Roundabouts 101:
As Easy as 1-2-3

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Presentation Outline

- Overview
- Roundabout Size
- Roundabout Location
- Approach Geometry
- High Speed Environments
- Discussion
Overview

- Roundabouts are increasingly common intersection control forms.
- Safety, operations, capacity, cost effectiveness, and aesthetics are common considerations.
- Extensive national and state documentation on roundabout planning, operations, design, and safety.
- Strongly supported by FHWA; including continued applied research funding.
- Increasing public acceptance...but not always.

80 documented, programmed, or planned.
Project-Level Considerations

The level of effort to implement a roundabout is influenced by location and local history. Objectively evaluate roundabouts with the other alternatives considering:

Location
- New roadway system?
- Retrofit to existing intersection?

Local history
- First roundabout in an area?
- Roundabouts have gained acceptance?
- Bad experience in the area?

Involving key stakeholders early in the decision process
- Elected officials
- Staff from affected agencies
- General public
ICE: Common Considerations and Factors

Considerations
- Foot Print
- Traffic Operations
- Multi-modal Quality of Service
- User types
- Safety Performance
- Service Life
- Expandability
- Initial Capital Costs
- Benefit/Cost

Influencing factors
- Rural/Urban Context
- High-Speed Environments
- Intersection Forms
- Corridors versus Isolated
- Adjacent Traffic Control
- Freight Movement
- Special Vehicles
- Pedestrian and Bicyclist
- Demand
- Special user needs
Key Process Changes and Requirements

- Must consider **signal, yield and multi-way stop control** during or before completing the project initiation phase of the project development process.
- The **safety performance** characteristics must be considered when developing engineering and investment recommendations.
- The **authority** to recommend or approve yield-controlled roundabouts and single point interchanges is delegated to the Districts.
Step 1: Assessment/screening of traffic control/management strategies

- Typically part of Traffic Engineering Performance Assessment (TEPA) in support of Project Study Report/Project Development Support (PSR/PDS) process

Outcomes:
- Identify strategies that merit further consideration because they meet the control need and are practical to pursue or implement.
ICE: Two Step Process (Later project steps) – Caltrans Example

Step 2: Traffic Analysis and Engineering Studies

- Typically part of Project Approval & Environmental Documentation (PA&ED) process or Permit Engineering Evaluation Report

Outcomes:
- Traffic and Performance Analysis Findings
- Life-cycle/Investment Analysis Findings
- Future investment needed to extend life
- Multi Modal Level of Service

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Signal</th>
<th>Roundabout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations &amp; Maintenance – Lowest Cost</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Landscaping Maintenance – Lowest Cost</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Pavement Rehabilitation – Lowest Cost</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Bridge – Lowest Cost</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Crash Costs – Lowest Cost</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
Overview: As easy as 1-2-3

Roundabouts fundamentals begin with three basic elements to achieve optimal performance:
- Size
- Location
- Approach configuration

Consult NCHRP publications for more detailed guidance.

These publications are free from the web in pdf.
Other Roundabout Resources

State and local guides:
- Provide local guidance
- Allow more flexibility compared to national documents
- Share practice details

Consider other state guides as potential resources
- Materials augment national guidance
- Typically consistent with NCHRP Report 672 principles
- Examples can be confidence builders as you adapt to your conditions
Roundabouts: A performance-based approach

- **Initial Operational Analysis**
- **Other Input (env., PI)**

**Identify Initial Design Elements**

- **Single-Lane Roundabouts**
- **Multilane Roundabouts**
- **Mini-Rbts**

**Check Performance**

**Design Details and Applications**

**Iterate**
Presentation Outline

- Overview
- **Roundabout Size**
- Roundabout Location
- Approach Geometry
- High Speed Environments
- Discussion
What influences roundabout size?

- Capacity needs—Lane numbers and arrangements
- Design Vehicle
- Roadway Skew

And....

- Inscribed circle location
- Approach configuration

Hey, those last two are some of our tools to achieve optimal performance!
Determining lane numbers using planning tools

- Rules of thumb
- Simple volume relationships
- AADT-level graphs

Many times, these planning level tools support roundabout planning without the use of analytical software.

This could be enough to support ICE decisions in some cases.
Lane Numbers and Assignments

- Each entry, exit, and section of circulatory roadway should have the appropriate number of lanes, properly assigned
- Use operational analysis to determine initial lane configuration
- Refine operational analysis as design is refined
- Geometric design, signing/striping, and operational analysis need to agree
- OK to have mixture of single- and multilane entries

Having more lanes than are necessary can contribute to adverse operations and safety performance
Planning Rules of Thumb

- Roundabouts give higher capacity and lower delays than AWSC under same conditions.
- Roundabout likely to have higher delays than TWSC if TWSC is operating without problems.
- Single-lane roundabout can be assumed to operate within capacity any location where peak hour volume signal warrant not met.
- A roundabout within capacity will generally produce lower delays than signal under same conditions.
Preliminary Lane Configuration

How many lanes to serve demand?

Planning level approach: Basic assumptions:

- AADT level
- K factor of 0.09 to 0.10 (ratio of peak-hour to daily traffic)
- D factor of 0.52 to 0.58 (direction distribution of traffic)
- Ratio of minor street to total entering traffic of 0.33 to 0.50
- Acceptable v/c ratio of 0.85 to 1.00
- Proportion of left turns

Three legs: Use 75% of values
Planning-Level Daily Intersection Volumes

Exhibit 3-12, p. 3-22

Double-lane roundabout may be sufficient (additional analysis needed)

Single-lane roundabout may be sufficient (additional analysis needed)

Single-lane roundabout likely to operate acceptably

Double-lane roundabout likely to operate acceptably

Left-Turn Percentage

AADT

0 5,000 10,000 15,000 20,000 25,000 30,000 35,000 40,000 45,000 50,000
Planning-Level Daily Intersection Volumes: Mini-Roundabouts

Exhibit 3-16, p. 3-22

- AADT Capacity (vehicles)
- Percent Left Turns
- 25% Cross Traffic
- 50% Cross Traffic
### Planning-Level Volume Thresholds

<table>
<thead>
<tr>
<th>Volume Range (sum of entering and conflicting volumes)</th>
<th>Number of Lanes Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 1,000 veh/h</td>
<td>▪ Single-lane entry likely to be sufficient</td>
</tr>
<tr>
<td>1,000 to 1,300 veh/h</td>
<td>▪ Two-lane entry may be needed</td>
</tr>
<tr>
<td></td>
<td>▪ Single-lane may be sufficient based upon more detailed analysis.</td>
</tr>
<tr>
<td>1,300 to 1,800 veh/h</td>
<td>▪ Two-lane entry likely to be sufficient</td>
</tr>
<tr>
<td>Above 1,800 veh/h</td>
<td>▪ More than two entering lanes may be required</td>
</tr>
<tr>
<td></td>
<td>▪ A more detailed capacity evaluation should be conducted to verify lane numbers and arrangements.</td>
</tr>
</tbody>
</table>

Source: New York State Department of Transportation

NCHRP Report 672 Exhibit 3-14
## Comparison of Roundabout Categories

<table>
<thead>
<tr>
<th>Design Element</th>
<th>Mini-Roundabout</th>
<th>Single-Lane Roundabout</th>
<th>Multilane Roundabout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desirable maximum entry design speed</td>
<td>15 to 20 mph (25 to 30 km/h)</td>
<td>20 to 25 mph (30 to 40 km/h)</td>
<td>25 to 30 mph (40 to 50 km/h)</td>
</tr>
<tr>
<td>Maximum number of entering lanes per approach</td>
<td>1</td>
<td>1</td>
<td>2+</td>
</tr>
<tr>
<td>Typical inscribed circle diameter</td>
<td>45 to 90 ft (13 to 27 m)</td>
<td>90 to 180 ft (27 to 55 m)</td>
<td>150 to 300 ft (46 to 91 m)</td>
</tr>
<tr>
<td>Central island treatment</td>
<td>Fully traversable</td>
<td>Raised*</td>
<td>Raised*</td>
</tr>
<tr>
<td>Typical maximum service volumes</td>
<td>≤15,000 veh/day</td>
<td>≤25,000 veh/day</td>
<td>≤45,000 veh/day</td>
</tr>
</tbody>
</table>

* (may have traversable apron)

NCHRP Report 672, Exhibit 1-9
Example Planning Problem
Existing Lane Configuration (AWSC)
Example Planning Problem

- Existing AADT: 15,000 veh/day
- Assume 3% growth rate per year
- 10 Year Horizon AADT:
  \[15,000 \times (1.03)^{10} \approx 20,000\] veh/day
- 20 Year Horizon AADT:
  \[15,000 \times (1.03)^{20} \approx 27,000\] veh/day
- Assume ~20% left turns
Example Planning Problem (cont.)

AADT vs. Left-Turn Percentage Graph:

- **20% Left Turns**
  - 50,000 AADT: Double-lane roundabout may be sufficient (additional analysis needed).
  - 40,000 AADT: Single-lane roundabout may be sufficient (additional analysis needed).
  - 30,000 AADT: Single-lane roundabout likely to operate acceptably.
  - 20,000 AADT: Double-lane roundabout likely to operate acceptably.
  - 15,000 AADT: Single-lane roundabout likely to operate acceptably.

AADT values range from 0 to 50,000 with increments of 5,000.

Left-Turn Percentage ranges from 0% to 40% with increments of 10%.
Foot Print: Inscribed Circle Diameter

- Typical ranges for categories and design vehicles
- Add 50 to 60 feet (i.e. 25 to 30 feet outside ICD) for an approximate right-of-way foot print

<table>
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<th>Typical Design Vehicle</th>
<th>Common Inscribed Circle Diameter Range*</th>
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<td>SU-30 (SU-9)</td>
<td>45 to 90 ft (14 to 27 m)</td>
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<td>B-40 (B-12)</td>
<td>90 to 150 ft (27 to 46 m)</td>
</tr>
<tr>
<td></td>
<td>WB-50 (WB-15)</td>
<td>105 to 150 ft (32 to 46 m)</td>
</tr>
<tr>
<td></td>
<td>WB-67 (WB-20)</td>
<td>130 to 180 ft (40 to 55 m)</td>
</tr>
<tr>
<td>Multilane Roundabout (2 lanes)</td>
<td>WB-50 (WB-15)</td>
<td>150 to 220 ft (46 to 67 m)</td>
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* Assumes 90-degree angles between entries and no more than four legs. List of possible design vehicles not all-inclusive.

NCHRP Report 672 Exhibit 6-9
Planning Level “Foot Print” and impacts

25’ Buffer for Right-of-way

Building Impacts!

ICD 150’
Example Planning Problem (cont.)

- Roundabout size requirements:
  - Today: Single-lane
  - 10 years: Single-lane (may require more analysis)
  - 20 years: Double-lane

- Do you build it today as single-lane or double-lane?

- Are there other options?

Industry trends are to NOT overbuild in the near term
Temporary Roundabouts

Multi-lane
- Curbing
- Striping
- Delineators

Single-lane
- Thermoplastic
- Striping
What else influences size? Design Vehicle

- Dictates many of the roundabout dimensions
- Choice of design vehicle will vary
- Don’t produce overly tight design
  - Typically provide 1 to 2 ft (0.3 to 0.6 m) shy distance between vehicle path and curb to accommodate variations in drivers (AASHTO Policy)
  - Don’t assume drivers will cab-over the truck apron
- It’s ok to mix the design vehicles in the same roundabout
  - STAA or CA Design vehicles on through movements
  - Bus or service vehicle for turning movements
- There’s a difference between “designing” for and “accommodating” a design vehicle
Roundabout size and design vehicle affect layout
Small roundabouts/big trucks lead to small central islands...
Design vehicle influence on roundabout size

Typical ranges for categories and design vehicles

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NCHRP Report 672 Exhibit 6-9
Effect of Skew: Approach Angles

- Perpendicular approaches often are more amenable to achieving desired speeds.

- However, perpendicular approaches are not a design requirement.

- If approaches skewed, make corresponding adjustments to other design components.
Effect of skew: Approach Angles

Possible remedies:
- Changing the inscribed circle diameter
- Offsetting the approach centerline to the left of the center of the roundabout
- Reducing entry widths and entry radii
Example Approach Geometry

Poor deflection
Presentation Outline

- Overview
- Roundabout Size
- Roundabout Location
- Approach Geometry
- High Speed Environments
- Discussion
What influences location?

- Logical placement of circle in your first iteration
- Avoiding impacts to certain properties
- Opportunity impacts to certain properties

And....

- Roundabout size
- Approach configuration

Hey, those last two are some of our tools to achieve optimal performance!
Roundabout location—On centerlines
Roundabout location—To the south
Roundabout location—To the east
Presentation Outline

- Overview
- Roundabout Size
- Roundabout Location
- Approach Geometry
- High Speed Environments
- Discussion
What influences approach geometry?

- Target entry speed
- Use of existing roadways
- Speed management considerations
- Multi-lane entry needs (natural path)

And….

- Roundabout size
- Roundabout location

Hey, those last two are some of our tools to achieve optimal performance!
Approach Angles: Offset to the Left

When it might be appropriate:
- Allows for increased deflection
- Beneficial for accommodating large trucks with small inscribed circle diameter – allows for larger entry radius while maintaining deflection and speed control
- May reduce impacts to right-side of roadway

Trade-offs:
- Increased exit radius or tangential exit reduces control of exit speeds and acceleration through cross-walk area
- May create greater impacts to the left side of the roadway
Approach Angles: Radial Offset

When it might be appropriate:
- Reduces amount of alignment changes along the approach roadway to keep impacts more localized to intersection
- Allows for some exit curvature to encourage drivers to maintain slower speeds through the exit

Trade-offs:
- Increased exit radius reduces control of exit speeds/acceleration through crosswalk area
- May require a slightly larger inscribed circle diameter (compared to offset left design) to provide the same level of speed control
Approach Angles: Offset to the Right

When it might be appropriate:

- Could be used for large inscribed circle diameter roundabouts where speed control objectives can still be met
- This strategy is not commonly used but may be appropriate in some instances (provided that speeds objectives are met) to minimize impacts, improve view angles, etc.

Trade-offs:

- Often more difficult to achieve speed control objectives, particularly at small diameter roundabouts
- Increases the amount of exit curvature that must be negotiated
Approach Treatment: Path Overlap

Path overlap

Speed and trajectory of vehicle at yield point determines natural path
Capacity Problem Due to Entry Path Overlap

Note poor lane utilization
Design Techniques to Avoid Path Overlap

- Median widened toward exit lanes to maximize entry deflection
- Large-radius departure curve
- Range of alignments may be appropriate
- Projection of approach alignment offset to left of roundabout center
- Original centerline
- Small-radius entry curve (R = 65 to 120 ft [20 to 35 m] typical)
- Large-radius approach curve
- Large radius (R > 150 ft [45 m]) or tangent at yield point

NCHRP Report 672 Exhibit 6-30
Path Overlap: Cedar Falls, Iowa
Path Overlap: Cedar Falls, Iowa
A design avoiding path overlap

Muirfield Dr. & Brand Rd.
Dublin, Ohio

Photo: Burgess & Niple, Inc.
Presentation Outline

- Overview
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- Roundabout Location
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- Discussion
Rural Roundabouts

Historical safety of rural roundabouts:
- Overall reduction in crashes
- Reduced crash frequency and severity
- Increase in single vehicle crashes

Specific design guidance:
- Maximize visibility of the central island
- Add changes in cross section or alignment to alert drivers on approaches

Maryland State Highway Administration initiated its roundabout program in the mid-1990s to address rural safety needs.

Roundabouts were so successful SHA integrated them in all environments.
Guidelines for Selecting Speed Reduction Treatments at High-speed Intersections

- Provide sufficient transition between the segment operations and the intersection operations
- Visually
- Comfortable deceleration
- Guidelines are not meant to be a new standard
Rural roundabouts – splitter islands

Freeway Exit Ramp Deceleration Model

- AASHTO Exhibit 10-73 – Deceleration lengths
  - Design speed = 65 mph
  - Target speed = 25 mph
  - Desired deceleration length = 500 - 570′

NCHRP Report 672 Exhibit 6-69
Rural roundabouts – Speed Profiles
Support Approach Geometric Design

Design to fit profile
- Curve 1 = 40 mph
- Curve 2 = 30 mph

Radii
- Magnitude: 250’- 500’
- Design as appropriate for the context
High Speed Approach Treatments

- Extend splitter island and curbing

NCHRP Report 672 Exhibit 6-69

NCHRP Report 672 Exhibit 6-70

Photo source: WSDOT

Photo source: Isebrands
Rural example (Paola, KS):
Note use of longer splitter island

Photo: Lee Rodegerdts
High Speed Approach on Divided Highway

Dodgeville, WI
Source: Google Earth
Speed Management: Approach Treatments

Consider using:
- Longer splitter islands
- Advance approach curves

Photo: W&H Pacific, Inc.
Geometry inconsistent with approach speed

Photo: Dan Burden
Geometry inconsistent with approach speed

Photo: Dan Burden
Rural Roundabouts – visibility
Rural Roundabouts – curbing

Cross section change alerts driver of upcoming intersection

Creates “funneling” effects, along with extended splitter islands
Roundabouts are increasingly common intersection control forms.

Because of their safety, operations, capacity, cost effectiveness, and aesthetics, they will continue to be considered.

There is extensive national and state documentation on roundabout planning, operations, design, and safety performance.

Knowing roundabout fundamentals will help you consider roundabout concepts in any project context.

Roundabout Design: It’s as easy as 1-2-3.
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