Seminar Objectives

- Identify general characteristics of modern roundabouts.
- Understand user and location considerations for modern roundabouts.
- Learn the geometric design basics of modern roundabouts.
Main References


Intersection Design Alternative: The Modern Roundabout

- Roundabouts are becoming a popular option to conventional intersection design in the United States.
- FHWA recommends it as proven safety countermeasure.
  - Reduction in vehicle speeds
  - Reduction in conflict points
  - Improved crash rate and injury rate records
- Lower overall delay than other controlled intersections in typical conditions
- Driver behavior affects the performance of roundabouts
Key Roundabout Characteristics

- Geometric features that create a low-speed environment
- Circular shape
- Yield control on entry
- Deflection at entry

Roundabout Operation Rules
Other Circular Roadway Designs

ROTARY

TRAFFIC CIRCLE

Source: Unknown

United States Geographical Survey

NEIGHBORHOOD
TRAFFIC CIRCLE

Lee Rodegardts

Other Roundabouts?

Photo: Maryland SHA.
Key Objectives of Roundabout Geometric Design

- Slow entry speeds
- Appropriate number of lanes
- Smooth channelization
- Adequate accommodation for design vehicles
- Meeting needs of pedestrians and bicyclists
- Appropriate sight distance and visibility

Roundabout Geometric Elements
Location Considerations

- A modern roundabout should be considered anywhere a traffic signal or stop control is under consideration.
- Roundabouts can be advantageous in a number of locations.
- However, certain constraints may adversely affect their feasibility at a specific site.

Roundabout Application

<table>
<thead>
<tr>
<th>Common site applications</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schools</td>
<td>Reduction in vehicle speeds in and across the roundabout, improve pedestrian crossings</td>
</tr>
<tr>
<td>Rural intersections</td>
<td>Reduce fatal and injury crashes, even on high speed approaches</td>
</tr>
<tr>
<td>Gateway treatments</td>
<td>Creates community focal points, landscaping and other gateway features</td>
</tr>
<tr>
<td>Commercial developments</td>
<td>Aesthetically pleasing design alternative to traffic signals with similar traffic capacity needs</td>
</tr>
<tr>
<td>Intersections w/ high delay</td>
<td>Reduces delay at stop-controlled or signalized intersections</td>
</tr>
<tr>
<td>Residential subdivisions</td>
<td>Low-speed and low-noise with little routine maintenance</td>
</tr>
<tr>
<td>Interchanges</td>
<td>More efficient use of bridge structure between ramp terminals, extends design life and substantially reduces construction costs</td>
</tr>
<tr>
<td>Corridors</td>
<td>Produce efficiency through a gap acceptance process, no need for platoon progression, reduces the number of travel lanes and ROW impacts</td>
</tr>
</tbody>
</table>
Wide Nodes – Narrow Roads

More lanes may be needed for capacity

Potentially greater impact at intersection corners

Property lines

Potentially fewer properties affected between intersections

Access management opportunities facilitated by U-turns at roundabouts

LEGEND

Red: Area required for roundabout but not for signal

Blue: Area required for signal but not for roundabout

Roundabout Constraints

<table>
<thead>
<tr>
<th>Site constrains</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial intersections</td>
<td>Level of service on the arterial might be better with a signalized intersection</td>
</tr>
<tr>
<td>Physical complications</td>
<td>ROW limitations, utility conflicts, drainage problems, grades or unfavorable topography</td>
</tr>
<tr>
<td>Conflicts w/ high traffic volumes</td>
<td>Heavy pedestrian or bicycle movements might require supplemental traffic control</td>
</tr>
<tr>
<td>Proximity of generators w/high traffic</td>
<td>High volumes of trucks or oversized vehicles</td>
</tr>
<tr>
<td>Proximity of other conditions</td>
<td>Drawbridges or at-grade rail crossings that require preemption</td>
</tr>
<tr>
<td>Proximity of bottlenecks</td>
<td>Routinely back up traffic, such as over-capacity signals. If traffic comes to a halt, the roundabout operation is impeded.</td>
</tr>
<tr>
<td>Delay to major road</td>
<td>Unacceptable delay to major road could be created</td>
</tr>
</tbody>
</table>
### Categories of Modern Roundabouts

- Two-lane
- Single-lane
- Mini-roundabout

### Roundabout Category Comparison

<table>
<thead>
<tr>
<th>Design Element</th>
<th>Mini roundabout</th>
<th>Single-lane roundabout</th>
<th>Multiple-lane roundabout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desirable maximum entry design speed (mph)</td>
<td>15 to 20</td>
<td>20 to 25</td>
<td>25 to 30</td>
</tr>
<tr>
<td>Maximum number of entering lanes per approach</td>
<td>1</td>
<td>1</td>
<td>≥2</td>
</tr>
<tr>
<td>Range of inscribed circle diameter (feet)</td>
<td>45 to 90</td>
<td>90 to 180</td>
<td>150 to 300</td>
</tr>
<tr>
<td>Central island treatment</td>
<td>Fully traversable</td>
<td>Raised (may have traversable apron)</td>
<td>Raised (may have traversable apron)</td>
</tr>
<tr>
<td>Typical max. daily volume on 4-leg roundabout before requiring detailed capacity analysis (vpd)</td>
<td>Up to 15,000</td>
<td>Up to 25,000</td>
<td>Up to 45,000 (for two-lane round-about)</td>
</tr>
</tbody>
</table>
Levels of Operational Analysis

- Planning level
  - Based on daily volumes
  - Determine necessary number of lanes

- Operational level
  - Based on peak hour volumes
  - Determine capacity to analyze operations

Planning Level - Number of Lanes

- Number of lanes affects capacity and size

[Graph showing AADT vs. Left-Turn Percentage with different analysis points for single and double-lane roundabouts.]
Rule of Thumb for Single-Lane Roundabouts

- If the sum of the entering and conflicting volumes is less than 1,000 vehicles per hour (veh/h), then a single-lane entry can be reasonably assumed to operate within its capacity.

Example: Estimating Number of Lanes Using Turning-Movement Volumes

- Entering volume + Circulating volume = X
  - 250 + 617 = 867 < 1,000
  - 534 + 224 = 758 < 1,000
  - 317 + 534 = 851 < 1,000
  - 751 + 203 = 954 < 1,000

SINGLE LANE → OK
### Exhibit 3-14 Volume Thresholds for Determining the Number of Entry Lanes Required

<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>1,300 to 1,800 veh/h</td>
<td>Single-lane may be sufficient based upon more detailed analysis.</td>
</tr>
<tr>
<td>Above 1,800 veh/h</td>
<td>Two-lane entry likely to be sufficient</td>
</tr>
<tr>
<td></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

### Operational Level Capacity of Single-Lane and Multilane Entries

[Graph showing capacity analysis against conflicting flow rate]
Key Considerations in Horizontal Design

1. Design speed
2. Design vehicle
3. Size
4. Path alignment
5. Central Island
6. Splitter Islands
7. Sight Distance
8. Cross and Longitudinal Slopes
9. Signs and Markings
10. Non-motorized Transportation

Consideration 1: Design Speed

- Design speed is defined by the theoretical speed drivers could achieve through the roundabout
- Achieve an appropriate design speed for the entry movements and consistent speeds for all movements

<table>
<thead>
<tr>
<th>Site Category</th>
<th>Recommended Maximum Theoretical Entry Design Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini-Roundabout</td>
<td>20 mph (30 km/h)</td>
</tr>
<tr>
<td>Single Lane</td>
<td>25 mph (40 km/h)</td>
</tr>
<tr>
<td>Multilane</td>
<td>25 to 30 mph (40 to 50 km/h)</td>
</tr>
</tbody>
</table>
Consideration 2: Design Vehicle

- The design vehicle is best identified at the start of the project and evaluated early in the design process.

Consideration 3: Size

- The size of a roundabout is determined by a number of design objectives, such as design speed, path alignment, and design vehicles.

<table>
<thead>
<tr>
<th>Roundabout Configuration</th>
<th>Typical Design Vehicle</th>
<th>Inscribed Circle Diameter Range*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini-Roundabout</td>
<td>SU-30 (SU-9)</td>
<td>45 to 90 ft</td>
</tr>
<tr>
<td>Single-Lane Roundabout</td>
<td>B-40 (B-12)</td>
<td>90 to 150 ft</td>
</tr>
<tr>
<td></td>
<td>WB-50 (WB-15)</td>
<td>105 to 150 ft</td>
</tr>
<tr>
<td></td>
<td>WB-67 (WB-20)</td>
<td>130 to 180 ft</td>
</tr>
<tr>
<td>Multilane Roundabout (2 lanes)</td>
<td>WB-50 (WB-15)</td>
<td>150 to 220 ft</td>
</tr>
<tr>
<td></td>
<td>WB-67 (WB-20)</td>
<td>165 to 220 ft</td>
</tr>
<tr>
<td>Multilane Roundabout (3 lanes)</td>
<td>WB-50 (WB-15)</td>
<td>200 to 250 ft</td>
</tr>
<tr>
<td></td>
<td>WB-67 (WB-20)</td>
<td>220 to 300 ft</td>
</tr>
</tbody>
</table>

* Assumes 90-degree angles between entries and no more than four legs.
Consideration 4: Path Alignment

- Multilane roundabouts should align vehicles into the appropriate lane within the circulatory roadway.
- A good design balances entry speed and path alignment.

Position of Roundabout

(a) Centered on Existing Intersection  
(b) Center Shifting to the South  
(c) Center Shifting to the East
Entry Alignments

Alternative 1: Offset Alignment to the Left of Center

ADVANTAGES:
- 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 crosswalk area
- May create greater impacts to the left side of the roadway

Entry Alignments

Alternative 2: Alignment through Center of Roundabout

ADVANTAGES:
- 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
Entry Alignments

Alternative 3: Alignment to Right of Center

**ADVANTAGES:**
- Could be used for large inscribed circle diameter roundabouts where speed control objectives can still be met.
- Although not commonly used, this strategy may be appropriate in some instances (provided that speed 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.

Entry Alignment Design

- Entry widths for single-lane entrances range from 14-18 ft.
- Entry radii at urban single-lane roundabouts range from 50-100 ft.
- Typical entry angles are between 20° and 40°.
Exit Alignment Design

- Exit curb radii should be no less than 50 feet, with values of 100-200 feet being more common.

Issues at Entry and Exit with Large Vehicles

(a) Entry over-tracking
(b) Exit over-tracking
Multi-lane Roundabout (Path Overlap)

Desirable Vehicle Path
Path Alignment

- Entry and exit lanes should be designed without too much separation to avoid problems.
Vehicle Path Radii Consistency

- **R1** - the entry path radius, is the minimum radius on the fastest through path prior to the entrance line.
- **R2** - the circulating path radius, is the minimum radius on the fastest through path around the central island.
- **R3** - the exit path radius, is the minimum radius on the fastest through path into the exit.
- **R4** - the left-turn path radius, is the minimum radius on the path of the conflicting left-turn movement.
- **R5** - the right-turn path radius, is the minimum radius on the fastest path of a right-turning vehicle.

Fastest Vehicle Path (Single Lane Roundabout)

Maximum entering design speeds based on a theoretical fastest path of 20 to 25 mph are recommended.
Fastest Vehicle Path (Double Lane Roundabout)

At multilane roundabouts, maximum entering design speeds of 25 to 30 mph are recommended based on a theoretical fastest path assuming vehicles ignore all lane lines.

Fastest Vehicle Path
Critical Right-Turn Movement
Fastest Path Speeds

- Speed-radius relationships

\[ V = 3.4415R^{0.3661}, \quad \text{for } e = +0.02 \]
\[ V = 3.4614R^{0.3673}, \quad \text{for } e = -0.02 \]

Estimation of Entry Speed

\[ V_1 = \min \left( V_{\text{lane}}, \frac{1}{1.47} \sqrt{\left(1.47V_2\right)^2 + 2a_{i2}d_{i2}} \right) \]

where

- \( V_1 \) = entry speed, mph;
- \( V_{\text{lane}} \) = speed predicted based on path radius, mph;
- \( V_2 \) = circulatory speed for through vehicles predicted based on path radius, mph;
- \( a_{i2} \) = deceleration between the point of interest along \( V_1 \) path and the midpoint of \( V_2 \) path = -4.2 ft/s²; and
- \( d_{i2} \) = distance along the vehicle path between the point of interest along \( V_1 \) path and the midpoint of \( V_2 \) path, ft.
Estimation of Exit Speed

\[ V_3 = \min \left\{ \frac{V_{\text{sphere}}}{1.47 \sqrt{1.47V_2^2 + 2a_{23}d_{23}}} \right\} \]

where

- \( V_3 \) = exit speed, mph;
- \( V_{\text{sphere}} \) = sphere speed predicted based on path radius, mph;
- \( V_2 \) = circulatory speed for through vehicles predicted based on path radius, mph;
- \( a_{23} \) = acceleration between the midpoint of \( V_2 \) path and the point of interest along \( V_3 \) path = 6.9 ft/s²; and
- \( d_{23} \) = distance along the vehicle path between midpoint of \( V_2 \) path and point of interest along \( V_3 \) path, ft.

Speed Consistency (Cont.)

<table>
<thead>
<tr>
<th>Inscribed Circle Diameter (m)</th>
<th>Approximate ( R_i ) Value</th>
<th>Maximum ( R_i ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Radius (ft)</td>
<td>Speed (mph)</td>
</tr>
<tr>
<td>Single-Lane Roundabout</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>35</td>
<td>13</td>
</tr>
<tr>
<td>115</td>
<td>45</td>
<td>14</td>
</tr>
<tr>
<td>130</td>
<td>55</td>
<td>15</td>
</tr>
<tr>
<td>150</td>
<td>65</td>
<td>15</td>
</tr>
<tr>
<td>Double-Lane Roundabout</td>
<td></td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td>165</td>
<td>60</td>
<td>16</td>
</tr>
<tr>
<td>180</td>
<td>65</td>
<td>16</td>
</tr>
<tr>
<td>200</td>
<td>75</td>
<td>17</td>
</tr>
<tr>
<td>215</td>
<td>85</td>
<td>18</td>
</tr>
<tr>
<td>230</td>
<td>90</td>
<td>18</td>
</tr>
</tbody>
</table>

(Robinson, 2000)
**Consideration 5: Central Island**

- A circular central island is preferred because the circulatory roadway helps promote constant speeds
  - Typical circulatory roadway widths range from 16 to 20 ft for single-lane roundabouts
- The size plays a key role in determining the amount of deflection imposed on the through vehicle’s path
- The island may include enhancements, serving an aesthetic purpose and providing conspicuity of the intersection for approaching motorists

**Truck Apron**

- Generally be 3-15 feet wide
- Cross slope of 1%-2% away from the central island
- To discourage use by passenger vehicles, the outer edge of the apron should be raised 2-3 in
Consideration 6: Splitter Island

- Splitter islands provide refuge for pedestrians, control speeds, guide traffic, separate traffic streams, and deter wrong-way movements.
- Longer splitter islands can help reduce confusion for entering motorists.

Splitter Island Dimensions
Consideration 7: Sight Distance and Visibility

- Adequate sight distance and visibility are needed for a roundabout to operate safely.
- Intersection sight distance is evaluated at each entry to ensure a driver can see and safety react to potentially conflicting vehicles.

\[ d_1 = \text{Entering stream distance} \]
\[ d_2 = \text{Circulating stream distance} \]

Intersection Sight Distance

\[
 d_1 = (1.468) (V_{\text{major, entering}}) (t_c) \\
 d_2 = (1.468) (V_{\text{major, circulating}}) (t_c)
\]

where

- \( d_1 \) = length of entering leg of sight triangle, ft;
- \( d_2 \) = length of circulating leg of sight triangle, ft;
- \( V_{\text{major}} \) = design speed of conflicting movement, mph, discussed below; and
- \( t_c \) = critical headway for entering the major road, s, equal to 5.0 s.

Two conflicting traffic streams should be checked at each entry:

1. **Entering stream**, which is composed of vehicles from the immediate upstream entry. The speed for this movement can be approximated by taking the average of the theoretical entering \( (R_i) \) speed and the circulating \( (R_c) \) speed.

2. **Circulating stream**, which is composed of vehicles that enter the roundabout prior to the immediate upstream entry. This speed can be approximated by taking the speed of left-turning vehicles (path with radius \( R_c \)).
Stopping Sight Distance @ Roundabout Approach

- Stopping sight distance should be provided at every point within a roundabout and on each approach.
- The roundabout should be visible from a distance and focus the attention of drivers.

Stopping Sight Distance @ Circulatory Roadway

**LEGEND**
- **d**: Distance related to stopping sight distance and circulatory speed
- 6 ft (2 m)
Cross slope of 2% away from the central island should be used for the circulatory roadway on single-lane roundabouts.

Two common methods for vertical design of circulatory roadway within a multilane roundabout are outward sloping and crowned circulatory roadway.

Roundabouts should preferably be located where grades through the intersection are less than 4%.
Consideration 9: Pavement Markings and Signs

- Markings and signs are integral to roundabout design and should facilitate through and turning movements.
- Typical pavement markings delineate the entries, exits, and circulatory roadway.
- Overall signing concept similar to intersection signing.
Example of Roundabout Signing

- MUTCD 2009
  Part 2 Signs
Consideration 10: Pedestrian Design Treatments

- Sidewalks at roundabouts should be set back from the circulatory roadway to discourage pedestrians from crossing to the central island.

Consideration 10: Bicycle Design Treatments

- Bicycle lanes should end in advance of roundabouts.
- Bicyclists may act as a vehicle or pedestrian.
Key Dimensions of Non-Motorized Design Users

<table>
<thead>
<tr>
<th>User</th>
<th>Dimension</th>
<th>Affected Roundabout Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicyclist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>5.9 ft (1.8 m)</td>
<td>Splitter island width at crosswalk</td>
</tr>
<tr>
<td></td>
<td>Minimum operating width</td>
<td>Bike lane width on approach roadways; shared use path width</td>
</tr>
<tr>
<td>Pedestrian (walking)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width</td>
<td>1.6 ft (0.5 m)</td>
<td>Sidewalk width, crosswalk width</td>
</tr>
<tr>
<td>Wheelchair user</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum width</td>
<td>2.5 ft (0.75 m)</td>
<td>Sidewalk width, crosswalk width</td>
</tr>
<tr>
<td>Operating width</td>
<td>3.0 ft (0.90 m)</td>
<td>Sidewalk width, crosswalk width</td>
</tr>
<tr>
<td>Person pushing stroller</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>5.6 ft (1.70 m)</td>
<td>Splitter island width at crosswalk</td>
</tr>
<tr>
<td>Skaters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical operating width</td>
<td>6 ft (1.8 m)</td>
<td>Sidewalk width</td>
</tr>
</tbody>
</table>

Other Design Details and Applications

- Right-turn bypass lanes
- Access management: restrict nearby driveways
- At-grade rail crossings: challenges related to crossing control and queue clearance
- Bus stops: Can be provided on the entry or exit side of a roundabout, but not within the circulatory roadway