Roundabout Prequalification Training

Presenters

American Structurepoint, Inc.
- Jeremy Grenard, PE, PTOE
- Craig Parks, PE

Why Roundabouts?
- Everybody else is building them?
- They look cool?
- Circles are better than squares?
- We want to be like the Europeans?
SAFETY!

- According to the Insurance Institute of Highway Safety (IIHS), more than 800 people die and over 200,000 are injured in the U.S. each year in crashes that involve red light running.
- In 2000, the IIHS found that roundabouts had 79% fewer accidents with injuries than ordinary intersections.
- Since 2000, IIHS has issued a total of five reports promoting the use of roundabouts.

Speed Reduction

Vehicular Conflict Points
Type of Crashes

- Typical 4-leg intersection
  - Angle
  - Left turn
  - Sideswipe

Why Roundabouts?

- INDOT desires roundabouts to be considered for any intersection improvement project
- Another tool in the toolbox
- Not always the answer, but often you'll be surprised!

Why Prequalification?

- Proven safety measure
- INDOT desires roundabouts to be considered in your planning process
- Sound design plays a major role in the function of a roundabout
- Understanding the important parameters of roundabouts is crucial to sound design.
What makes a Modern Roundabout?

- Smooth Exit
- Deflected Entry
- Diameter 100'-220'
- No Pedestrians in Center
- Yield on Entry

Definitions

- Circulatory Roadway
- Splitter Island
- Exit
- Central Island
- Approach

INDOT Roundabout Design Policy

- FHWA Guide (NCHRP 672)
- 2009 MUTCD (pavement markings and signage)
- HCM 2010 (operations)
- IDM Chapter 51-12.0 (written prior to NCHRP 672)
- Soon to be replaced by IDM 305-5.0 (supplement to NCHRP 672)
Roundabout Design Checklist

**Purpose:** To provide guidance to designers and reviewers on many of the major items to be considered during the design of roundabouts

- Not a comprehensive list nor a set of hard and fast rules
- Documentation is critical for reviewers to understand the designer’s intentions
- Diverging from the ranges outside of the desirable ranges shown is acceptable but needs to be justified with design documentation

Roundabout Design Checklist

- Divided into four major categories
  - Planning
  - Design Documentation
  - Roundabout Design
  - Design Plans

- Designers should submit completed checklist and documentation with all roundabout submittals
Roundabout Planning
Scoping and Justification of Alternatives

“A comparison of roundabout practicality/feasibility vs. other intersection types should be conducted, taking into consideration safety, traffic operations, capacity, ROW impacts, and cost.”

Roundabout Planning
Evaluation Criteria

- Operations
- Safety
- R/W impacts
- Construction cost
- User costs
- Constructability
- Public input
- Maintenance of traffic
- Noise and environmental impacts

Roundabout Planning
Locations Where Roundabouts Can Be Beneficial

- High-speed rural intersections
- Locations with mediocre/poor crash history
- Locations with traffic operational problems
- Closely spaced intersections
- Near structures, including freeway interchange ramps
- Access management
- Gateway or transition locations
- Where community enhancement is desired
- Near schools
- Corridors
NCHRP currently performing research to analyze roundabout corridors.

Our experience: work very well when all roundabouts are operating under capacity.

No need to coordinate timings.

Every vehicle on every approach must slow down to enter the roundabout.

Slower speeds increase motorist and pedestrian safety.

Locations Where Roundabouts Can Be Beneficial - Corridors:

- Within a system of coordinated signals
- On a steep grade
- Where stopping sight distance cannot be achieved
- Near rail crossings
- Near a signalized intersection

Memo or report with the following, where applicable:

- Traffic volumes and crash history
- 20-year traffic projections
- Capacity analysis
- Conceptual geometric design
- Public involvement
- Comparison to other intersection types, including "Do Nothing"
- Crash analysis
- Selection of preferred option
Roundabout Planning
Traffic Data

- 20-year forecasts
- Consider staged construction
  Interim year analysis required
- Turning movements critical
  Roundabout capacity dependent on approach
  and conflicting circulating traffic

Roundabout Planning
Traffic Data - Calculating Volumes

Roundabout Planning
Capacity Analysis - Tools

Capacity Analysis (Macroscopic):
- RODEL / ARCADY
- SIDRA Intersection
- Equations from FHWA Roundabout Guide
- Equations from NCHRP Report 572 “Roundabouts in the United States” (published in 2007)
- HCM 2010 (HCS 2010, Synchro, SIDRA, etc.)

Simulations (Microscopic):
- Vissim
- Paramics
- Others
Roundabout Planning
Capacity Analysis - Tools

- Roundabout geometric features used in design should match those in the capacity analysis if a capacity model with geometry inputs is being used (ARCADY, RODEL, SIDRA)
- Learn the theory, limitations, and strengths of the software that you are using!

Roundabout Planning
Capacity - Approach vs. Circulating Flow

Roundabout Planning
Capacity - Rules of Thumb

- Single-lane roundabouts – up to 25,000 vpd
- Two-lane roundabouts – up to 40,000 vpd
- Three-lane roundabouts – in excess of 55,000 vpd
- Highly dependent upon turning movement percentages
- Rule of Thumb -> Single lane approach volume = 1,100 – 1,200 vph
Roundabout level of service is similar to that of an unsignalized intersection.

<table>
<thead>
<tr>
<th>Control Delay (seconds)</th>
<th>Level of Service to Volume to Capacity Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-10</td>
<td>A</td>
</tr>
<tr>
<td>10-15</td>
<td>B</td>
</tr>
<tr>
<td>&gt;15</td>
<td>C</td>
</tr>
<tr>
<td>25-35</td>
<td>D</td>
</tr>
<tr>
<td>&gt;35</td>
<td>E</td>
</tr>
<tr>
<td>50-60</td>
<td>F</td>
</tr>
</tbody>
</table>

* For approaches and intersections with two or more entry and exit directions, LOS is defined only by control delay.

Level of service should meet the IDM thresholds for different facility types. (Currently Chapters 53-56)

Calculated queue lengths should not cause blocking of nearby drives or intersections (95th percentile queue length).
Slide 29

**J G1**  Added slide
Jeromy Grenard, 7/10/2013

Slide 30

**J G2**  Added graphics
Jeromy Grenard, 7/10/2013
Design Documentation
Speeds Appropriate / Fastest Paths

- Definitions of paths per FHWA Guide
- Refer to NCHRP 872 Sections 6.7.1 and 6.7.2
- R1-R2-R3 movement is typically fastest path

Design Documentation
Speeds Appropriate / Fastest Paths

**Speeds - Fastest Path**

- FHWA Guide provides this illustration to create these paths and graphs to measure the resulting speeds
- Proper deflection in advance of roundabout will negate the ability to reach R1 speed based on radius/speed tables
- Actual speed should be measured by acceleration calculations based on speeds where entry is the limiting factor

Design Documentation
Speeds Appropriate / Fastest Paths

<table>
<thead>
<tr>
<th>Roundabout Type</th>
<th>Recommended Fastest Path Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini Roundabout</td>
<td>20 mph</td>
</tr>
<tr>
<td>Single Lane Roundabout</td>
<td>25 mph</td>
</tr>
<tr>
<td>Multi Lane Roundabout</td>
<td>25 - 30 mph</td>
</tr>
</tbody>
</table>

- Speeds can exceed these recommendations
- Engineering judgment must be used
- Documentation must be provided
Slide 33

JG3  Table colors and formatting
    Jeromy Grenard, 7/10/2013
**Design Documentation**

**Speed Differential / Consistency**

- Desirable to have all speeds within roundabout 10mph – 15mph
- Refer to NCHRP 6.7.3.1
- Should be balanced with other roundabout needs. All variances should be explained in documentation

**Design Documentation**

**Stopping Sight Distance**

- All SSD calculations must be shown graphically
- Refer to NCHRP 6.7.3.1
- SSD is a level 1 criteria

**Design Documentation**

**Stopping Sight Distance**

- Three locations should be checked:
  - Approach sight distance
  - Sight distance on circulatory roadway
  - Sight distance to crosswalk on exit
Design Documentation
Intersection Sight Distance

• All ISD calculations must be shown graphically
• Refer to NCHRP 6.7.3.2
• ISD is soon to be a level 1 criteria
• Too much ISD can increase roundabout speeds
• Use equations found in NCHRP 672

Design Documentation
Intersection Sight Distance - Revisions to IDM

• Eye location set 50' from yield line
• Use NCHRP 672 equation 6-6 and 6-7 with $t_c = 5.0s$
• $d_1$ can be minimized to 50' behind yield line (documentation required)

Future IDM
Eqn 6-6: $d_1 = (1.468)(V_{major, entering})(t_c)$
Eqn 6-7: $d_2 = (1.468)(V_{major, circulating})(t_c)$

Design Documentation
Intersection Sight Distance - Revisions to IDM

• NCHRP 672 equation 6-6 and 6-7 with $T_c = 5.0s$
Design Documentation
Allowable Landscaping Areas

• Include an overlay of graphical checks of ISD and SSD on a single sheet

• Overlays will reveal areas where landscaping height is and is not restricted

• Must perform checks even if landscaping is not part of original plans

Design Documentation
Allowable Landscaping Areas

• Splitter Island Maximum landscaping height will be 1.5’ from top of curb

• Refer to NCHRP 672 Chapter 9 for additional guidance

Design Documentation
Lighting Design

FHWA Roundabout Guide:
“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.”
ADD IN GRAPHIC

Craig Parks, 7/10/2013
• Present guidance and resources
  – NCHRP 672, Chapter 8
  – IESNA Publication DG-19-08
  – AASHTO
  – Proprietary methods and vendor assistance

• Several studies have been completed to determine the
  best lighting practices at roundabouts.
  – Approaches
  – Circulatory Roadway
  – Exits
• Light placement in advance of pedestrian facilities is
  critical
• Pavement markings, signs, and lighting designs go hand-
  in-hand

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

Lighting Design

- All roundabouts need to be lit
- Place one light in advance of each approach crosswalk
- Additional lighting at roundabouts should be considered to better illuminate the roundabouts and eliminate dark spots
- Light pollution to neighboring residents can be a concern
- Center island landscaping can incorporate uplighting for additional visibility

Roundabout Design

Geometry

- Roundabout geometry plays a major role in the capacity and safety of the roundabout
- Geometry of roundabout design needs to match geometry in capacity analysis
- If geometry is different than engineer’s report, designer should re-run capacity analysis

Inscribed Circle Diameter
Roundabout Design

Inscribed Circle Diameter

<table>
<thead>
<tr>
<th>Roundabout Type</th>
<th>Low End</th>
<th>High End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Lane</td>
<td>90'</td>
<td>180'</td>
</tr>
<tr>
<td>Two Lane</td>
<td>150'</td>
<td>220'</td>
</tr>
<tr>
<td>Three Lane</td>
<td>200'</td>
<td>300'</td>
</tr>
</tbody>
</table>

- Refer to NCHRP 6.3.1
- Exhibit 6-9 provides better detail of inscribed diameters
- Document rationale if larger or smaller sizes are used

Roundabout Design

Approach Alignment

- Right offset should be avoided.
- Left offset is preferred because it typically improves deflection
- Justification of right offset should be provided with documentation
- Refer to NCHRP 6.3.2

Roundabout Design

Approach Alignment

- Why is left offset preferred?
  - Desired deflection is easier to achieve
  - Can utilize a smaller circle without reducing deflection
  - Results in slower entry speeds
Changed Table colors
Jeromy Grenard, 7/8/2013
Roundabout Design
Circulatory Roadway Width

- Refer to NCHRP 6.4.3 and 6.5.3
- "Rule of Thumb" is that circulatory roadway is 100% to 120% of entry width

<table>
<thead>
<tr>
<th>Roundabout Type</th>
<th>Low End</th>
<th>High End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Lane</td>
<td>16'</td>
<td>20'</td>
</tr>
<tr>
<td>Two Lane</td>
<td>28'</td>
<td>32'</td>
</tr>
<tr>
<td>Three Lane</td>
<td>42'</td>
<td>48'</td>
</tr>
</tbody>
</table>
JG5  Changed table colors
Jeromy Grenard, 7/8/2013
Roundabout Design

Approach Radii

- Design should match the geometry used in the capacity analysis
- A wide range may be appropriate depending upon the components of the design
- Refer to NCHRP 6.4.5 and 6.5.4

<table>
<thead>
<tr>
<th>Roundabout Type</th>
<th>Low End</th>
<th>High End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Lane</td>
<td>50'</td>
<td>100'</td>
</tr>
<tr>
<td>Multi-Lane</td>
<td>65'</td>
<td>120'</td>
</tr>
</tbody>
</table>

Roundabout Design

Entry Width

- Measured perpendicular to left and right curb lines
- Refer to NCHRP 6.4.2 and 6.5.2

<table>
<thead>
<tr>
<th>Roundabout Type</th>
<th>Low End</th>
<th>High End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Lane</td>
<td>14'</td>
<td>18'</td>
</tr>
<tr>
<td>Two Lane</td>
<td>24'</td>
<td>30'</td>
</tr>
<tr>
<td>Three Lane</td>
<td>36'</td>
<td>45'</td>
</tr>
</tbody>
</table>
Slide 55

JG6  Changed table colors
Jeromy Grenard, 7/8/2013

Slide 57

JG7  Changed table colors
Jeromy Grenard, 7/8/2013
Roundabout Design
Exit Radii

- Typically 100’ to 800’
- 300’ to 600’ is desirable
- Refer to NCHRP 6.4.6 and 6.5.6
- Exit radii as small as 50’ can be used if necessary to control speeds at crosswalk
- Smaller exit radii can affect natural flow of traffic through roundabout and reduce capacity

Roundabout Design
Entry Path or Exit Overlap

- Only affects multi-lane roundabouts
- Refer to NCHRP 6.2.3
- Figure 51-22NN in current IDM illustrates how to avoid overlap
Striping and proper geometric design is crucial to achieving proper lane use!

Case Study - Entry Path Overlap

Roundabout Design
Truck Apron

Truck Apron
Roundabout Design

Truck Apron Width

- Truck apron allows large vehicles to track to the inside of the roundabout
- Minimum effective/constructible width is 3’, minimum width of 5’ is desirable
- No maximum width – based on turning templates
- Refer to NCHRP 6.4.7.1 and 6.8.7.4
- Documentation for proper design vehicle and illustrating adequate width should be included with design submittals

Roundabout Design

Pedestrian Crossing

- Crosswalk should be placed 20’-40’ behind Yield Line (one to two car lengths)
- Refer to NCHRP 6.4.1 and 6.8.1.2
- Ample length and width of splitter island should be designed to provide a safe refuge for pedestrians
- Placement should coincide with a vehicle’s slowest speed on approach
- Pay attention to cross-slope

Roundabout Design

Pavement Markings & Signs

- Pavement markings and signs are critical to the function of roundabouts
- Pavement marking schematics should be submitted with Stage 1 plans to illustrate design intent
- Pavement markings should be designed in accordance with MUTCD 3C and NCHRP 7.3
- Signs should be designed in accordance with MUTCD 2B.43-45 and NCHRP 7.4
Roundabout Design
Lighting Structures Placement

- Lights must be located in advance of crosswalks to avoid pedestrian back-lighting
- Refer to NCHRP Chapter 8 & IESNA Publication DG-19-08
- Light poles can be placed in central island if necessary but should not be placed in splitter islands

Roundabout Design
Entry Grade Profile

- Entry grade profile should be leveled out so as not to exceed 3%
- Entry grade profile is defined as the area approximately two car lengths from the outer edge of the circle
- Refer to NCHRP 6.8.7.5
Roundabout Design

Drainage Structures

• Avoid drainage structures within circulatory roadway
• Desirable location is between circulatory roadway and curb ramps
• Primary reason for concern is maintenance difficulties
• Refer to NCHRP 6.8.7.6
• In some situations, this can not be avoided to meet spread/encroachment requirements

Design Plans

• Spot elevations and/or grading plans should be clear and concise
• Sign types and locations should be clearly defined
• Specialty pavement markings must be clearly detailed

Design Plans

• Radii should be clearly labeled
• For early plan submittals – Provide the reviewer ample information to identify the critical elements (ICD, Approach & Exit Radii, etc.)
• For Stage 3 plans - Can a contractor build the roundabout with the information provided?
Future Policy Updates

- Indiana Design Manual Updates – Soon!
  - Significantly reduced
  - Largely relies on NCHRP 672
  - Incorporated into intersections chapter 305
  - May be organized per checklist

Future Policy Updates

- Checklist modifications
  - All roundabouts will now be considered 4R
  - Adding lane drop taper requirements
  - High speed approach detail modifications

Future Policy Updates

- Clear zone definition
  - Curb offset + 4’ for interior
  - Curb offset + 6’ for perimeter
  - Clear zone transition zone on approach
  - Pedestrian signal recommendations
Common Questions

- How important is public education?
- How do you maintain traffic during construction?
- What about visually impaired pedestrians?
- Are roundabouts safe on high speed facilities?
- What about bicyclists?

Single Lane Roundabout Layout

Getting Started

- 5 step process with a foundation of designing pavement marking alignments
- Multiple iterations of these 5 steps will need to be completed to achieve the optimum geometric design
- Curbs and edges of pavement are derived by the pavement markings in accordance with the FHWA Roundabout Guide.

Disclaimer: There are many approaches to achieve a sound geometric roundabout design. This approach is just one relatively simple method we have found to work.
Single Lane Roundabout Layout

**Geometric Basics**

- Inscribed diameter
  - Typically start with 130' and adjust based on existing conditions
  - Dependent on your design vehicle
- Circulatory roadway width
  - Dependent on your design vehicle
  - Typically start with 15'-16' for a single lane roundabout
- Truck apron width
  - Dependent on your design vehicle tracking
  - Typically start with 5'
Single Lane Roundabout Layout

**Geometric Basics**

- Approach Radius
  - Typically start with 100’
  - Affects your roundabout capacity and speeds

- Exit Radius
  - Typically start with 600’
  - Affects your roundabout capacity and speeds

---

**Situation**

- Simple 90 degree intersection
- Both roadways are 2 lane roads

---

**Step 1**

- Draw center circle
- Offset for circulatory roadway width
- Draw exits
Single Lane Roundabout Layout

Step 2
Fillet centerline to inside of circulatory roadway for exits

Step 3
Fillet inside of exit lane with inside circle to create inside approach lane

Step 4
Offset inside of exit lane to match approaching lane width
Single Lane Roundabout Layout

**Step 5**
Fillet with outside edge of circulatory roadway

---

Single Lane Roundabout Layout

**Step 6**
Trim & review your geometrics

---

Single Lane Roundabout Layout

**Deflection Check**
Tangent to outside edge of approach should line up close to point where inside edge of approach intersects circulatory roadway
Single Lane Roundabout Layout

**Situation 2**
- Offset intersection
- Higher speed on east-west road

**Step 1**
- Draw center circle to maximize deflection on higher speed approach
- Offset for *circulatory roadway width*
- Draw exits
**Single Lane Roundabout Layout**

**Step 2**
Fillet centerline to inside of circulatory roadway for exits

**Step 3**
Fillet inside of exit lane with inside circle to create inside approach lane

**Step 4**
Offset inside of exit lane to match approaching lane width
Single Lane Roundabout Layout

**Step 5**
Fillet with outside edge of circulatory roadway

---

Single Lane Roundabout Layout

**Step 6**
Trim & review your geometrics

---

Single Lane Roundabout Layout

**Splitter Islands**
Once layout is complete, create splitter islands as illustrated in Exhibit 6-13 of NCHRP 672
Single Lane Roundabout Layout

**Splitter Islands**
- Where pedestrian facilities exist, the splitter island should be at least 50’
- Additional modifications to geometry may be necessary to develop required splitter island length

---

**Alterations to Geometric Layout**
- Can decrease exit radii to avoid R/W impacts or slow exiting traffic due to crosswalk.
- Be careful not to reduce exit radii too much
- Can offset centerline in Step 4 additionally to create a longer splitter island
- When a median is involved, in Step 4 you can offset the line to match the inside approach edge of the existing median

---

Multi Lane Roundabout Layout
**Multi-Lane Roundabout Layout**

**Geometric Basics**

- **Inscribed diameter**
  - Typically start with 160' and adjust based on existing conditions
  - Dependent on your design vehicle

- **Circulatory roadway width**
  - Dependent on your design vehicle
  - Typically start with 30'-31' for a 2 lane roundabout

- **Truck apron width**
  - Dependent on your design vehicle tracking
  - Typically start with 5'

---

**Multi-Lane Roundabout Layout**

**Situation**

- Skewed intersection
- East-west roadway is a 4 lane facility
- North-south roadway is a 2 lane facility
**Multi-Lane Roundabout Layout**

### Step 1
- Draw Center Circle
- Offset for Circulatory Roadway Width
- Draw Exits

### Step 2
Fillet inside of exit Lanes to inside of circulatory roadway

### Step 3
- Fillet inside of exit lane with inside circle to create inside approach lane.
- Only do this for single lane entries!
Multi-Lane Roundabout Layout

**Step 4**
- Offset inside of exit lane to match approaching lane width
- Only do this for the single lane entries!

Multi-Lane Roundabout Layout

**Step 5**
- Fillet with outside edge of circulatory roadway
- Only do this for the single lane entries!

Multi-Lane Roundabout Layout

**Desired Path of Vehicles**
- Entry Path Overlap

- Speed & Trajectory of vehicle at yield point determines natural path

- Stripping and proper geometric design is crucial to achieving proper lane use!
Multi-Lane Roundabout Layout

**Step 6**
Create tangents on two-lane approaches to prevent entry path overlap.

Multi-Lane Roundabout Layout

**Step 7**
Trim and review geometry