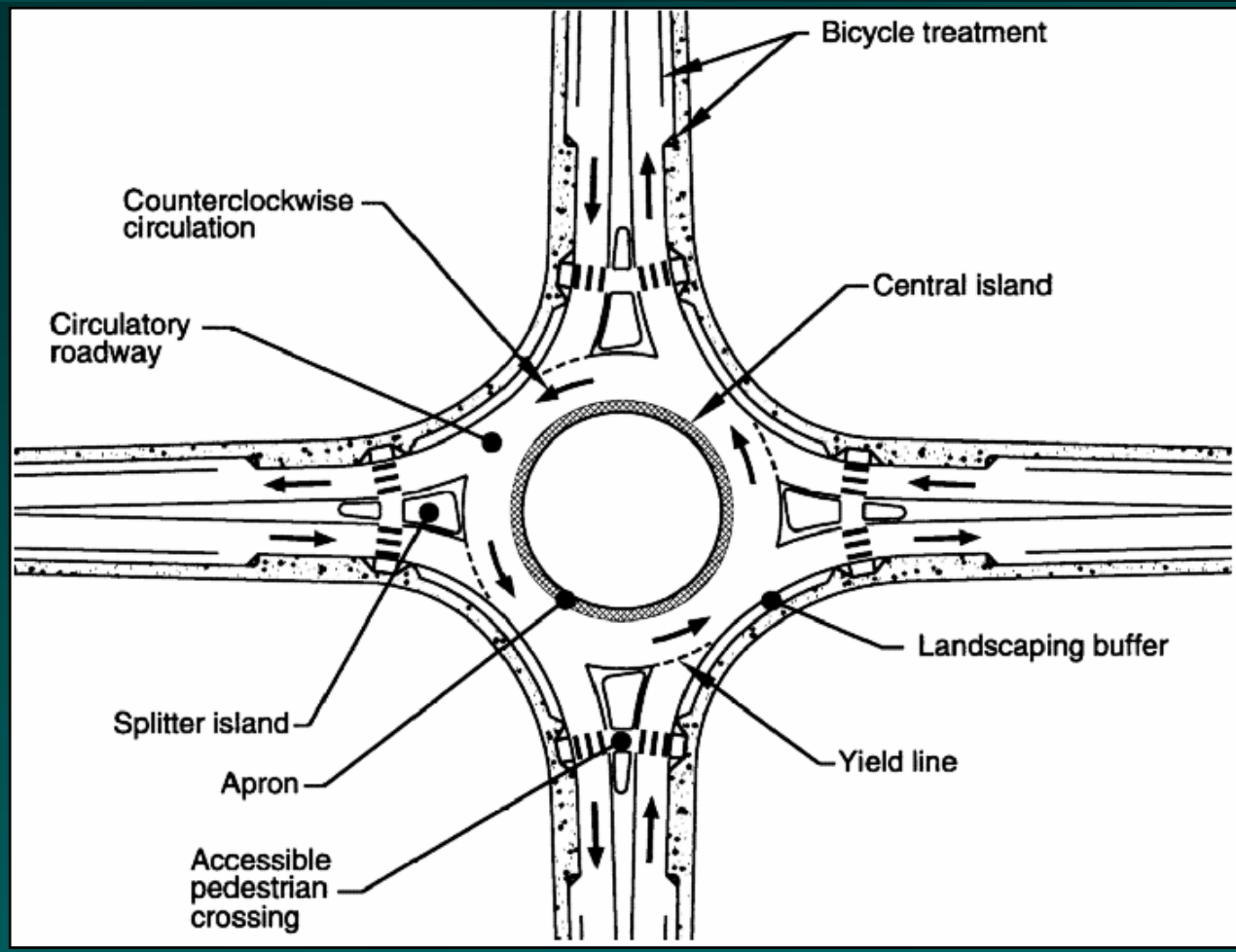
Geometric Design of Roundabouts

Geometric Design of Roundabouts

- Geometric Design
  - Geometric Elements
  - Basic Design Principles
  - Horizontal Geometry
  - Vertical Geometry
  - Example Problems

Design of Modern Roundabouts

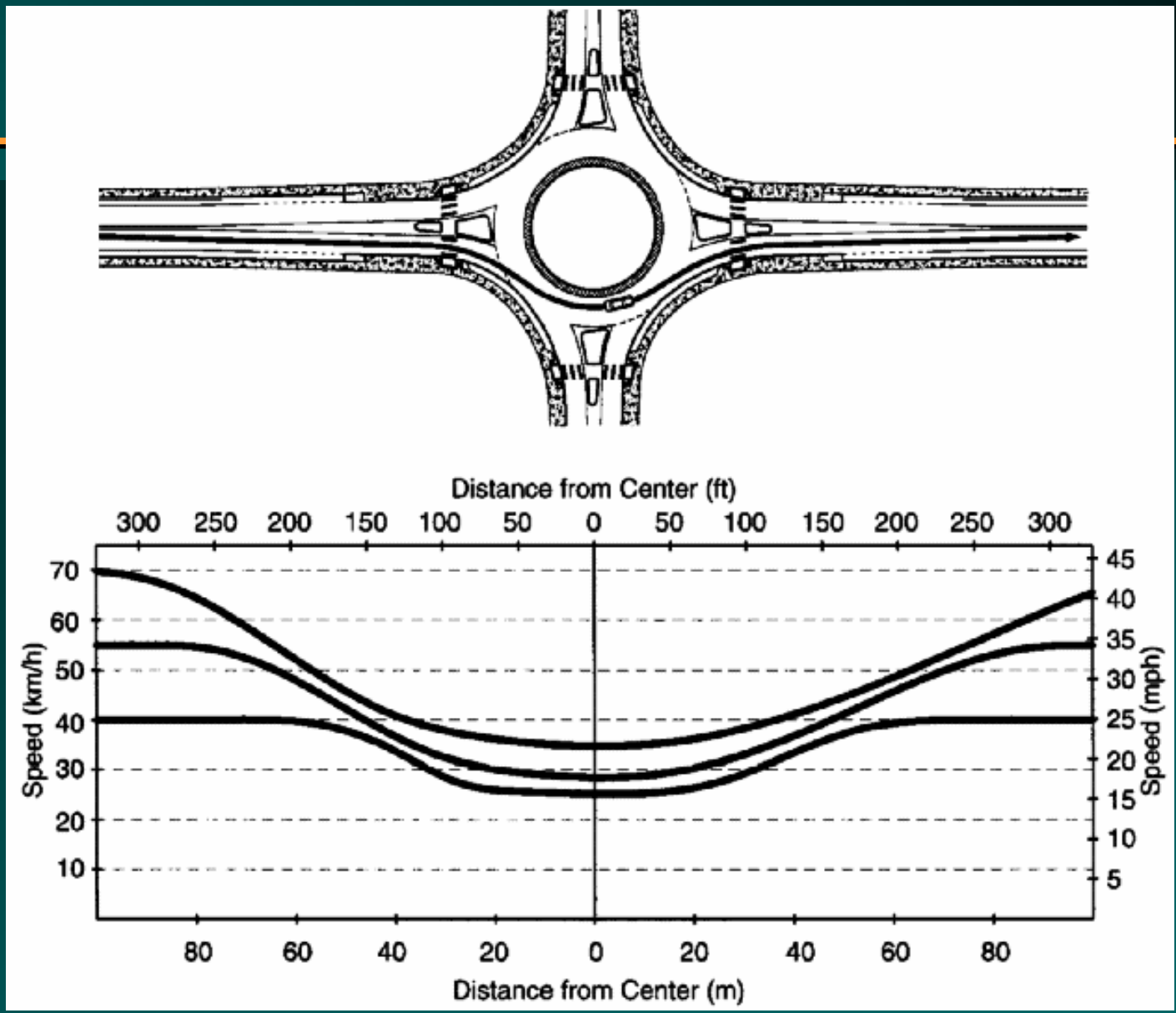
Geometric Design Elements



Initial Design Considerations

- Urban/rural environments
- Physical constraints
- Topography
- Sight distance constraints
- Alignments conditions

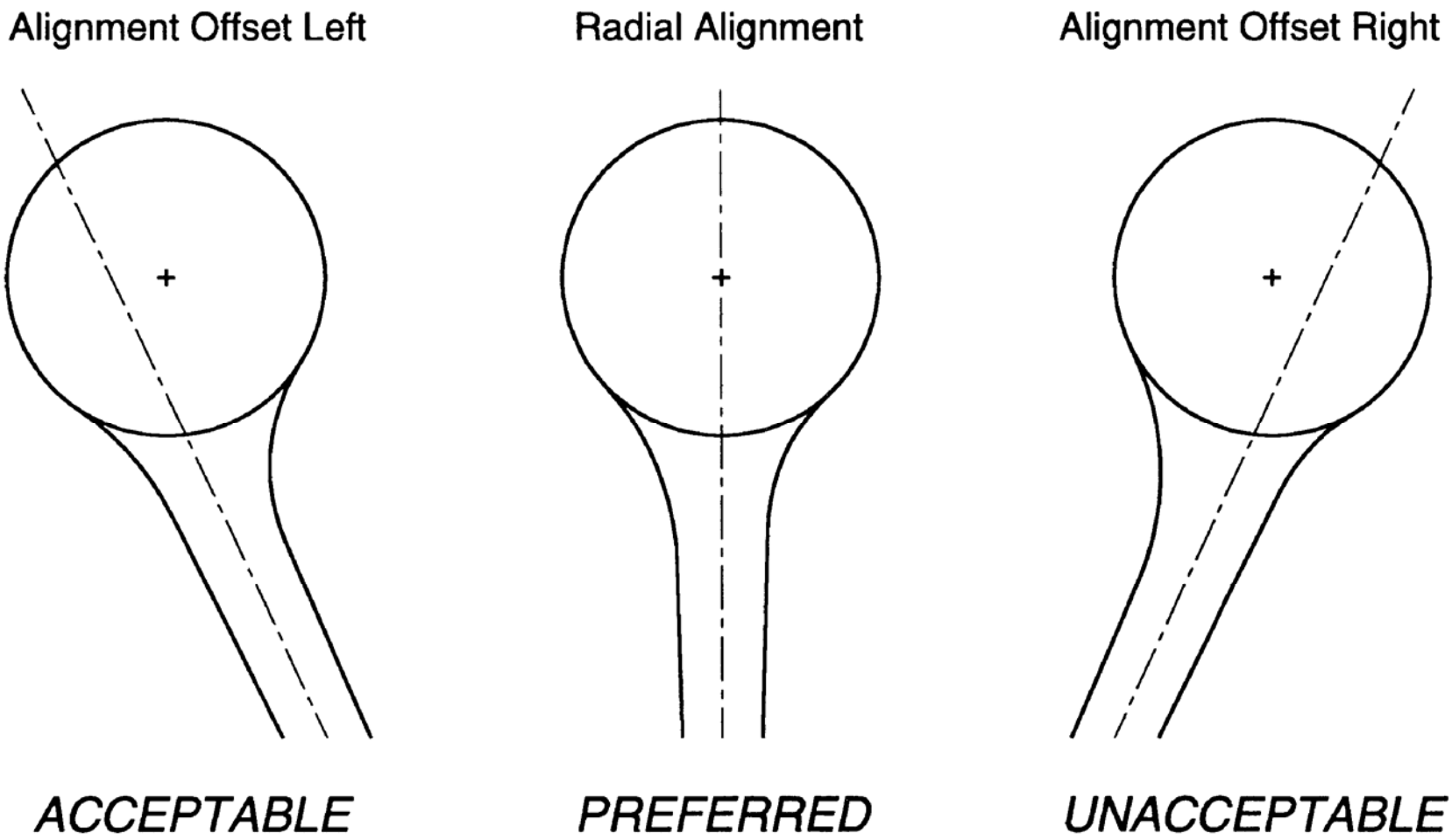
Speed Profile Through the Rdbt



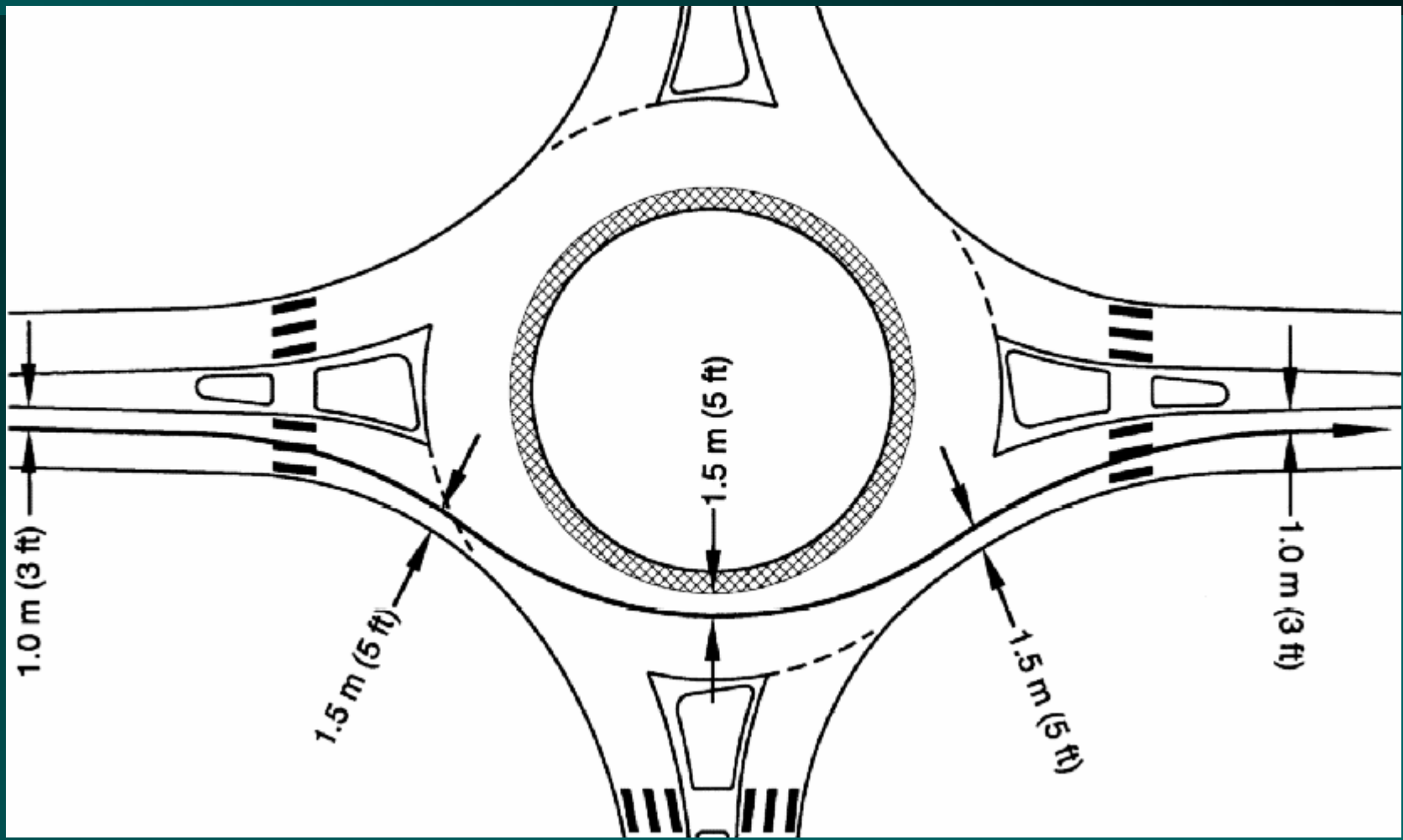
Maximum Entry Design Speeds

- Urban Single lane roundabouts < 35 km/h (20 mph)
- Rural Single lane roundabouts < 40 km/h (25 mph)
- Urban double lane roundabouts < 40 km/h (25 mph)
- Rural double lane roundabouts < 50 km/h (30 mph)

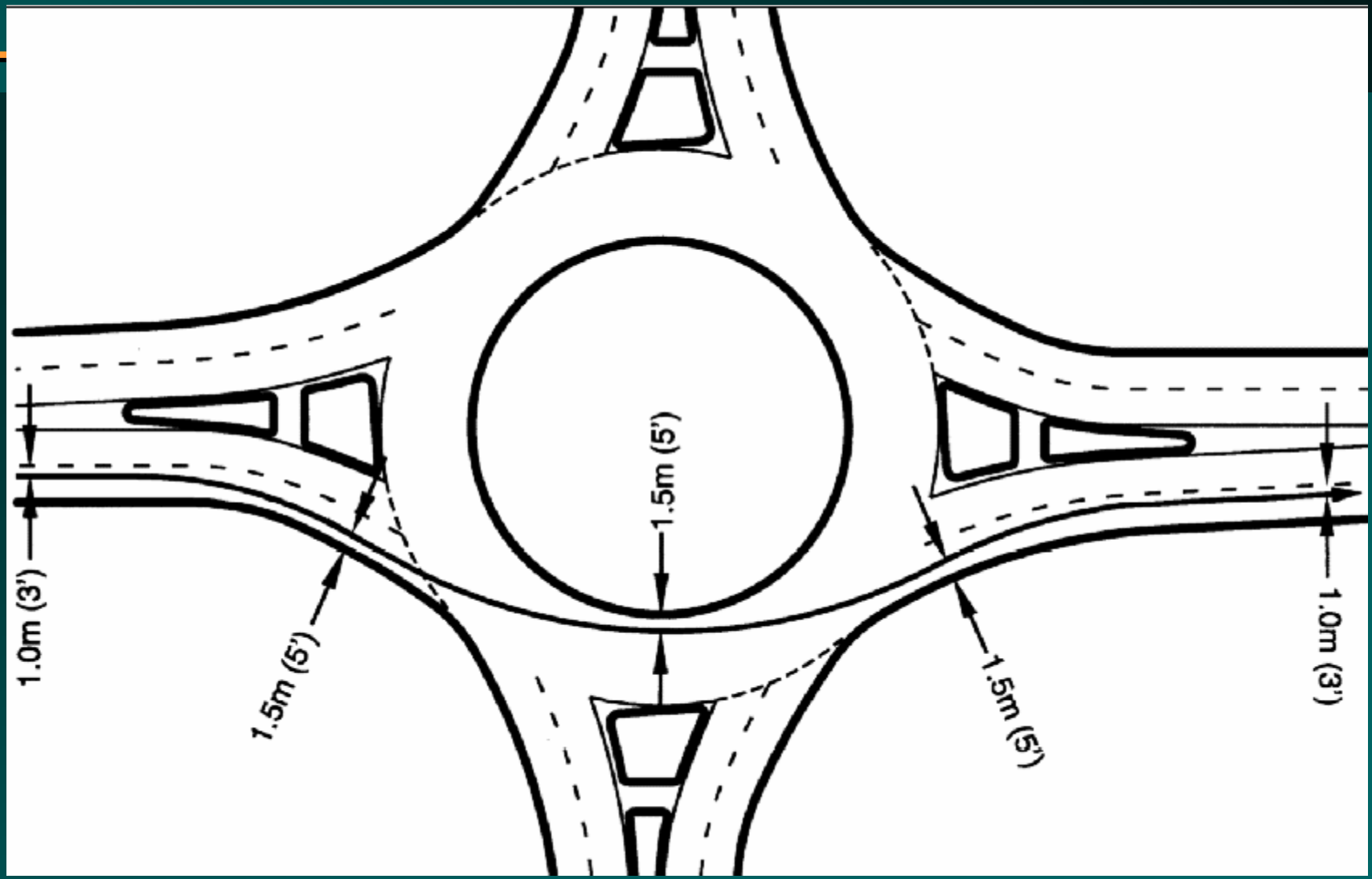
Alignment at Entries



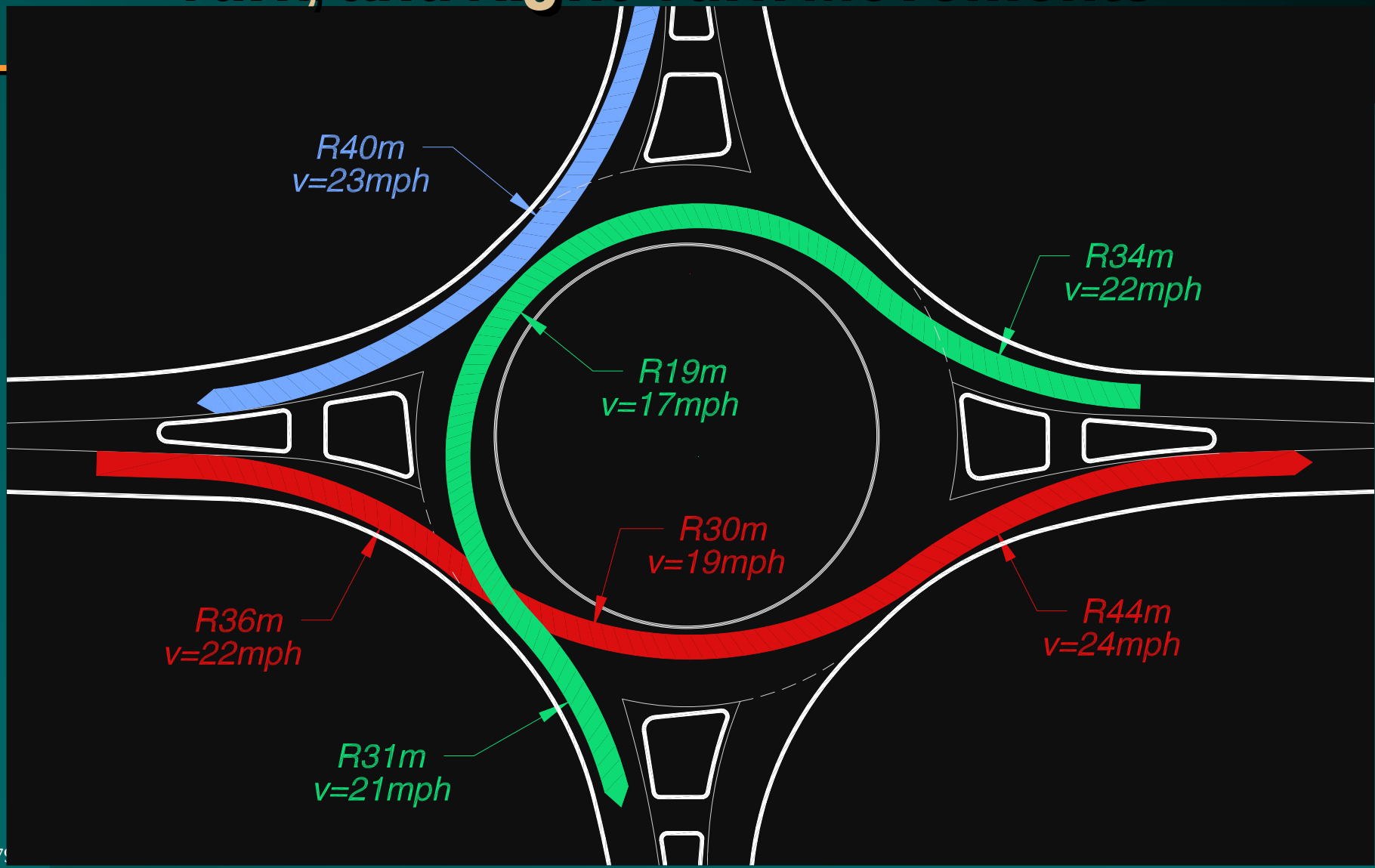
Fastest Path Through a Single Lane Roundabout



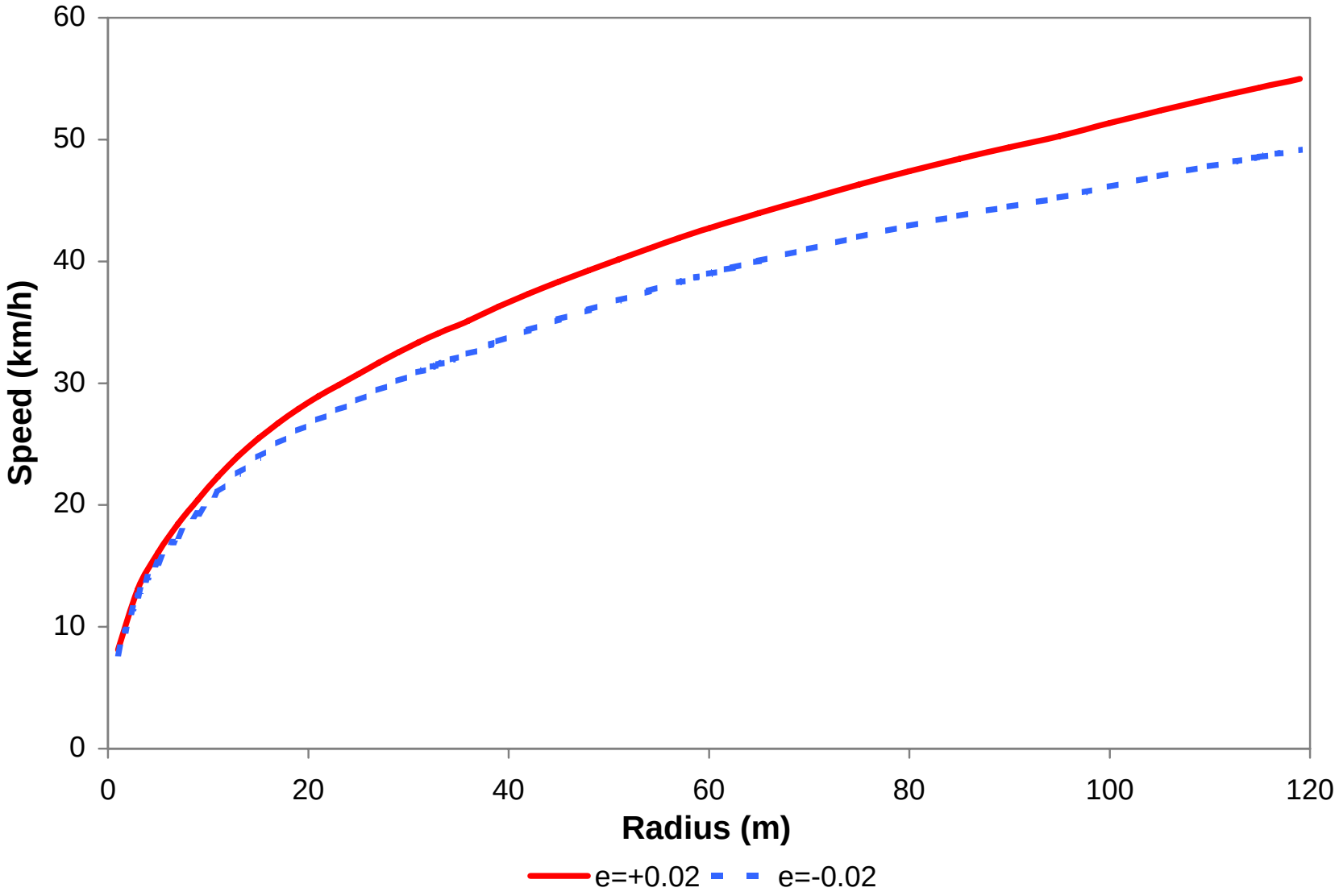
Fastest Path Through a Double Lane Roundabout



Fastest Vehicle Paths Through, Left-Turn, and Right-Turn Movements



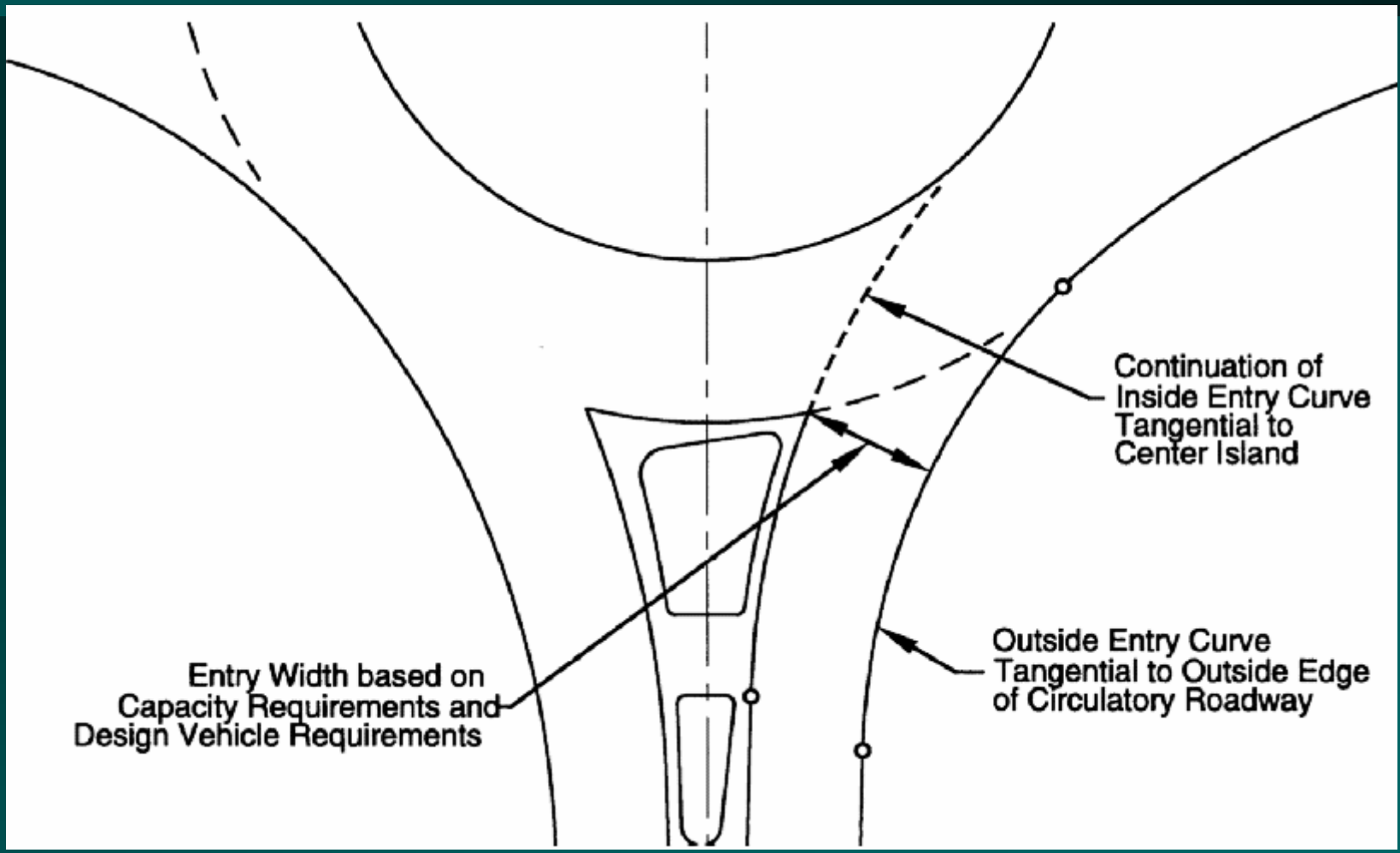
Speed vs Radius for Two Superelevations



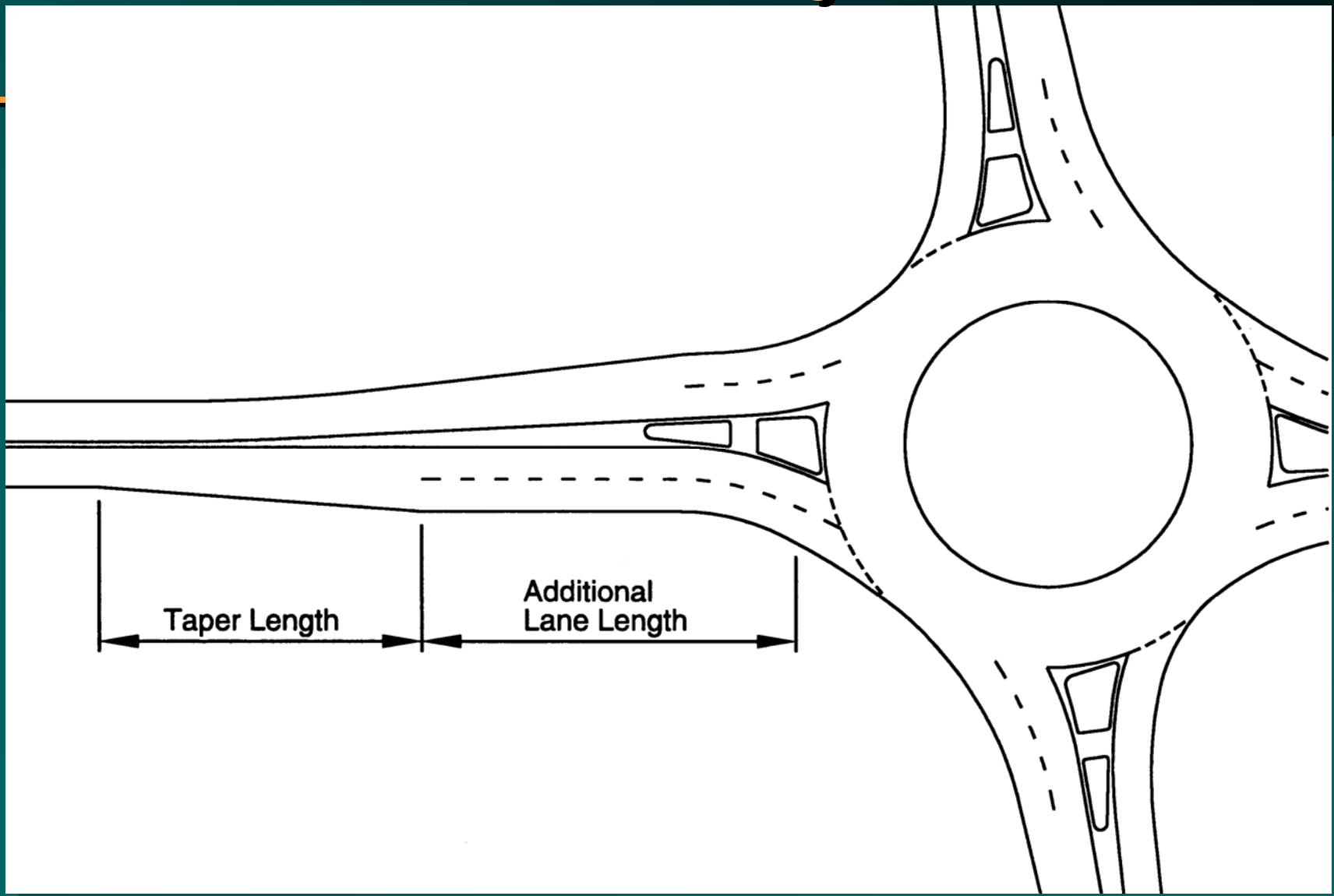
Typical Inscribed Diameters

Site Category	Typical Design Vehicle	Inscribed Circle Diameter Range*	
Mini-Roundabout	**Single-Unit Truck**	**13 – 25 m**	**(45 – 80 ft)**
Urban Compact	**Single-Unit Truck/Bus**	**25 – 30 m**	**(80 – 100 ft)**
Urban Single Lane	**WB-15 (WB-50)**	**30 – 40 m**	**(100 – 130 ft)**
Urban Double Lane	**WB-15 (WB-50)**	**45 – 55 m**	**(150 – 180 ft)**
Rural Single Lane	**WB-20 (WB-67)**	**35 – 40 m**	**(115 – 130 ft)**
Rural Double Lane	**WB-20 (WB-67)**	**55 – 60 m**	**(180 – 200 ft)**

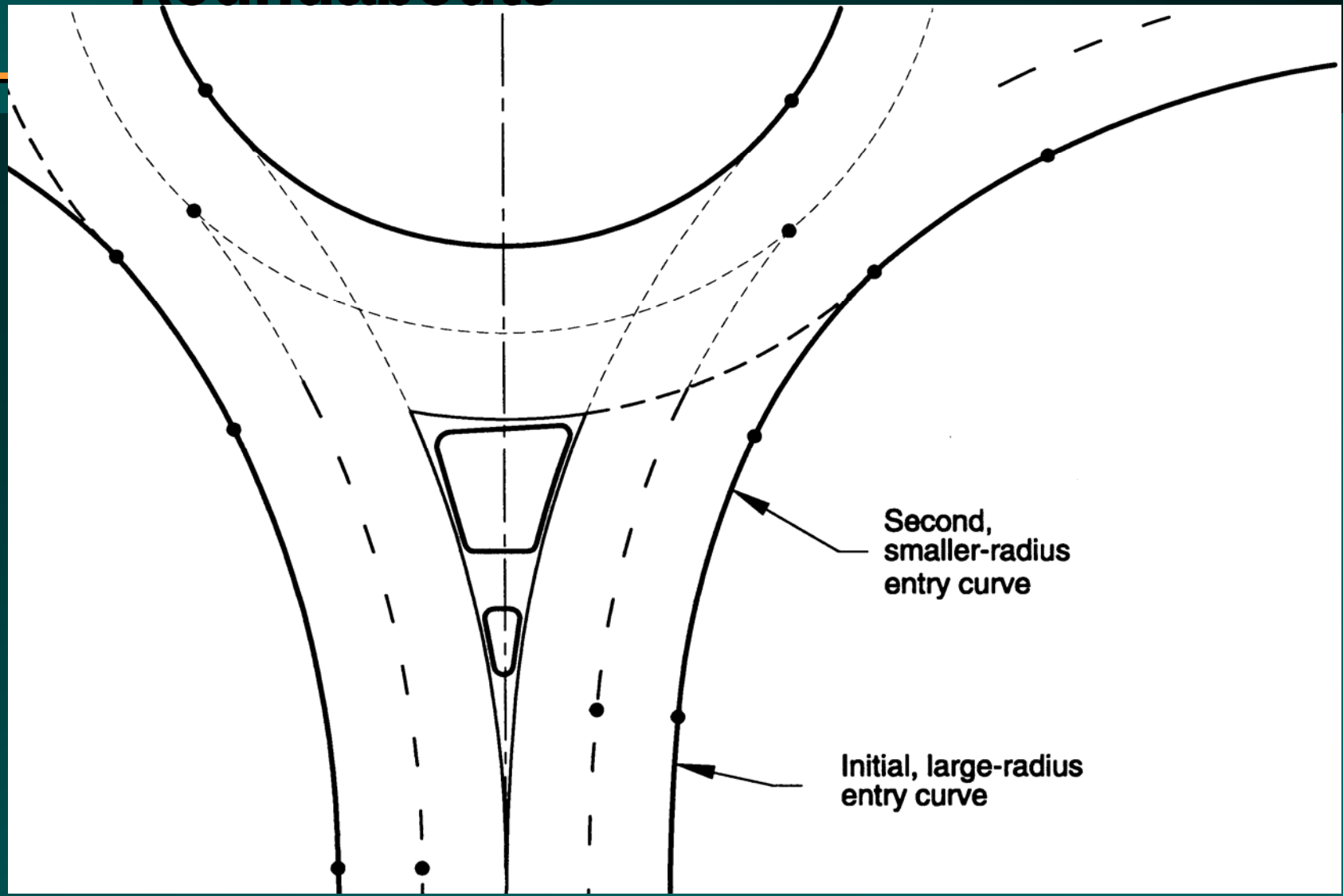
Entry Width Definition



Additional Flared Entry Lane



Design of Entries of Two-Lane Roundabouts

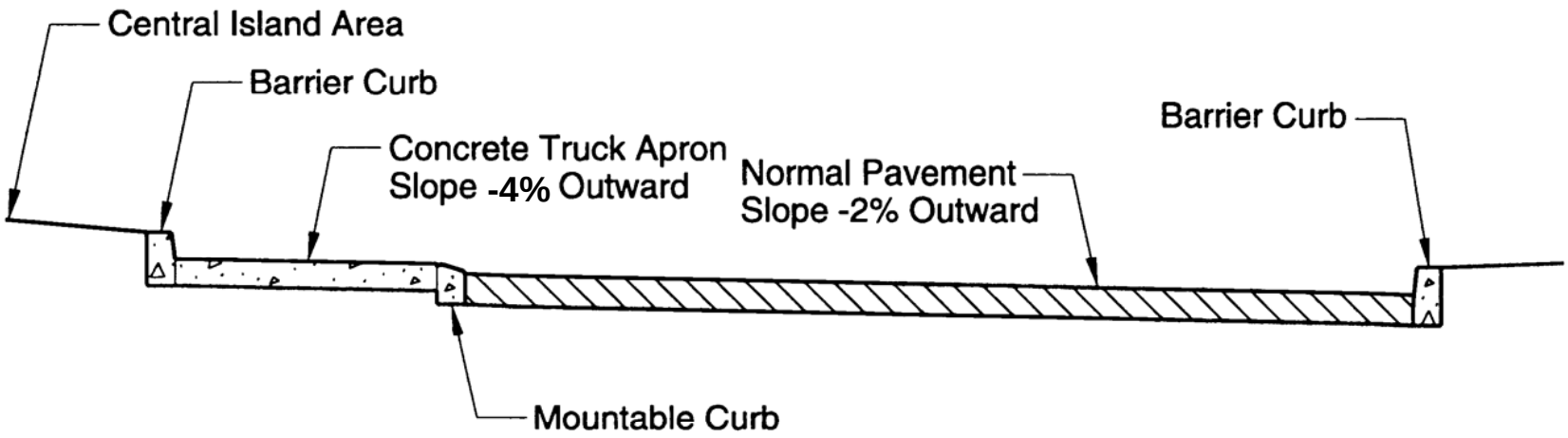


Minimum Widths for Two-Lane Roundabout

Inscribed Circle Diameter	Minimum Circulatory Lane Width*	Central Island Diameter
45 m (150 ft)	**9.8 m (32 ft)**	**25.4 m (86 ft)**
50 m (165 ft)	**9.3 m (31 ft)**	**31.4 m (103 ft)**
55 m (180 ft)	**9.1 m (30 ft)**	**36.8 m (120 ft)**
60 m (200 ft)	**9.1 m (30 ft)**	**41.8 m (140 ft)**
65 m (215 ft)	**8.7 m (29 ft)**	**47.6 m (157 ft)**
70 m (230 ft)	**8.7 m (29 ft)**	**52.6 m (172 ft)**

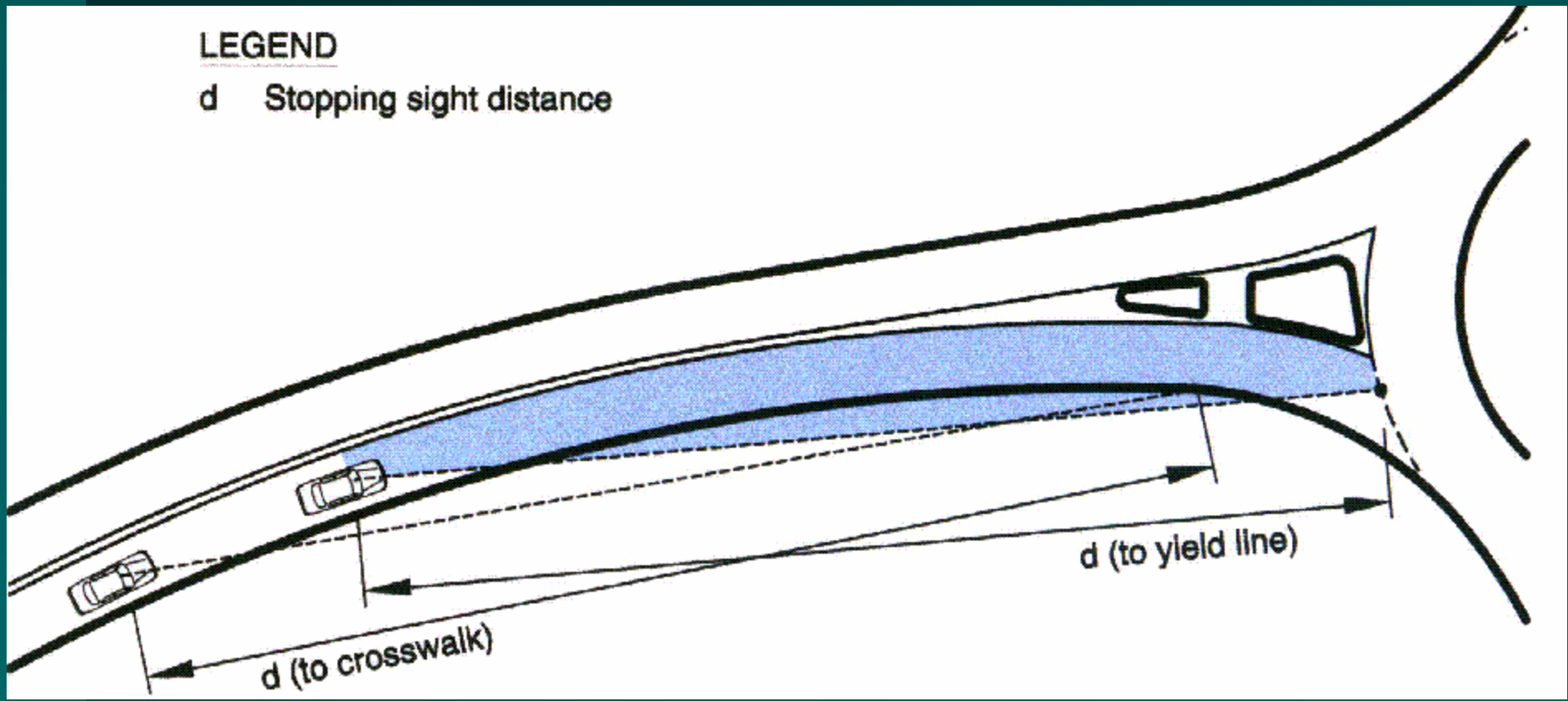
*** Based on 1994 AASHTO Table III-20, Case III(A) (**Error! Reference source not found.**). Assumes infrequent semi-trailer use.**

Typical Cross Section

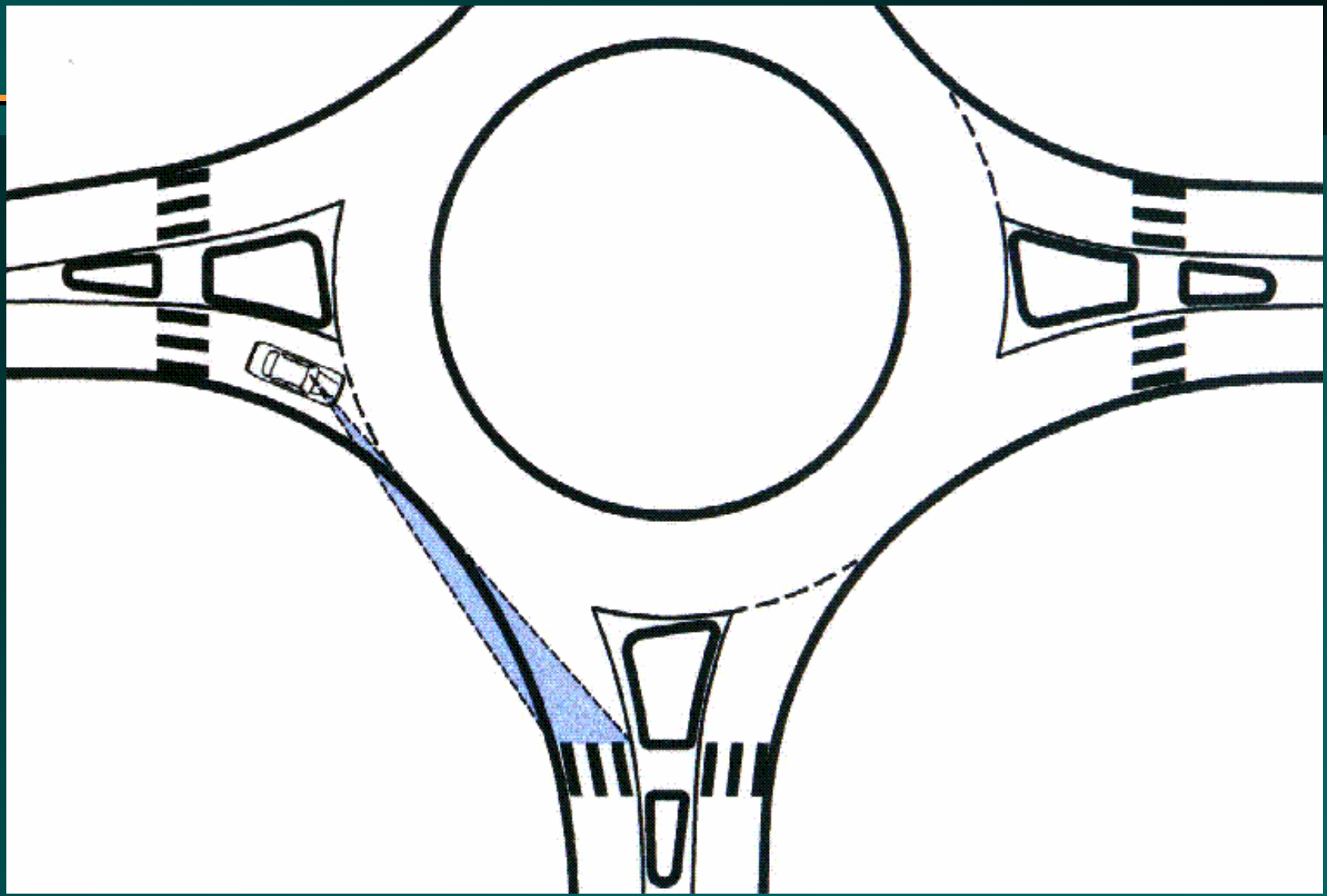


Traversable Surface

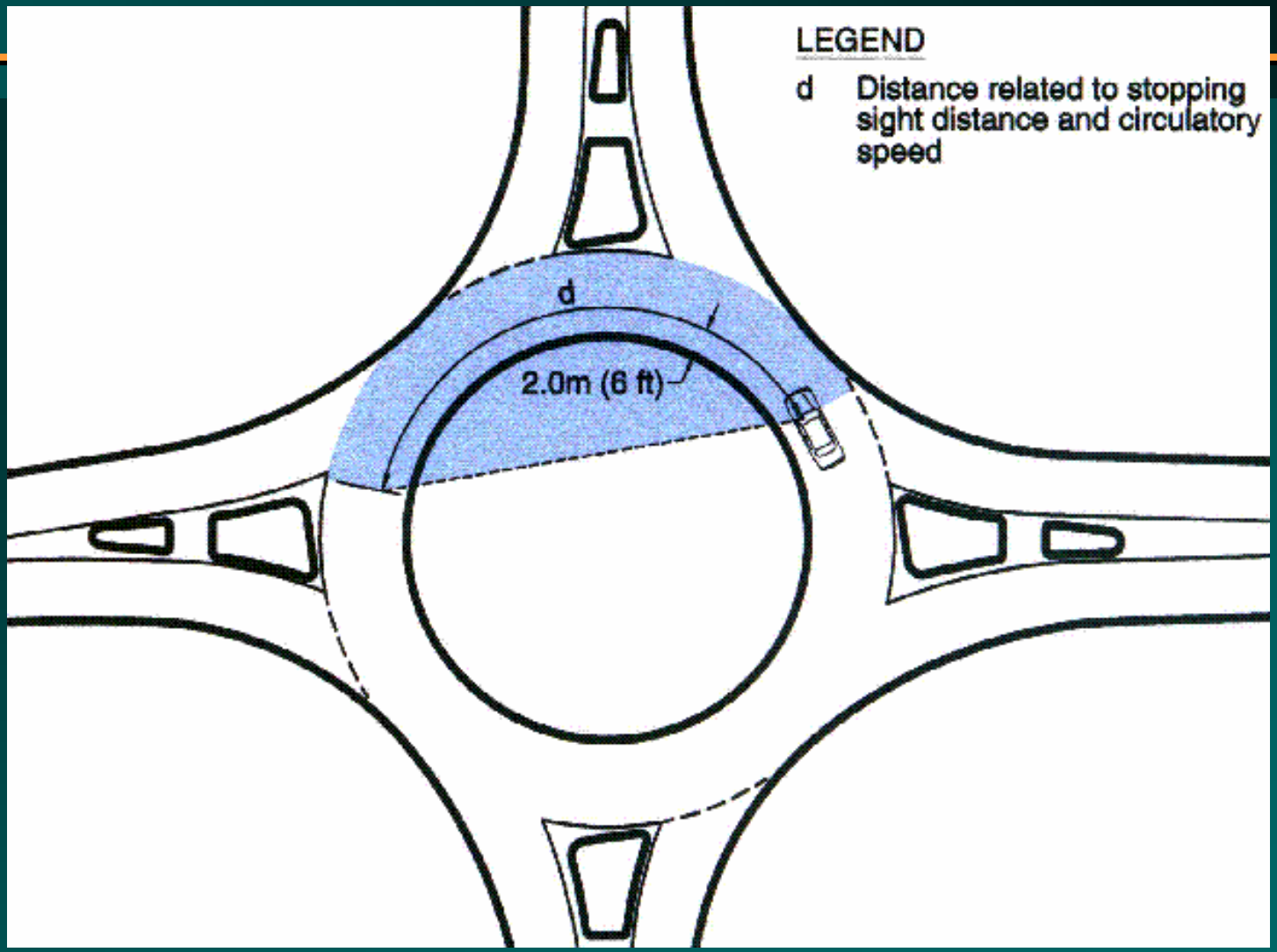
Required Stopping Sight Distance at Entries



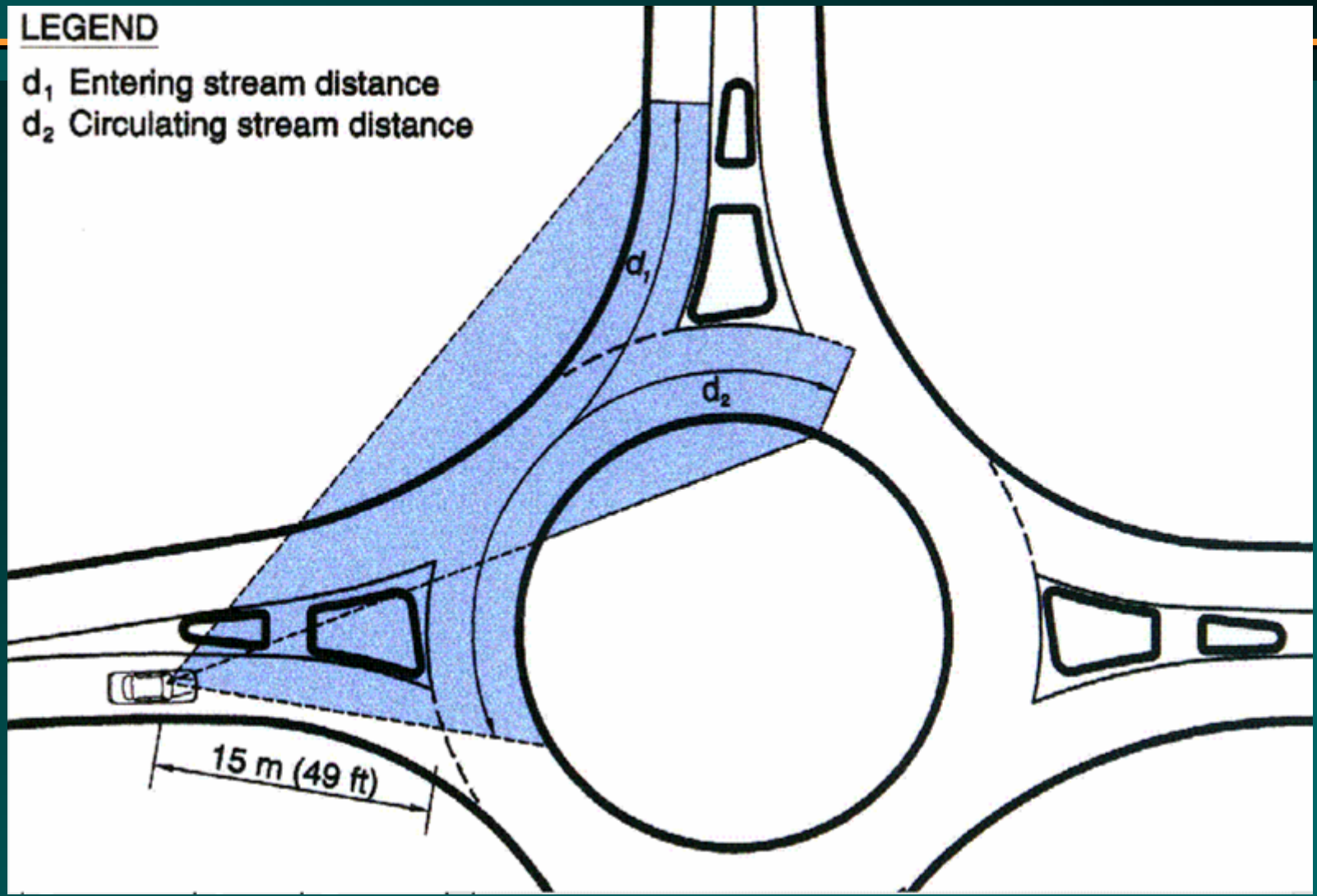
Stopping Sight Distance to Pedestrian Crosswalk



Stopping Sight Distance in the Circulatory Roadway



Required Intersection Sight Distance



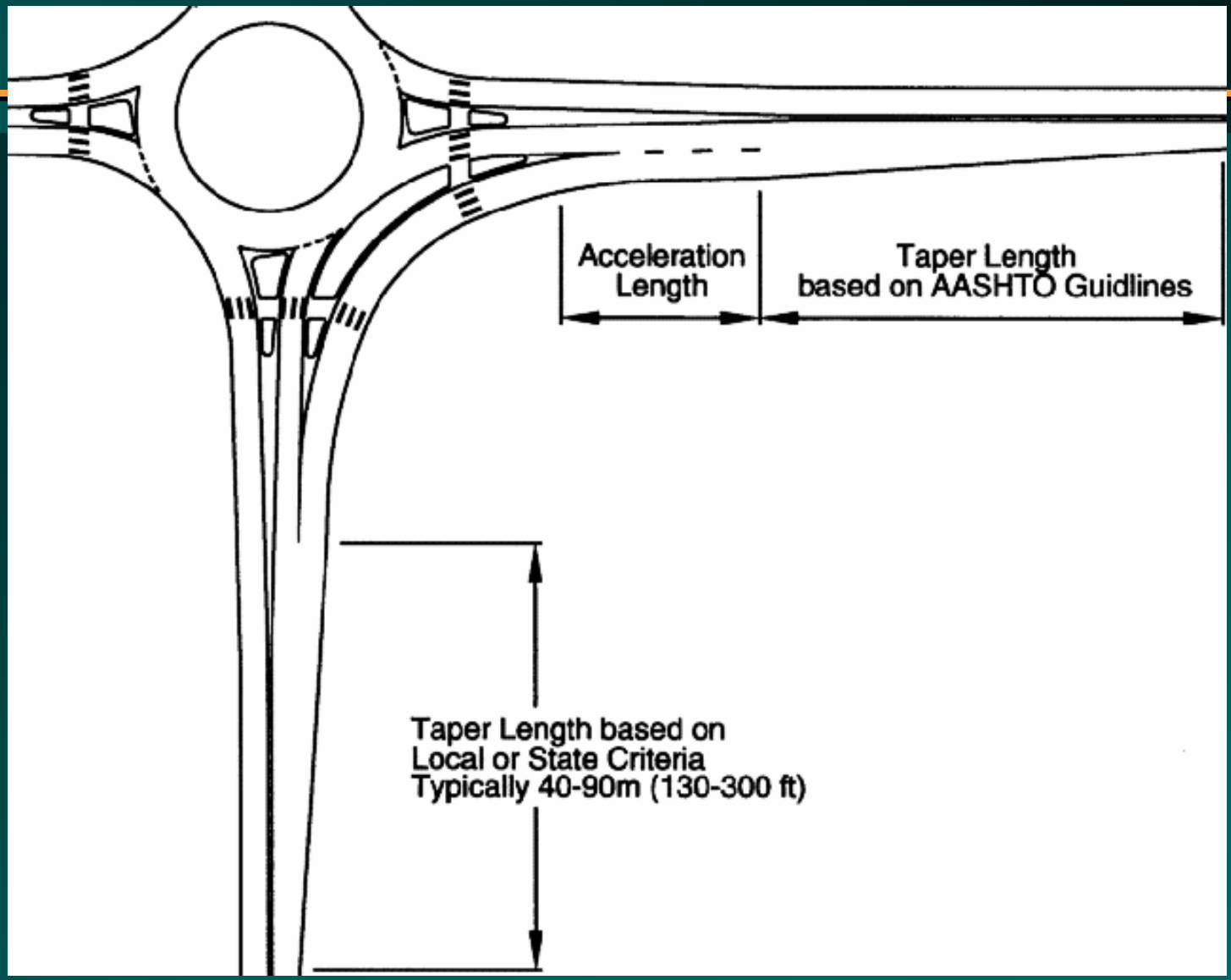
SSD

Speed (km/h)	Computed Distance* (m)
10	8.1
20	18.5
30	31.2
40	46.2
50	63.4
60	83.0
70	104.9
80	129.0
90	155.5
100	184.2

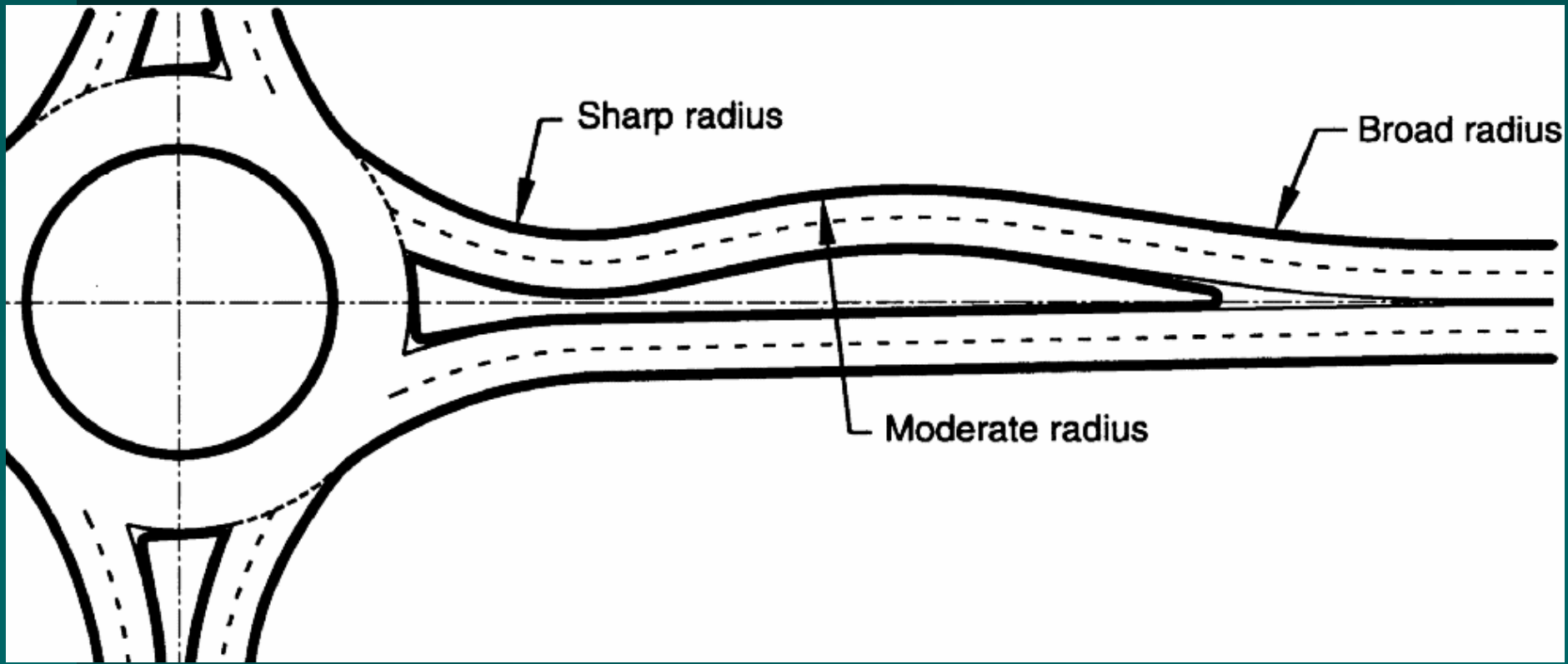
ISD

Conflicting Approach Speed (km/h)	Computed Distance (m)
20	36.1
25	45.2
30	54.2
35	63.2
40	72.3

Right-Turn Bypass Lane



Triple Reverse Curves



Operating Speed Models

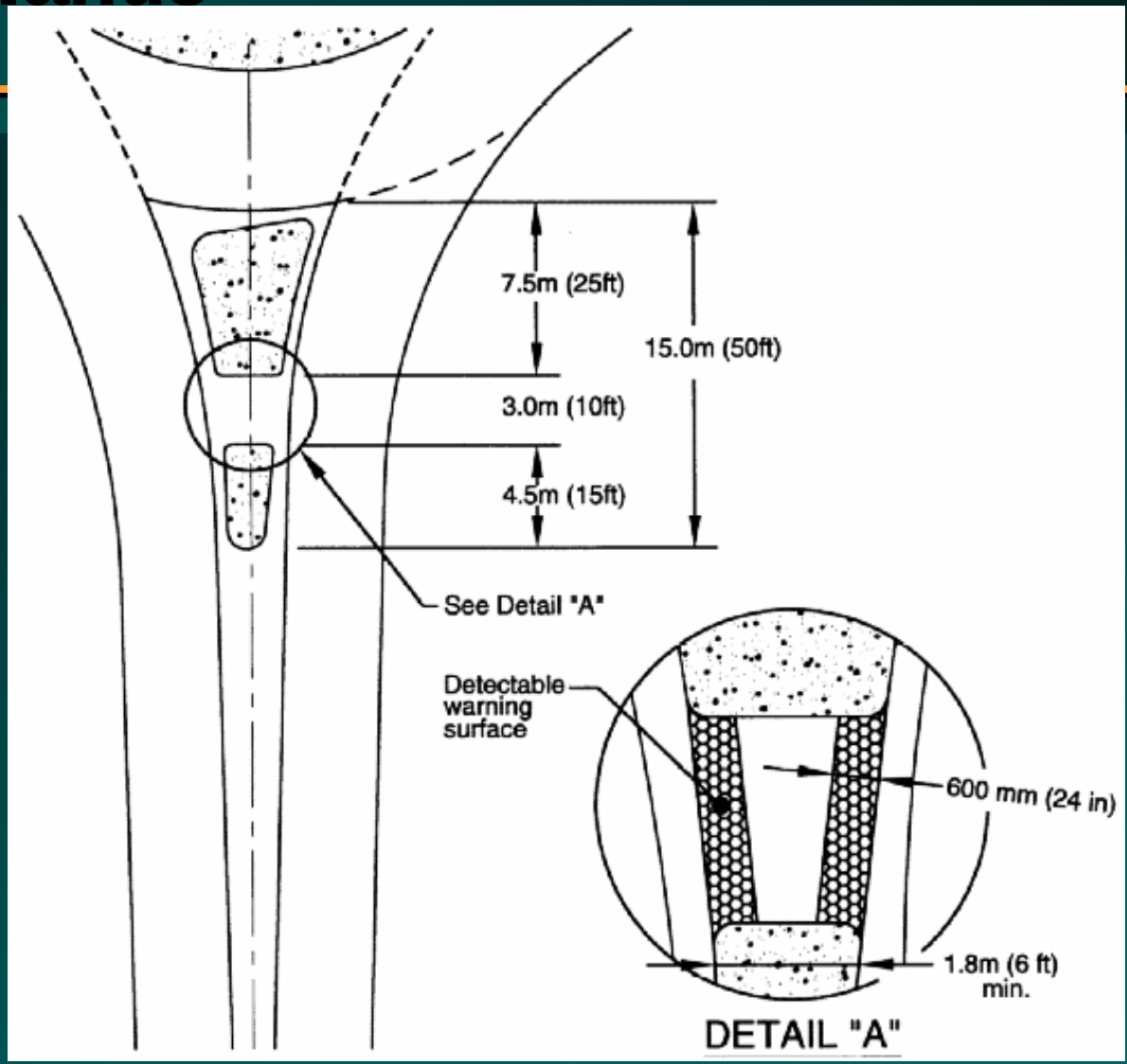
- Two-lane rural roads:
- V85 = 103.66 -1.95 D, for D ≥ 3o
- V85 = 97.9, for D < 3o
- V85 = 85th-percentile speed, km/h

- Four-lane rural roads:
- V85 = 103.66 -1.95 D

Pedestrians Treatment

- Provide for pedestrian convenience and safety
- Minimum width of refuge island, 1.8 m
- Located at 1 or more car length (7.5 m) from the yield line
- Provide ramps (with detectable warning surface) at curbs and keep the refuge at street level
- Other experimental treatments (speed table, pedestrian signal, active crosswalk flashing light system)

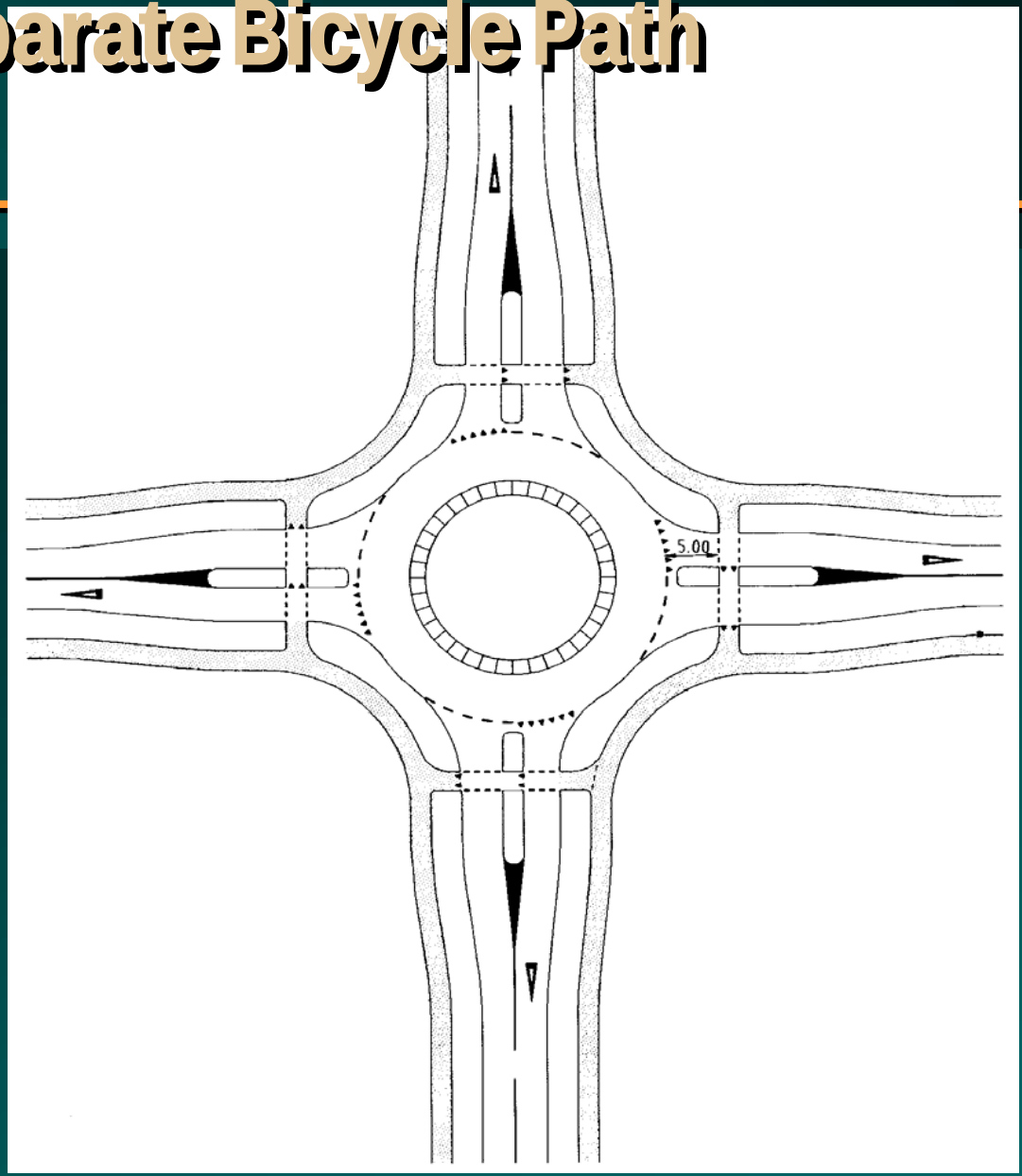
Minimum Dimensions for Splitter Islands



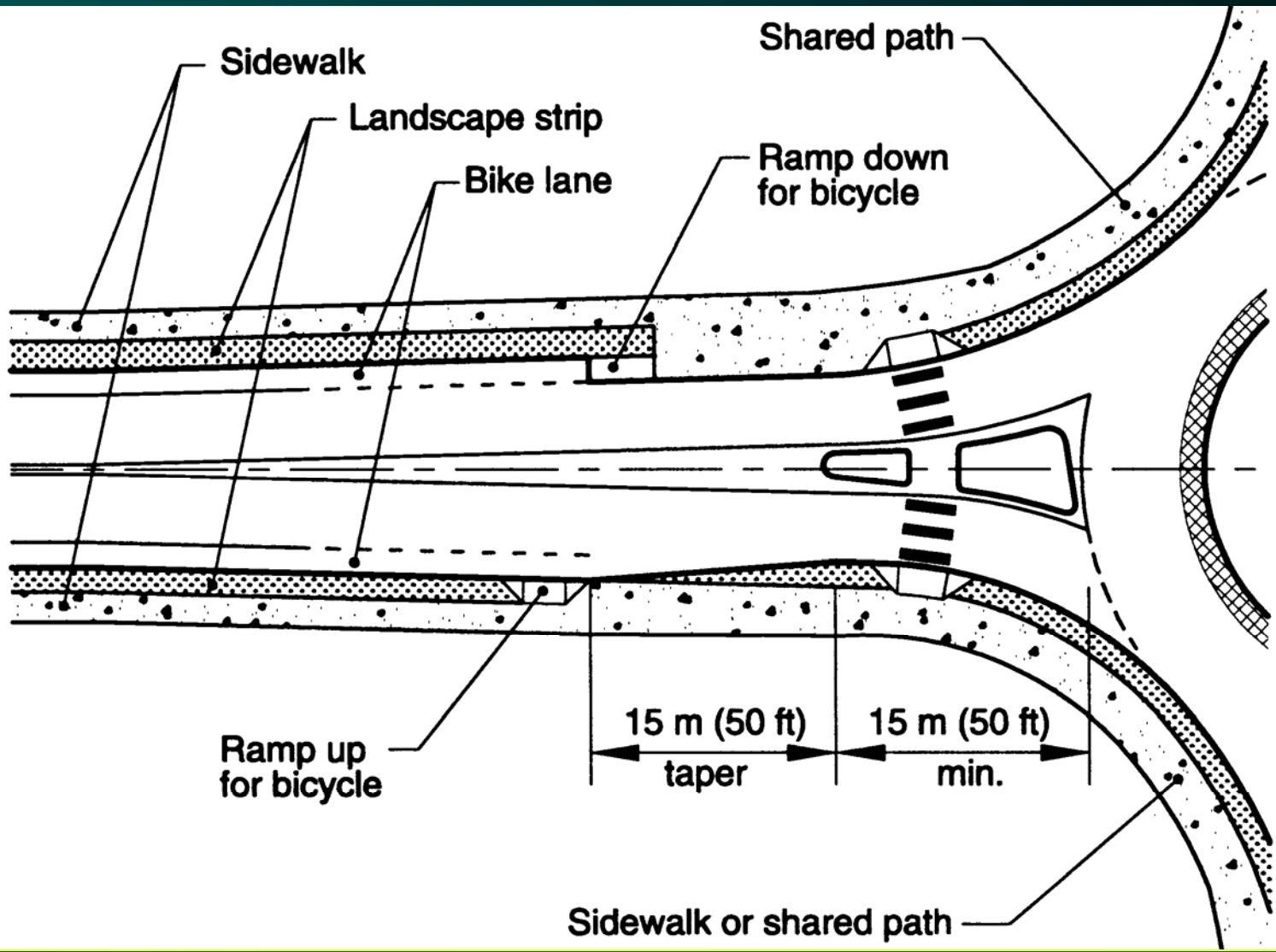
Bicyclists Treatment

- In most cases bicycles should be treated as vehicles (especially, single lane roundabouts)
- Bicycle lane should be terminated about 30 m ahead of the yield line
- Never design a bicycle lane in the circle
- For double lane roundabouts, provide a separate bicycle path

Separate Bicycle Path



Treatment for Bicycles



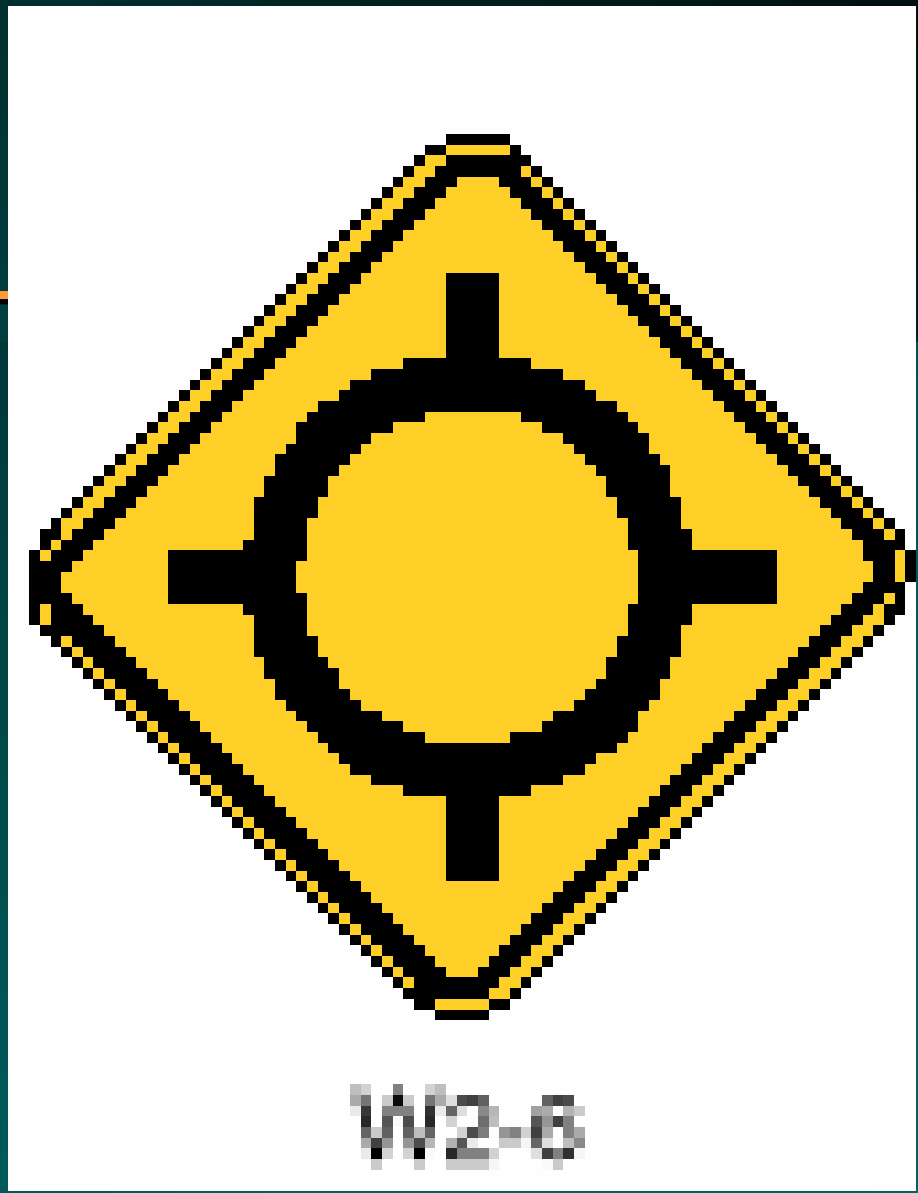
Traffic Design and Landscaping

Traffic Design and Landscaping

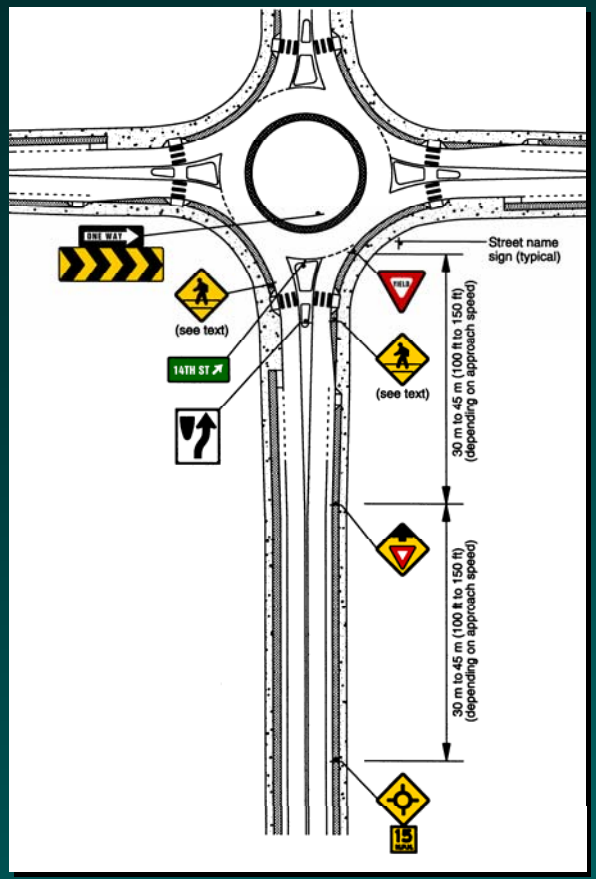
- Traffic Design and Landscaping
  - Signing
  - Pavement Markings
  - Lighting
  - Construction Staging
  - Landscaping

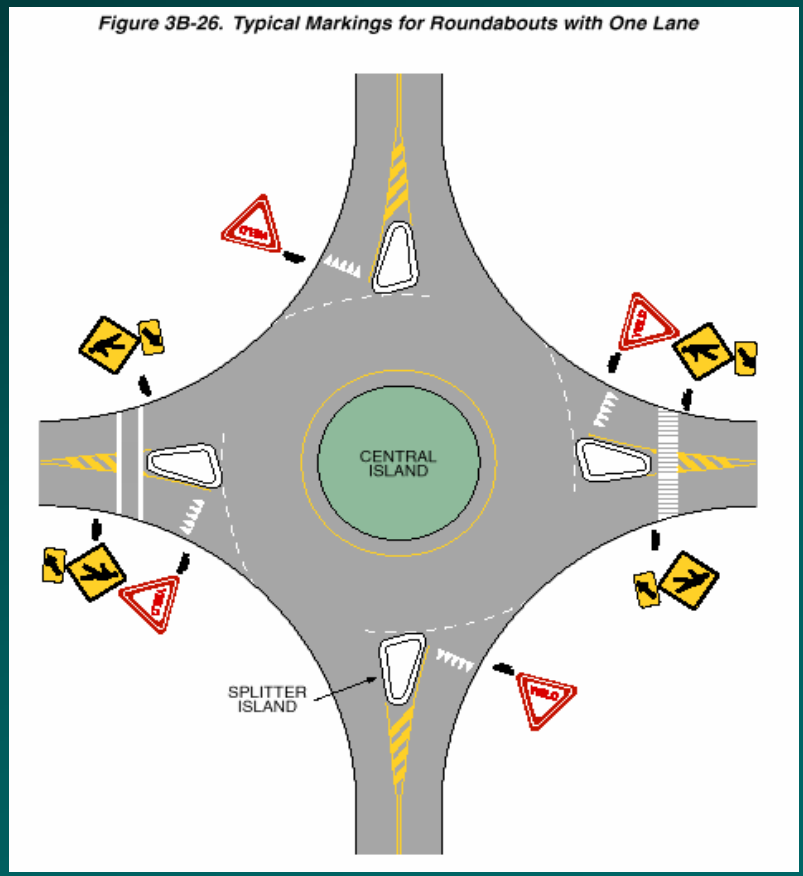
2000 MUTCD

- Circular Intersection
- Warning Sign



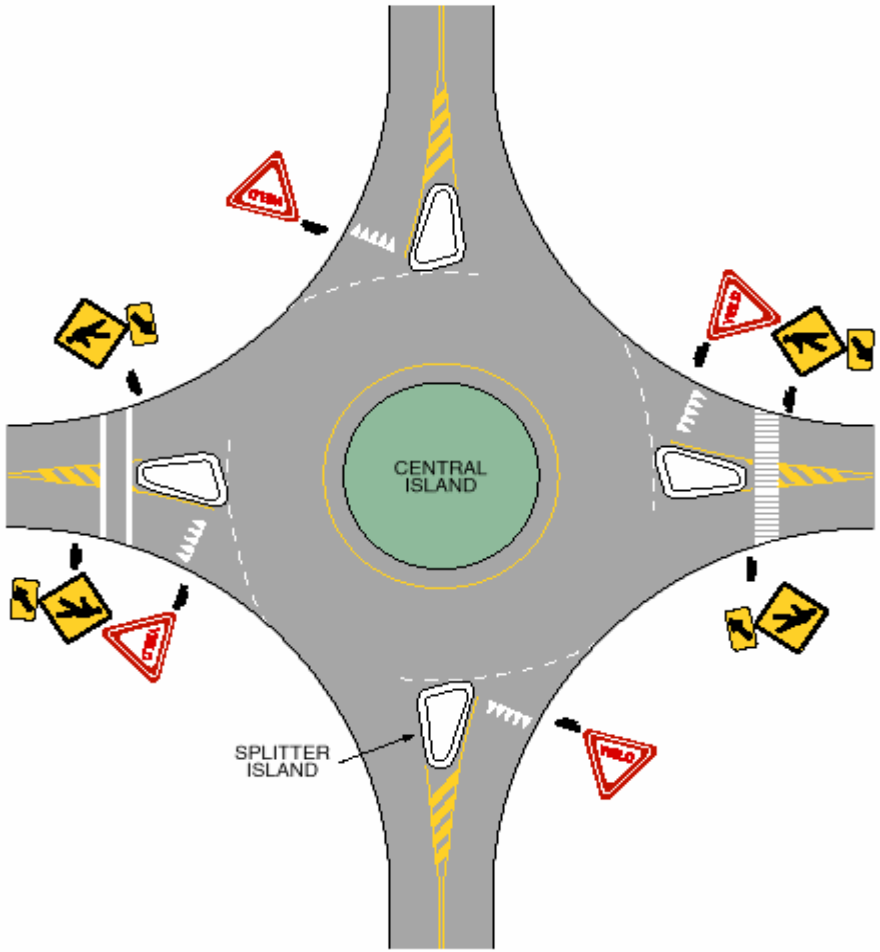
Typical Roundabout Traffic Control





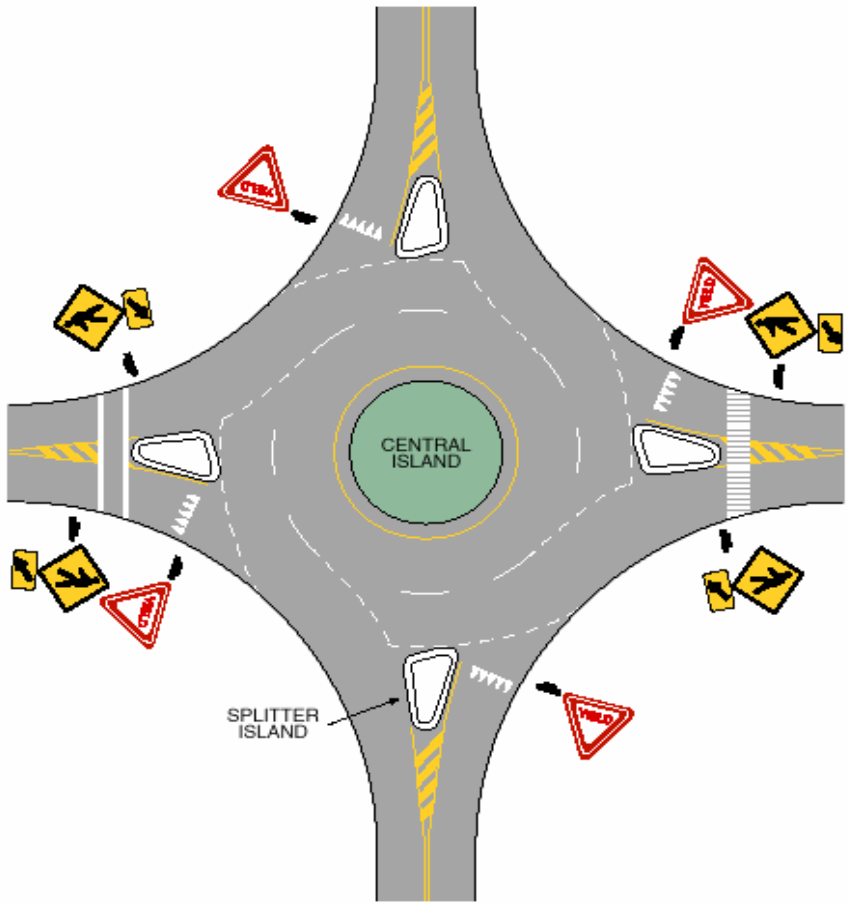
Typical Markings for Roundabouts with One Lane

Figure 3B-26. Typical Markings for Roundabouts with One Lane



Typical Markings for Roundabouts with Two Lanes

Figure 3B-27. Typical Markings for Roundabouts with Two Lanes



Guide Sign