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Morning Session

Introduction of the new
Indiana Roundabout Design Guide
IDM Chapter 51.12

Presenters

American Structurepoint, Inc

- Jeromy Grenard, PE, PTOE
- Craig Parks, PE

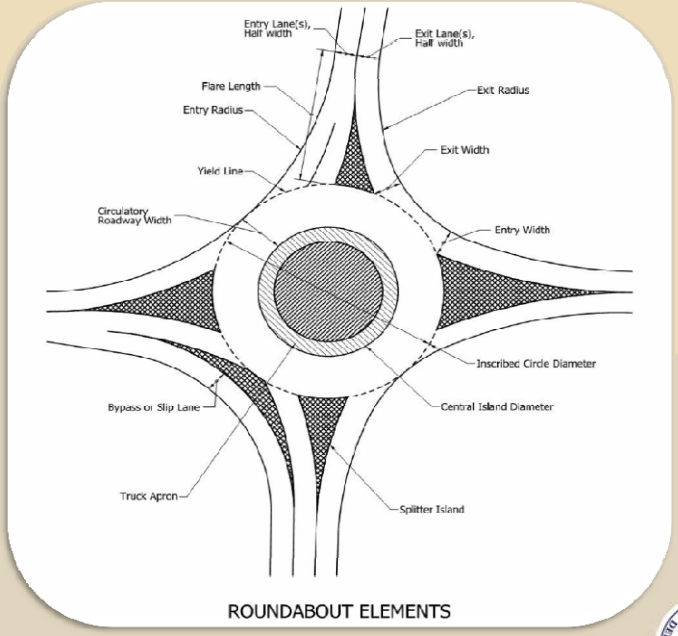
DLZ Indiana, LLC

- Wes Butch
- Haseeb Ghumman, PE, PTOE

Introduction
51-12.01

Introduction

- Guidance for designers & reviewers, not standards
- Based on design principles
- Degree of flexibility for some issues
- Supplement to the FHWA Roundabout Guide
- Written for INDOT staff/consultants



ROUNDABOUT ELEMENTS

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Roundabout Types
51-12.03

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Roundabout Types

- Variety of types; Match to specific site conditions
  - Mini
  - Urban Compact
  - Single Lane
  - Multilane
  - Teardrop

Mini Roundabout

- Small – ICD usually 45-110 feet
- Urban areas
- Posted speeds 30 mph or less
- Very high capacity for their size
- Mountable painted central island
- Inexpensive

Mini Roundabout

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Urban Compact Roundabout

- ICD typically 80 – 110 feet
- Design vehicle often controls design
- Raised, non-mountable central island
- Used in low-speed situations (35 mph or less)
- Single or multilane

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Urban Compact Roundabout

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Single Lane Roundabout

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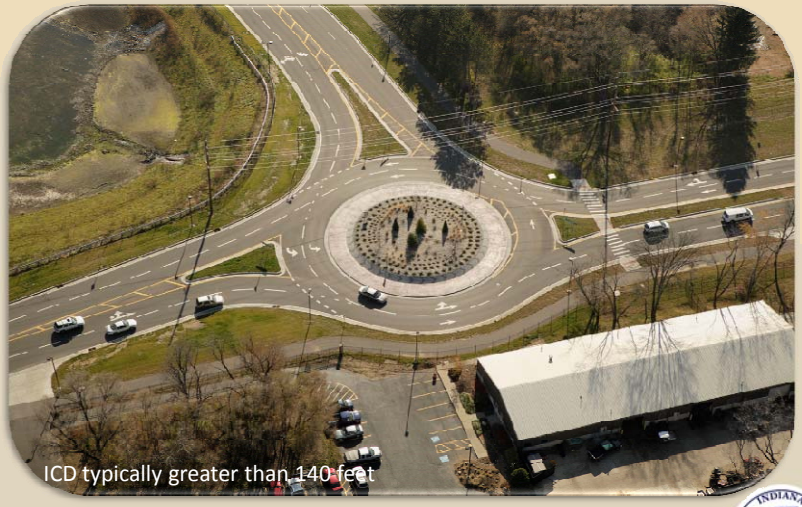
Multilane Roundabout



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Teardrop Roundabout

- Typically used at interchange ramp terminals
- Can allow for narrower/shorter bridges
- Can eliminate stacking/queuing on segment between roundabouts
- Locations where U-Turns at roundabouts are not desired or frequent

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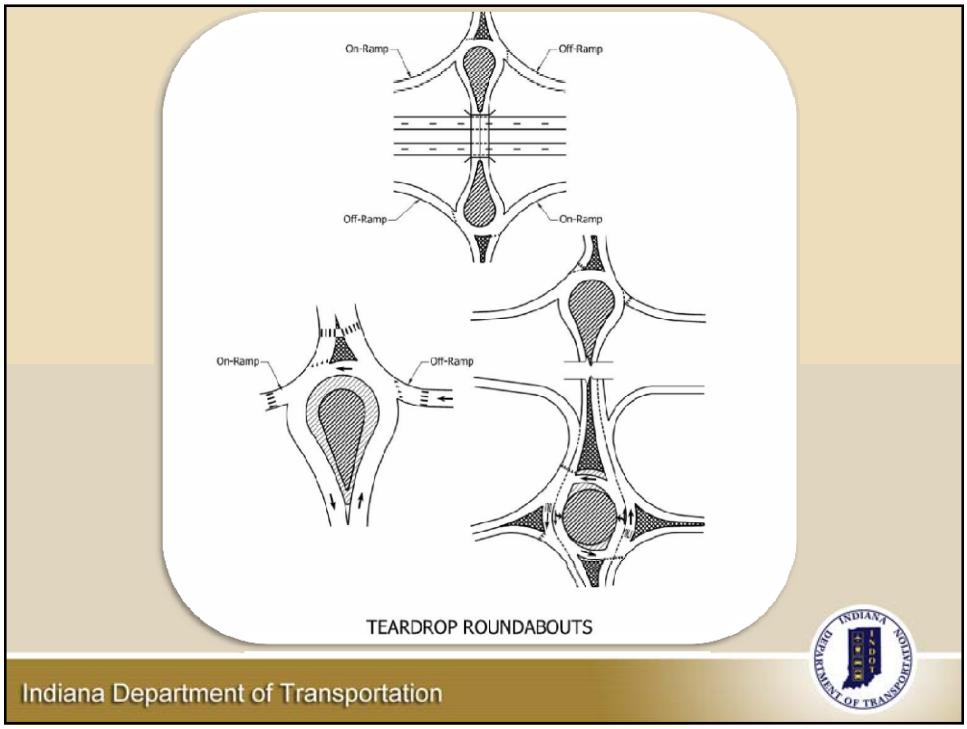

Teardrop Roundabout

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Planning
51-12.04

Planning Process

- Roundabout should be considered as one option in INDOT studies/designs
  - ✓ Data Collection
  - ✓ 20-year traffic projections
  - ✓ Capacity analysis
  - ✓ Roundabout concept design
  - ✓ Public involvement
  - ✓ Compare to other intersection types
  - ✓ Select preferred option

Typical Data Needs

- INDOT-approved design-year peak hour turning movement projections (AM/PM)
- Major off-peak traffic generators
- Design vehicle
- Electronic file of survey/aerial photo
- Right-of-way (ROW)
- Crash data (3 years), if available
- Traffic control for nearby intersections
- Major constraints near intersection
- Existing and future planned non-motorized facilities
- Truck percentages
- Accommodation of disabled persons

Evaluation Criteria

- Safety
- Capacity
- Traffic operations
- Cost
- Design life
- ROW impacts
- Ped/bike accommodations
- Aesthetics
- Interaction with nearby intersections
- Drives/access management
- Public input
- Constructability
- Traffic maintenance
- Social, economic, environmental impacts

Beneficial Locations & Applications

- High-speed rural intersections
- Intersections with crash histories
- Intersections with traffic operational problems
- Closely spaced intersections
- Intersections near structures
- Freeway interchanges
- As a part of an access management program
- Intersections with unusual geometry
- Gateway entry points
- Community enhancements
- Near schools

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High Speed Rural - Kansas

- 65 mph all approaches
- Before (2-way stop)
  - **25 inj crashes in 5 years**
- After (roundabout)
  - **3 PDO crashes in first 36 months**
  - **No inj crashes, no fatalities**

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MN High Speed Roundabout (Scott Co.)

- 55 mph all approaches, low volume
- Before (2-way stop)
  - **50 inj crashes & 2 fatalities in 5 years**
- After (roundabout)
  - **1 PDO crash in first 12 months**
  - **No inj crashes, no fatalities**

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Closely Spaced Intersections

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Fort Wayne

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Gateway Entrance

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Locations and Applications Where Care Should Be Exercised

- Intersections within a system of coordinated signals
- Intersections with steep grade
- Intersections where stopping sight distance cannot be achieved
- Intersections near railroad crossings
- Closely spaced intersections

Roundabout Operation
51-12.05

Operations

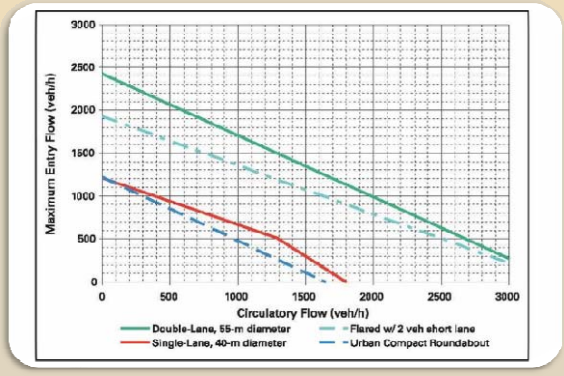
- Dependent upon geometric design and driver behavior
- Geometry intended to slow drivers
- Properly designed, drivers do not switch lanes or weave in a multi-lane roundabout

Operational Analysis Tools

- Several tools available for analyzing capacity of a roundabout
- INDOT not mandating use of a particular software
- Macro models: RODEL, aaSIDRA, ARCADY, etc.
- Micro-simulation models: VISSIM, PARAMICS, etc.

Roundabout Capacity (FHWA Guide)

Roundabout capacity is dependant on geometric features AND approach vs. circulating traffic flows.



FHWA Guide Figure 4-6
(based on extensive UK empirical data)

- Equations available in Appendix A of FHWA Guide.
- Geometric assumptions have been made in order to produce this graph

Roundabout Capacity

Roundabout Traffic Volumes

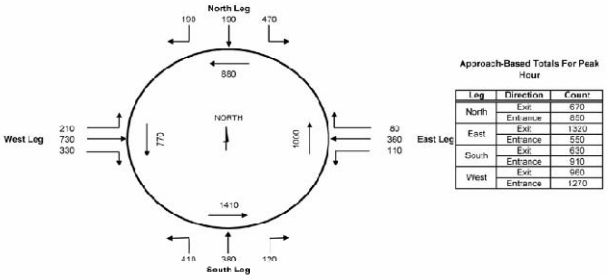
Intersection	Epiphany Avenue & Nirvana Drive
Peak Hour	PM PEAK
Analyst	TW

Base Year	2007
Forecast Year	2030
Annual Growth Rate (%)	1.50
Peak Hour Factor	0.95
Heavy Vehicle Percentage (%)	2

	South Leg			North Leg			West Leg			East Leg			
YEAR	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	HOUR TOTAL
2007	260	230	70	313	125	128	130	490	219	70	237	32	2359
2030*	410	330	120	470	190	190	210	730	330	110	360	50	3560

* Adjusted for peak hour factor and heavy vehicles.

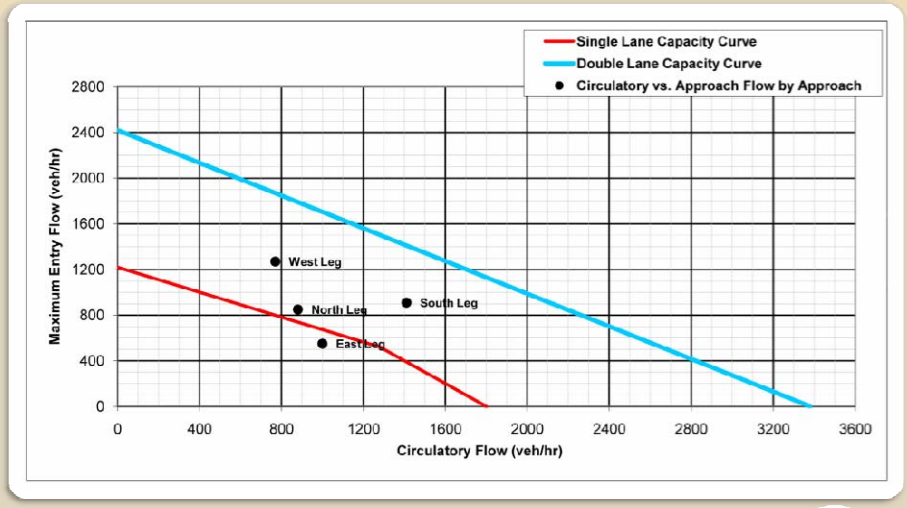
Year 2030 Traffic Volumes
Epiphany Avenue & Nirvana Drive
PM PEAK



Approach-Based Totals For Peak Hour

Leg	Direction	Count
North	Exit	670
	Entrance	880
East	Exit	1320
	Entrance	550
South	Exit	630
	Entrance	910
West	Exit	960
	Entrance	1270

Roundabout Capacity



Single-Lane Exit Capacity

- Difficult to achieve exit flow of > 1,400 vph
- Normal urban conditions: 1,200 to 1,300 vph
- If exit volumes > 1,200 vph: could signify a need for a multilane exit

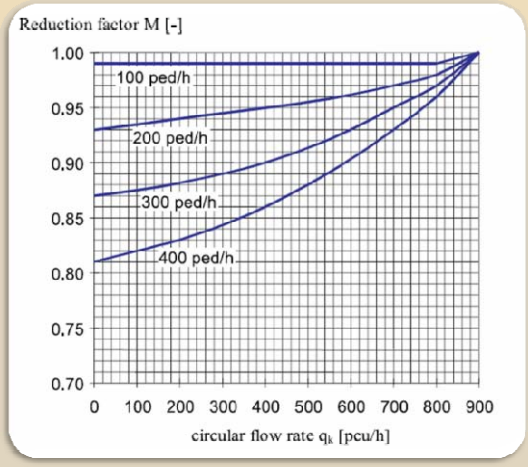
Truck Effects on Capacity

Vehicle Type	Passenger Car Equivalent (pce)
Car	1.0
Single-unit truck or bus	1.5
Truck with trailer	2.0
Bicycle or motorcycle	0.5

Source: (6), (7)

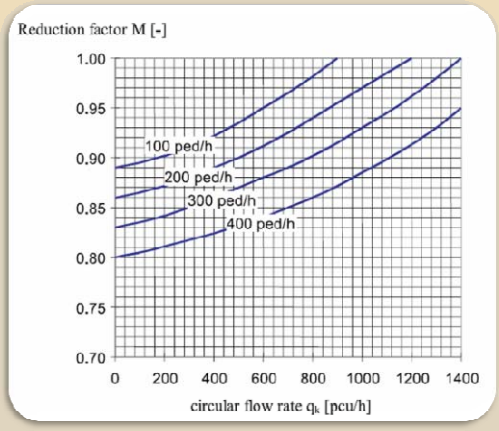
FHWA Guide Exhibit 4-1

Pedestrian Effects on Capacity Single Lane



FHWA Guide Exhibit 4-7

Pedestrian Effects on Capacity Multi-Lane



FHWA Guide Exhibit 4-8

Key Geometric Factors Influencing Capacity

- Strong effect on capacity
  - [Effective] Entry width
  - Flare length
  - Entry angle
  - Inscribed circle diameter (ICD)
- Little effect on capacity
  - Entry radius (provided it is 65 feet or larger)

Key Factors Influencing Capacity

- Lane use balance
  - Designer should strive for lane use balance on each approach
  - If lane balance not possible, capacity analysis should be performed on a lane-by-lane basis
- Right turn bypass lane
  - Use of right turn bypass lane can increase capacity if there are a high percentage of right turning vehicles
  - Use caution if a pedestrian crossing is present

Roundabout Safety
51-12.06

Safety

Valparaiso – SR 130/LaPorte Avenue/Sturdy Road

	2 years preceding construction	2 years following construction	% change
Total # of crashes	50	47	-6%
# Personal Injury crashes	17	6	-65%
Total injuries	24	8	-67%

Source: INDOT LaPorte District

Safety

Carmel – from 2002 to 2006

% of crashes with injury, all intersections: 29%

% of crashes with injury, single-lane roundabouts: 4%

% of crashes with injury, multi-lane roundabouts: 7%

Data source: City of Carmel

Accident Damage Cost Savings

Cost of accident damages is less at roundabouts than traditional signalized intersections

Intersection	Avg. Cost of Damages
96th Street *(signal)*	$13,600
116th Street *(signal)*	$7,300
126th Street *(RAB)*	$2,500
131st Street *(RAB)*	$2,500

Data source: Carmel Police Department - 2006

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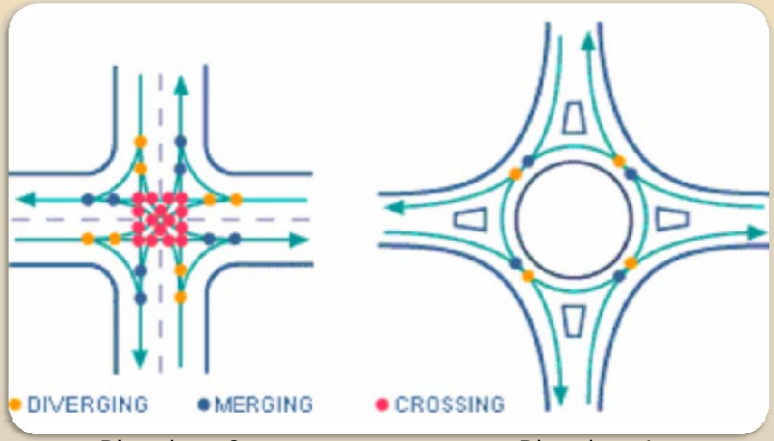
Vehicular Conflict Points



Diverging:	8
Merging:	8
Crossing:	16
TOTAL:	32

Diverging:	4
Merging:	4
Crossing:	0
TOTAL:	8

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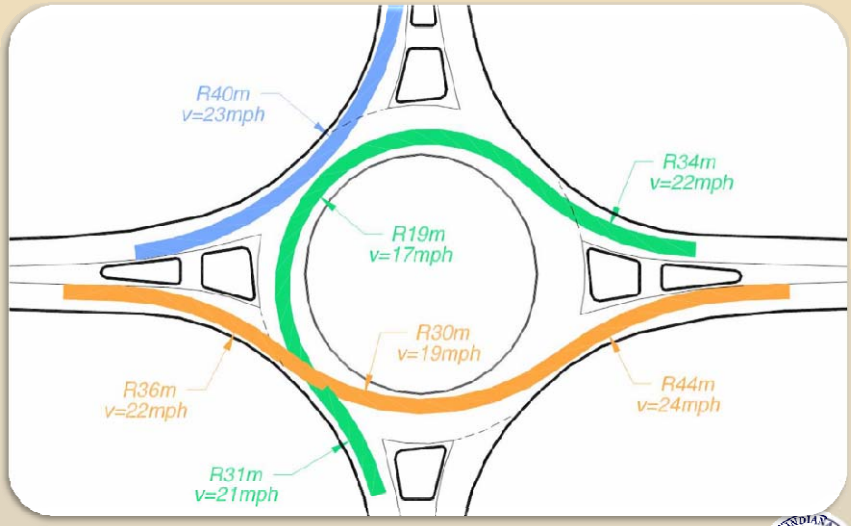
Speed Reduction



Source: FHWA Design Guide

Pedestrian Fatality in Pedestrian/Vehicle Crash

Vehicle Speed	Odds of Pedestrian Death, Source 1	Odds of Pedestrian Death, Source 2
20 mph	5%	5%
30 mph	45%	37%
40 mph	85%	83%

Source 1: Limpert, Rudolph. Motor Vehicle Accident Reconstruction and Cause Analysis. Fourth Edition. Charlottesville, VA. The Michie Company, 1994, p. 663.
Source 2: *Vehicle Speeds and the Incidence of Fatal Pedestrian Collisions,* Austrailian Federal Office of Road Safety, Report CR 146, October 1994, by McLean AJ,Anderson RW, Farmer MJB, Lee BH, Brooks CG.

Geometric Principles That Maximize Safety

1. Minimize
   - Entry widths
   - Circulatory roadway width
   - Inscribed circle diameter (ICD)
   - Number of lanes
2. Entry and exit radii
   - Entry radii not too large or small
   - Exit radii not too small
3. Speeds appropriate for roundabout type

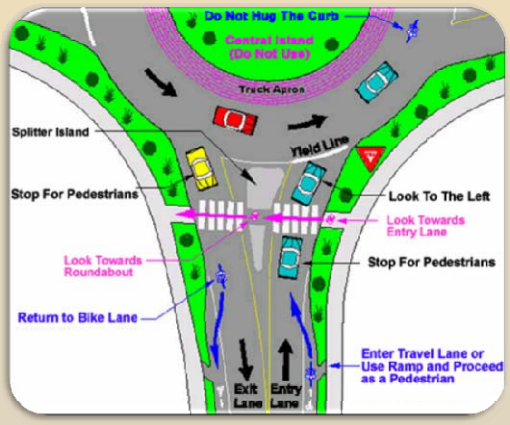
Geometric Principles That Maximize Safety

4. Entry angle between 20 and 30 degrees
5. To increase capacity, it is preferable to increase flare length than to increase entry width
6. Maximize angle between adjacent legs
7. Avoid entry and exit path overlap

Multimodal Considerations
51-12.07

Pedestrians

- Pedestrian crossings around 20 – 25’ behind yield line.
- ADA Access Board concern with accessibility for visually impaired pedestrians – research ongoing



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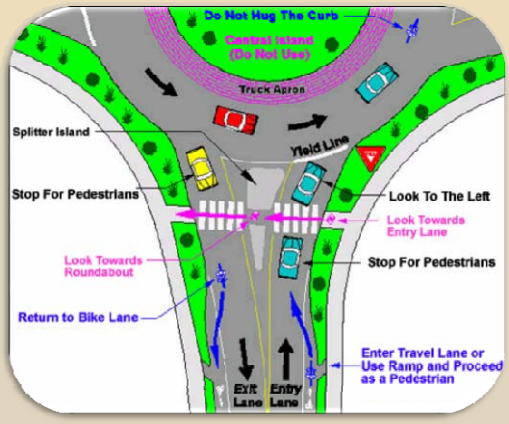
Bicycles

- Bicyclists can either merge into travel lane or exit onto ramp and proceed as a pedestrian
- Never stripe a bicycle lane in the circular roadway of a roundabout intersection!
- Why? Conflicts with turning vehicles



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Buses

- Single lane roundabout
  - Place stops on entry, in advance of crosswalk
  - If placed on exit, simulation may be used to determine if it will cause queuing into crosswalk or roundabout
- Multi-lane roundabout
  - Place stops on exit, after pedestrian crossing
  - If placed on entry, vehicles passing bus can be a threat for pedestrians in crosswalk

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Principle-Based Design Guidance
51-12.08

General Design Steps

1. Review of existing conditions
2. Review of future conditions
3. Understanding of specific design concerns
4. Performance of capacity analysis
5. Lane configuration and roundabout placement
6. Planning initial layout
7. Formalization of roundabout geometrics
8. Design-vehicle check and modifications
9. Safety and fastest path review
10. Accessorizing the design

Design Principles

- Goal: provide an operationally adequate facility with desirable safety performance
- These two objectives often competing
- Speed, capacity, and safety should be in balance
- Requires iterative design
  - Roundabout location
  - Alignment of legs
  - Entry and exit radii
  - Circulatory roadway width

Morning Session Questions and Discussion

Afternoon Session begins at 1:00 PM

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Afternoon Session

Introduction of the new
Indiana Roundabout Design Guide
IDM Chapter 51.12

Geometric Design
51-12.09

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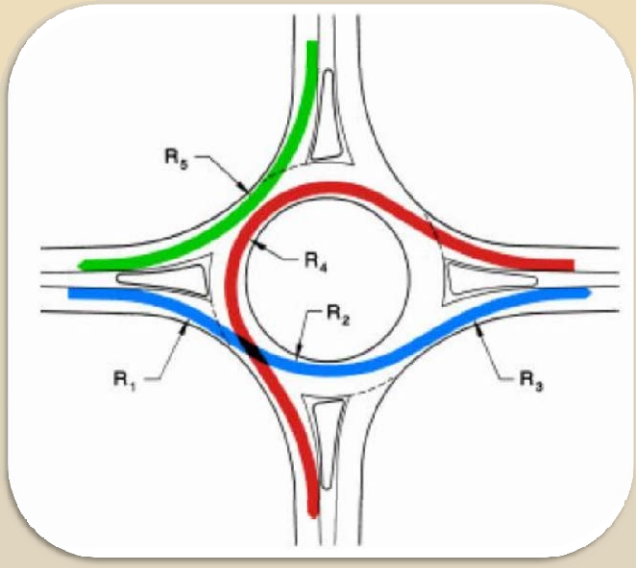
Geometric Design

- FHWA Roundabout Guide Ch 6
- New edition of FHWA Guide out later in 2010
- INDOT Guide has supplemental information, not in current FHWA Guide

Controlling Speeds

- **Essential to proper roundabout design!**
- Speeds affect traffic operations and safety
- Roundabout geometry used to control speeds
- Speeds affected by geometry:
  - Entry
  - Circulating road
  - Exit
  - Right turn
- Deflection around central island is the key
- Two speed regimes:
  - Peak hour – must stay in lanes
  - Off peak – some ignore lane markings
- Radii on the fastest possible path control speed

Controlling Speeds



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Controlling Speeds

- Curvature controls traffic speed
- Desire entry path curvature prior to yield line (R1)
- Avoid deceleration inside roundabout
- Avoid too much deceleration - all the benefits achieved at about 20 mph
- Over deceleration of entering traffic:
  - Reduces capacity
  - Causes entry path overlap
  - Causes approach crashes
- Typically control R1 so it is within 12 mph of R4
  - Usually minimizes Entry-Circulating Crashes
- Draw fast path in CAD using spline - detailed instructions in 51-12.09(03)
- FHWA Guide offsets incorrect:
  - Use 3’ from painted centerlines, 5’ from curb faces
- On multilane designs, control of R1 must not cause entry path overlap

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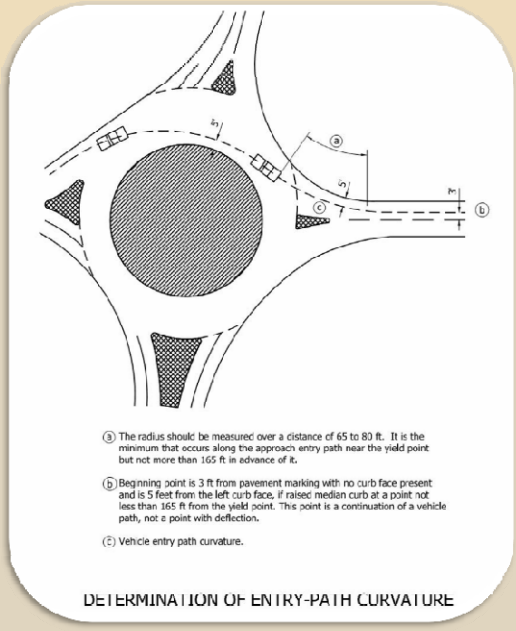

ⓐ The radius should be measured over a distance of 65 to 80 ft. It is the minimum that occurs along the approach entry path near the yield point but not more than 165 ft in advance of it.

ⓑ Beginning point is 3 ft from pavement marking with no curb face present and is 5 feet from the left curb face, if raised median curb at a point not less than 165 ft from the yield point. This point is a continuation of a vehicle path, not a point with deflection.

ⓒ Vehicle entry path curvature.

DETERMINATION OF ENTRY-PATH CURVATURE

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Speed Consistency

- Relative difference between consecutive and conflicting movements should be 12 mph or less
- R1 vs R4
- R1 vs R2 vs R3
- R1 and R2 typically control exit speeds, not R3

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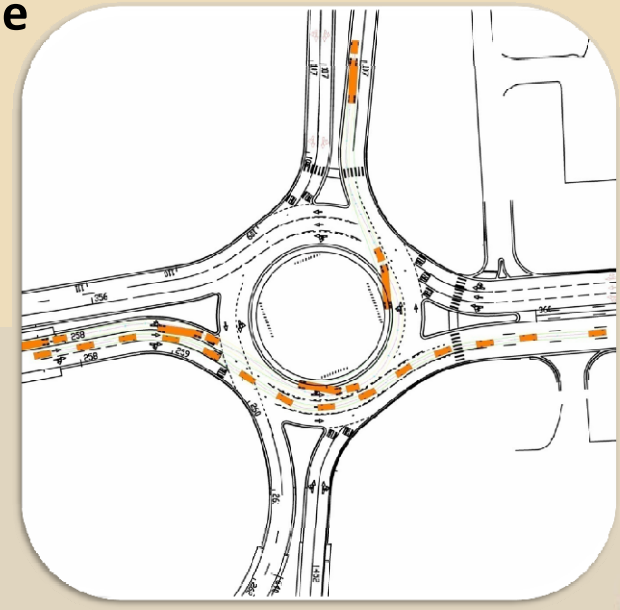
Design Vehicle

- WB-65 is standard
- Consider farm equipment, permitted loads, etc.
- Truck apron
- ICD/Entry/Circulating/exit widths
- Can control at single lane roundabouts
- Trucks in lane vs. overlapping at multilane roundabouts – debated nationwide

Trucks

- Geometry must accommodate design vehicle
- Use software to view swept path of design vehicle (e.g., Autoturn, Autotrack)
- Adjust geometry if needed
- May lead to different curb and pavement markings on splitter island

Example



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Design Vehicle

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Design Vehicle

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Design Vehicle

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Geometry

- General ranges
- Entry Radius
  - Single lane: 50’-80’
  - Two lane: 70’-100’
  - Three lane: 80’ – 120’
- Entry widths (curb face to curb face)
  - Single lane: 15’ – 22’
  - Two lane: 22’ – 28’
  - Three lane: 33’ – 40’
- Exit widths similar

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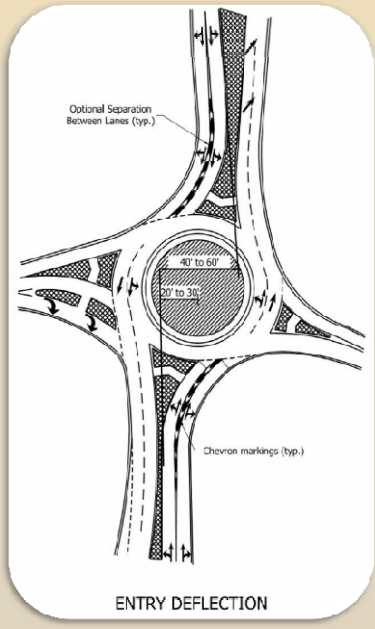
Geometry

- Circulating widths
  - Single lane: 18’ – 25’
  - Two lane: 30’ – 34’
  - Three lane: 42’ – 48’
- Splitters
  - Generally 50’ long
  - Extend until exit curvature completed
  - At least 6’ wide at narrowest part of ped xing
- There are exceptions to every one of these!
- No substitute for experience and judgment

Inscribed Circle Diameter

- Mini – 40’ to 110’
- Urban compact – 80’ to 110’
- Single lane – 100’ to 140’
- Two-lane – 140’ to 180’
- Three-lane – 215 ‘ to 275’
- Rural Single or Multilane roundabouts will have larger ICD.



ENTRY DEFLECTION

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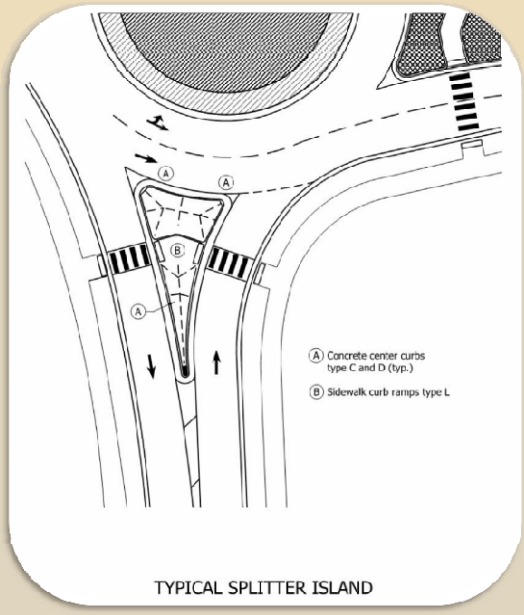

TYPICAL SPLITTER ISLAND

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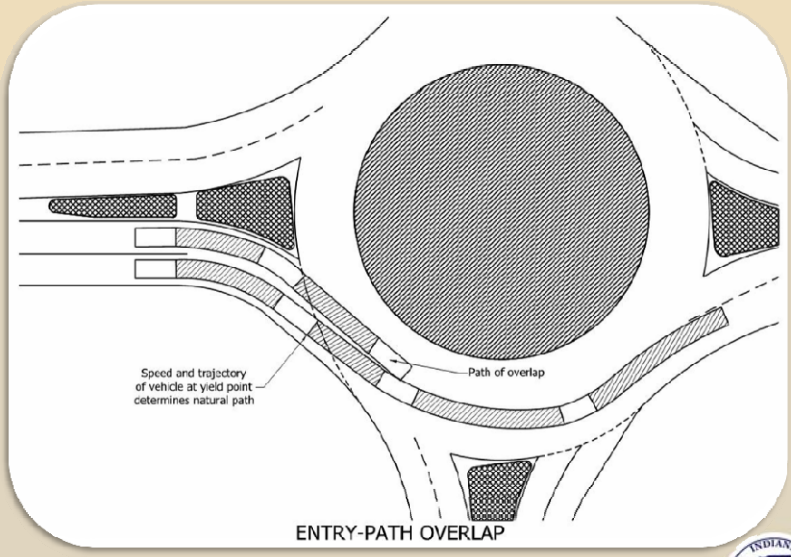
Bypass Lanes

Entry Design

- **Extremely important for multilane roundabouts!**
- Path overlap is somewhat subjective
- Debate over overlap:
  - entry is curvilinearly tangential to central island
  - Motorist is pointing into correct circulating lane at yield line
- Very complicated issue
- Not enough data to prove one is correct
- Both can work – case by case
- Controlling R1 while avoiding overlap – very challenging often conflict

Entry Design



ENTRY-PATH OVERLAP

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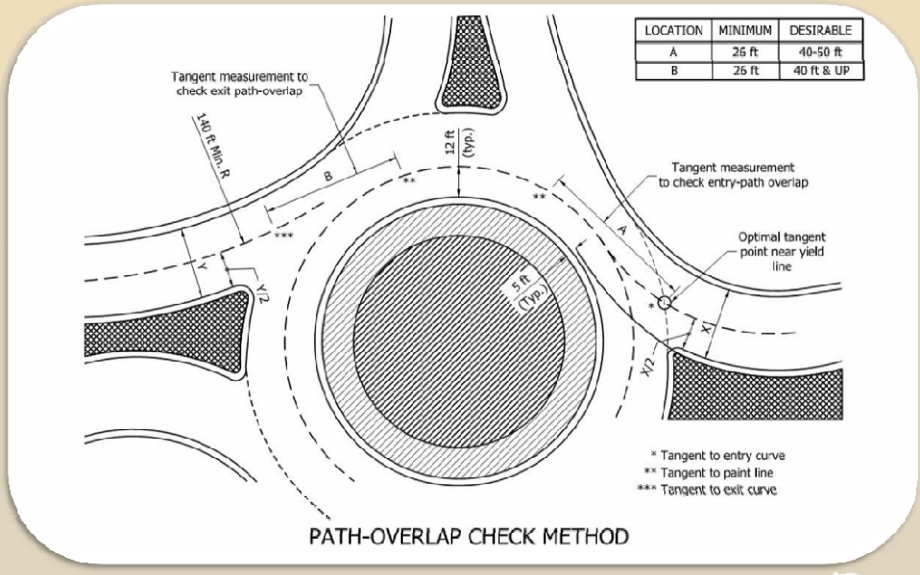

LOCATION	MINIMUM	DESIRABLE
A	26 ft	40-50 ft
B	26 ft	40 ft & UP

PATH-OVERLAP CHECK METHOD

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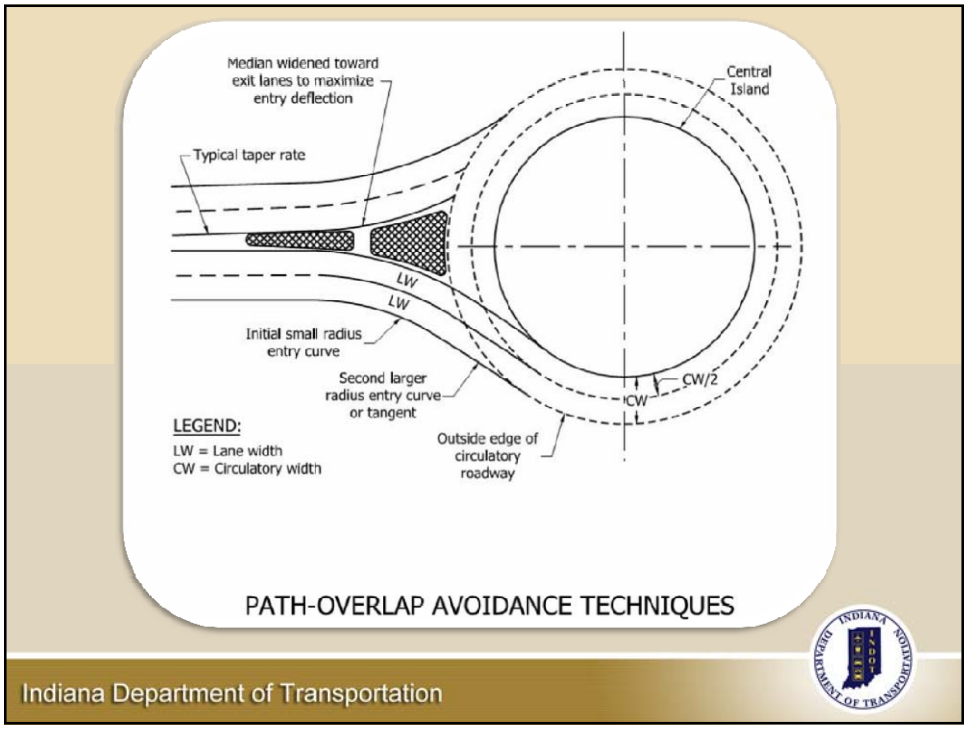
Median widened toward exit lanes to maximize entry deflection
Central Island
Typical taper rate
LW
LW
Initial small radius entry curve
Second larger radius entry curve or tangent
CW/2
CW
LEGEND:
LW = Lane width
CW = Circulatory width
Outside edge of circulatory roadway
PATH-OVERLAP AVOIDANCE TECHNIQUES
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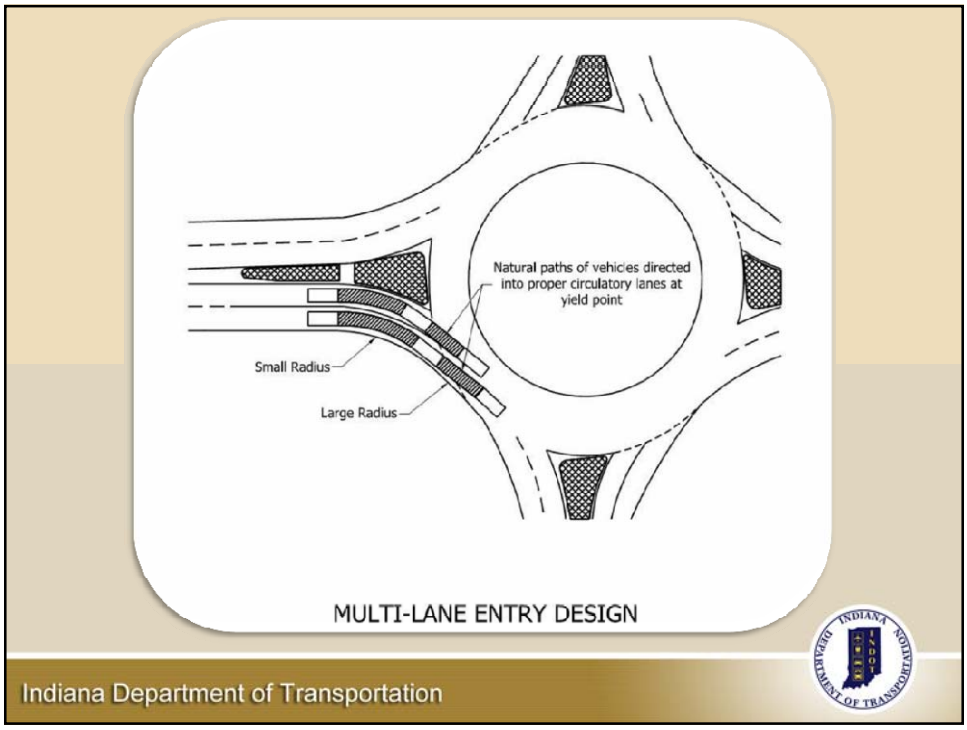
Natural paths of vehicles directed into proper circulatory lanes at yield point
Small Radius
Large Radius
MULTI-LANE ENTRY DESIGN
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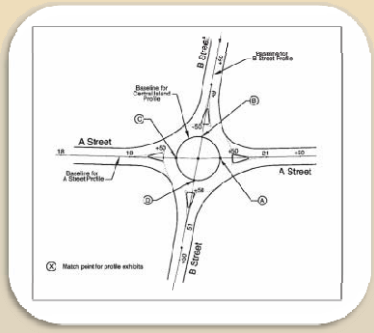
Exit Design

- Do not use tight radii
- Provide smooth path out to avoid overlap
- Use 35 MPH design speed on exit taper if merging from two to one lane

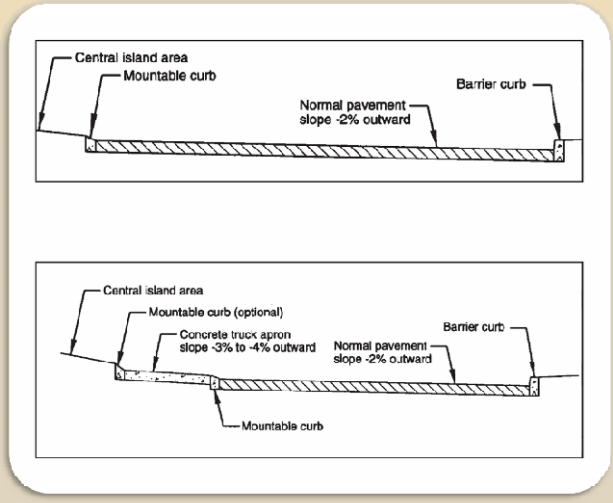
Vertical Alignment

- Section 12.09(16) refers designers to FHWA Guide, Section 6.3.11
- Iterative process
- Generally, profile of central island will result in a sine curve
- FHWA Figures 6-35 & 6-36 include example profiles



FHWA Fig. 6-34

Typical Sections



FHWA Fig. 6-37 & 6-38

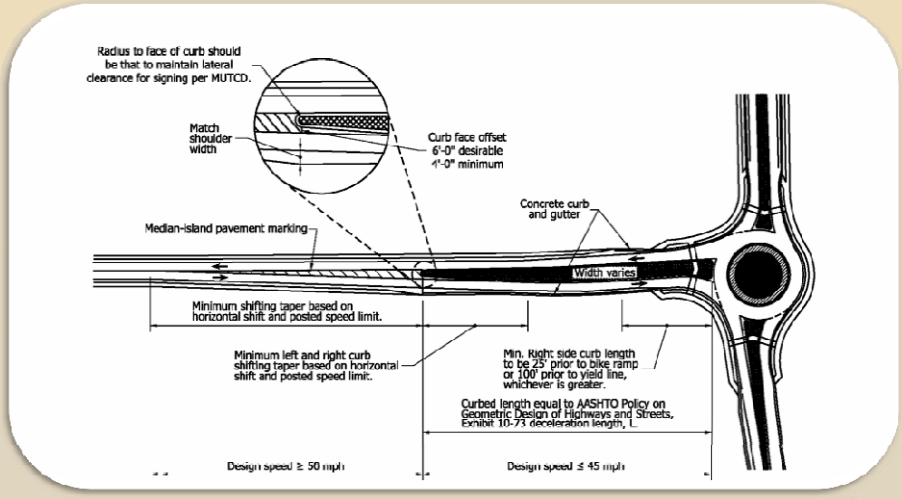
Clear Zone

- Dependent on approach speed, fastest path speed, and AADT
- Refer to IDM Section 49-2.0 & AASHTO Roadside Design Guide
- Clear zone will vary throughout roundabout
- In areas of curb & gutter, clear zone will still be 10’ from edge of travel way
- Follow IDM Chp. 49 for sideslope requirements

Approach Curbs

- Low speed portions (i.e. splitter islands) should include a standard 6” curb
- High speed rural approaches will require transition from shoulder section to vertical curb section
- IDM Figure 51-12QQ illustrates the transition from high speed to low speed elements

Approach Curbs

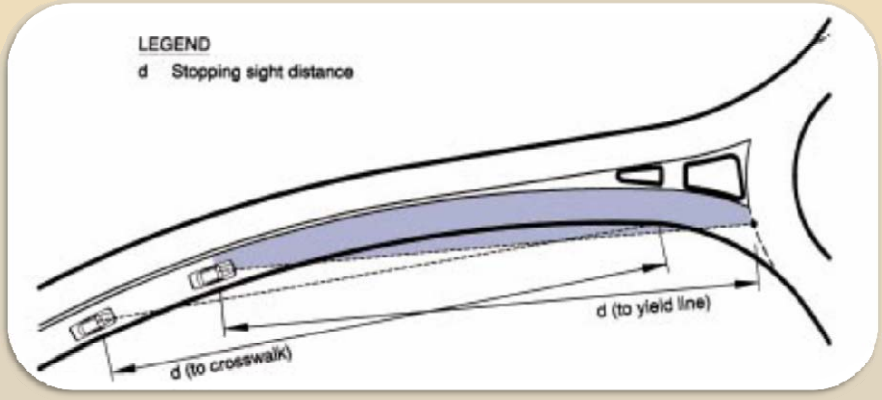


IDM Figure 51-12QQ

Stopping Sight Distance

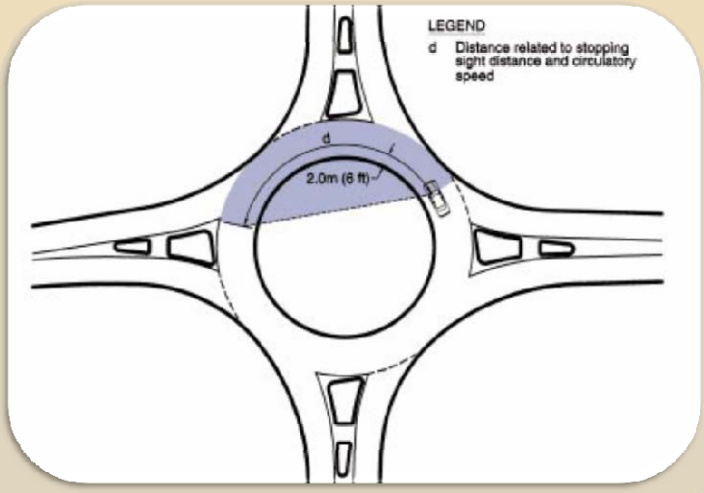
- FHWA Roundabout Guide, Section 6.3.9
- Designers should check:
  - Approach sight distance
  - Circulatory roadway sight distance
  - Sight distance to the crosswalk

Approach Sight Distance



FHWA Figure 6-29

Circulatory Roadway Sight Distance



FHWA Figure 6-30

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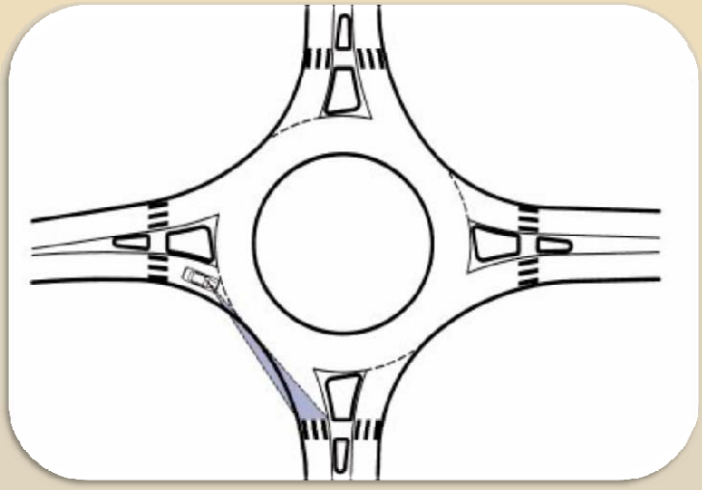
Sight Distance to Crosswalk



FHWA Figure 6-31

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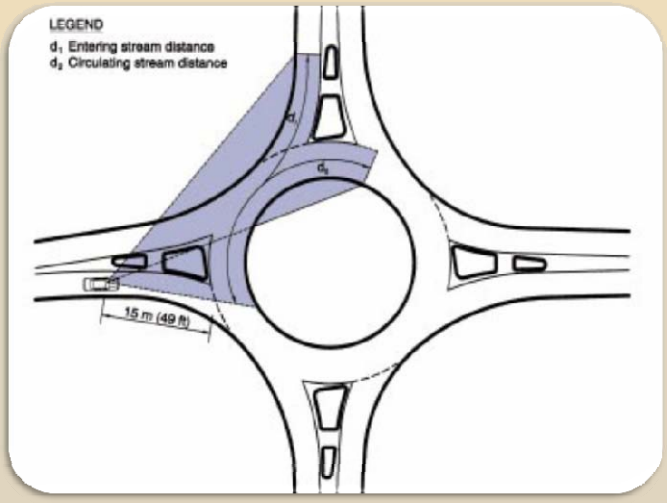
Intersection Sight Distance

- FHWA Roundabout Guide, Section 6.3.10
- Ideal to only provide that which is necessary
- Measure on travel path of vehicles – not in a straight line

Intersection Sight Distance



FHWA Figure 6-32

Sight Distance

- Restricting visibility at a roundabout can reduce the possibility of a crash
  - Reduce left visibility until driver is 50’ from yield line
  - Raising the central island
- Restrictions should not interfere with approach SSD or ISD

Landscaping Considerations

- Landscaping should be placed to maintain SSD and ISD, but can be placed to purposely reduce sight lines across roundabout
- Draw sight lines to determine areas that can be landscaped
- Refer to FHWA Section 7.5 for additional information on landscaping

Bicycle Provisions

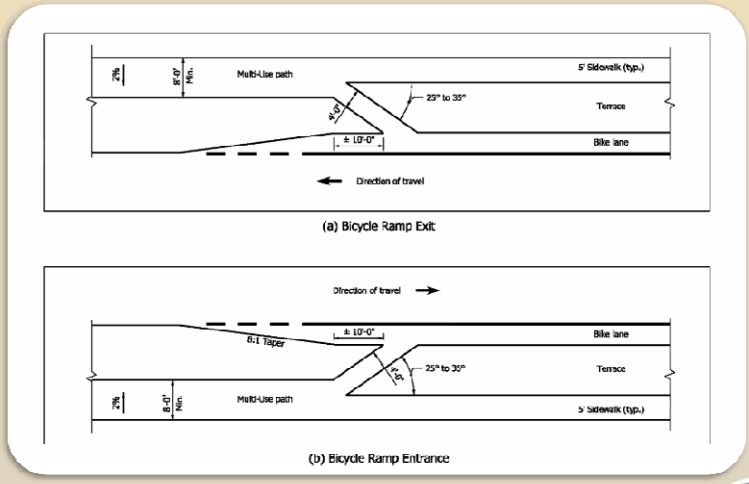
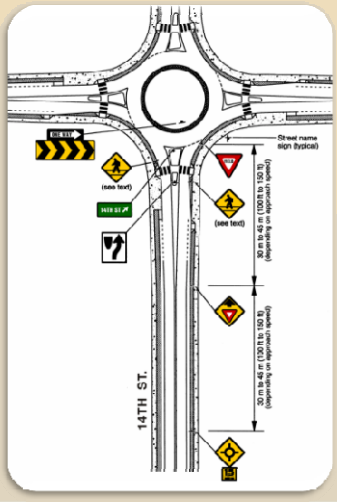


Figure 51-12W

Traffic Control Design
51-12.10

FHWA Advanced Signage Guide



- Sign clutter is often a complaint
- Signs can be reduced in certain areas

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Typical Regulatory Signs

Yield Sign

Can be supplemented with R1-54

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Typical Regulatory Signs

One Way Sign w/ Chevron

- Placed In Central Island in clear view of approaching vehicles
- Recommend lower mounting height

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Typical Regulatory Signs

Lane Indication Signs

- Used only on multi-lane approaches
- Recommend use of fishhook symbols

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Typical Warning Signs

- W2-6 "Circular Intersection Ahead"
- Contractors may want to provide a number of similar signs

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Typical Warning Signs

W2-6 can be supplemented with advisory plate and street crossing signs

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Typical Warning Signs

Yield Ahead Sign

Can be omitted in urban areas or for closely spaced roundabouts

Typical Warning Signs

Pedestrian Crossing Sign

- Only where pedestrian facilities exist
- Can be supplemented with W16-7p

Typical Guide Signs

Exit Guide Sign

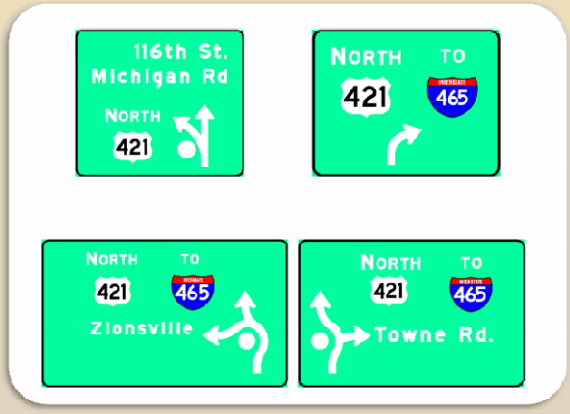
Placed in splitter island at a 45 degree angle to circulating traffic

Other Signs

Intersection Destination & Direction Signs

Bicycle Sign Assemblies

Other Signs



Overhead Lane-Use Signs

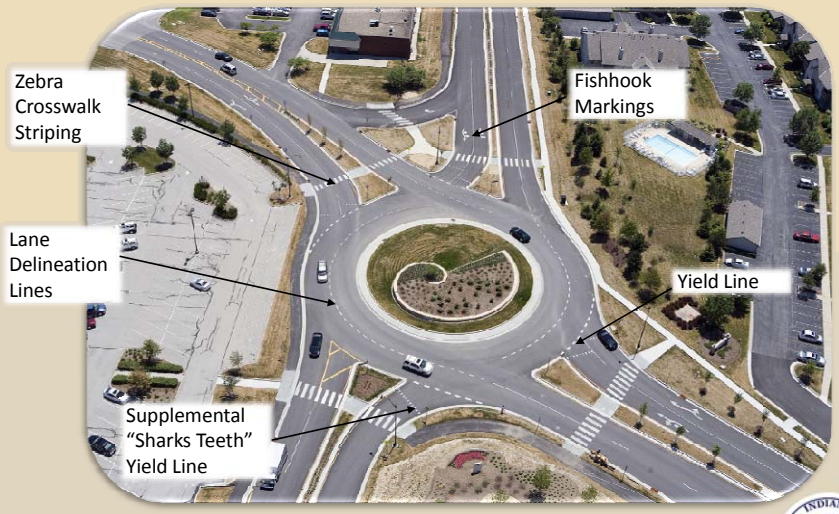
Pavement Markings

- FHWA Guide includes striping for single lane
- Neither FHWA or Millennium MUTCD include valuable information on multi-lane roundabouts
- NCUTCD Guidelines can be used as long as they don't conflict with FHWA

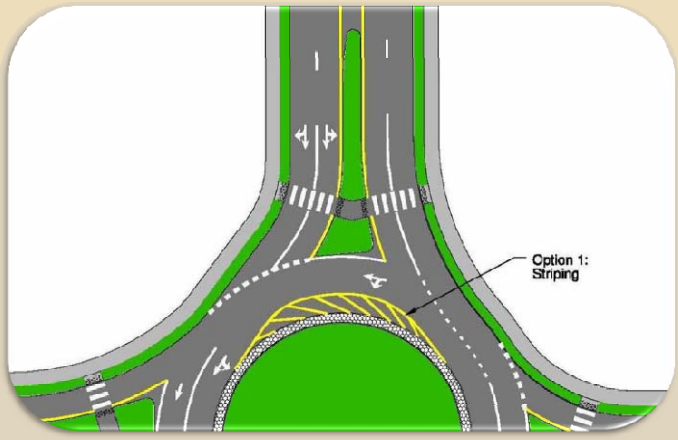
Pavement Markings

- Pavement markings should be an integral part of geometric design
- Minimize Lane changes within roundabout
- Should accommodate turning movement volumes

Pavement Markings



Pavement Markings



Lighting

FHWA Roundabout Guide (2000): "For a roundabout to operate satisfactorily, a driver must be able to enter the roundabout, move through the circulating traffic, and separate from the circulating stream in a safe and efficient manner. To accomplish this, a driver must be able to perceive the general layout and operation of the intersection in time to make the appropriate maneuvers. Adequate lighting should therefore be provided at all roundabouts."

Lighting

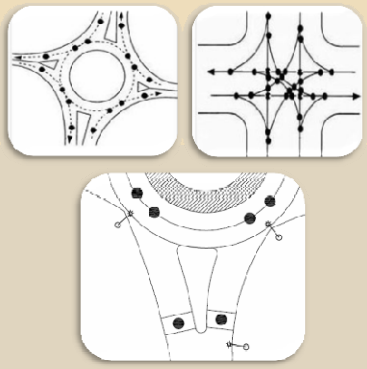
- Present guidance and resources
  - IDM Chapter 78
  - AASHTO (Roadway Lighting Design Guide)
  - IESNA (DG-19-08)
- Urban areas
  - Improve visibility of pedestrians and bicyclist
  - Be careful not to backlight pedestrians
  - Transition speed areas

Where to Consider Lighting

- Urban Areas
  - Improve visibility of pedestrians and bicyclists
  - Transition speed areas
- Suburban Areas
  - One or more approaches are illuminated
  - Competing non-roadway illumination
  - High night time volumes
  - Pedestrians
- Rural Areas
  - Retroreflective markings and signs

Conflict Points and Luminaire Placement

- Initial Locations
  - Crosswalks
  - 45°, 135°, 225°, 315° quadrant points
- Accommodate luminaire capability, and illumination and uniformity requirements
- Consider clear zone
- Evaluate arm lengths



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Work-Zone Traffic Control

- Full Intersection Closure is quickest and least expensive
  - Must have a detour route available
  - Typical closure time 45 days
- Partial Access can be maintained
  - Extends time of construction
  - Can be accomplished in many variations

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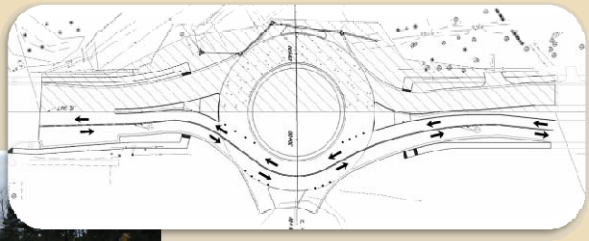
Work-Zone Traffic Control

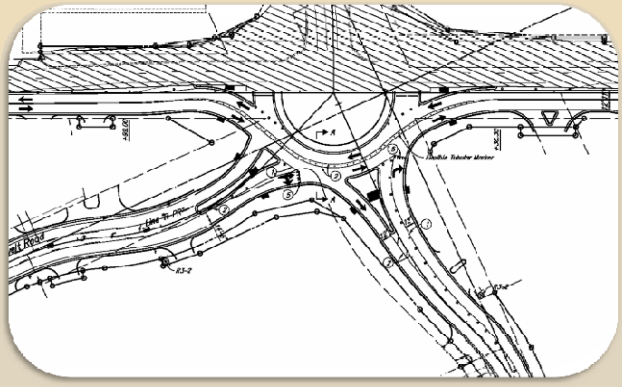
- Traffic routing during construction
  - Counterclockwise encouraged to train drivers
  - Other methods can be utilized if no other way

Example of Phased Construction



- Use tightly spaced barrels
- Not recommended in areas new to roundabouts

Example of Phased Construction



Use tubular markers to delineate lane usage

Public Involvement
51-12.11

Roundabout Education

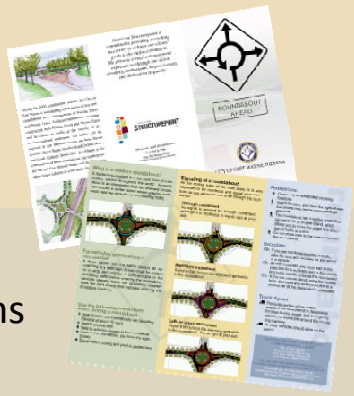
- There is no such thing as too much education
- Use safety benefits and data to explain implementation of roundabouts
- Implementation and realized benefits make believers out of naysayers

Public Involvement Techniques

- Websites

Public Involvement Techniques

- Websites
- Flyers
- Newspaper Articles
- Presentations
- Drivers Education Programs



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Roundabout Education

- Change is hard
- Before installation, up to 80% of public may be opposed to roundabouts
- After installation, approval rating of roundabout is typically 80%
- Be prepared for a learning curve

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Afternoon Session Questions and Discussion

Thank you for attending!

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