NCHRP 3-65: Applying Roundabouts in the United States

Design: Preliminary Findings

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Topics of Discussion

- Design speed modeling
- Other design findings for motor vehicles
- Pedestrian and bicycle observations
Acknowledgements

- Karen Giese – assisted in the speed analysis
- Ed Myers – assisted in design review
- David Harkey – led the ped/bike analysis
Current FHWA speed prediction method is based on AASHTO speed-radius function.
Design speed modeling: Vehicle path definitions

- $V_0$: approach path radius
- Through movements
  - $V1$: entry path radius
  - $V2$: circulating path radius
  - $V3$: exit path radius
- Left turns
  - $V1L$: entry path radius
  - $V4$: circulating path radius
  - $V6$: left turn path exit radius
- Right turns
  - $V5$: entry path radius
  - $V5x$: exit path radius

FHWA, Exhibit 6-12, p. 139
Design speed modeling: V4, Left-turn circulating speed (all sites)

\[ y = 1.1041x - 1.8409 \]

\[ R^2 = 0.6483 \]
Design speed modeling: Exit speed (all sites), unadjusted

\[ y = 0.2513x + 13.834 \]
\[ R^2 = 0.2933 \]
Proposed exit speed equation

\[ V_3 = \min \left\{ \frac{1}{1.47} \sqrt{(1.47V_2)^2 + 2a_{23}d_{23}} \right\} \]

Speed where exit radius is limiting factor

Speed where circulating speed and acceleration distance is limiting factor

- where:
  - \( V_3 \) = \( V_3 \) speed, in mph
  - \( V_{3pbase} \) = \( V_3 \) speed predicted based on path radius, in mph
  - \( V_2 \) = \( V_2 \) speed predicted based on path radius, in mph
  - \( a_{23} \) = acceleration along the length between the midpoint of \( V_2 \) path and the point of interest along \( V_3 \) path = 6.9 ft/s²
  - \( d_{23} \) = distance between midpoint of \( V_2 \) path and point of interest along \( V_3 \) path, in ft
Design speed modeling:
Exit speed (all sites), adjusted

\[ y = 0.6694x + 5.9115 \]

\[ R^2 = 0.5156 \]

- **Match Line**
- **85th %ile (15+ obs.)**
- **Linear (85th %ile (15+ obs.))**
Design speed modeling: 
Entry speed (all sites), unadjusted

\[ y = 0.3437x + 9.8447 \]

\[ R^2 = 0.4772 \]
Proposed entry speed equation

\[ V_1 = \min \left\{ \frac{1}{1.47} \sqrt{(1.47V_2)^2 + 2a_{12}d_{12}} \right\} \]

where:

- \( V_1 \) = \( V_1 \) speed, in mph
- \( V_{1pbase} \) = \( V_1 \) speed predicted based on path radius, in mph
- \( V_2 \) = \( V_2 \) speed predicted based on path radius, in mph
- \( a_{12} \) = deceleration between the point of interest along \( V_1 \) path and the midpoint of \( V_2 \) path = \(-4.2 \text{ ft/s}^2\)
- \( d_{12} \) = distance along the vehicle path between the point of interest along \( V_1 \) path and the midpoint of \( V_2 \) path, in ft
Design speed modeling:
Entry speed (all sites), adjusted

\[ y = 0.6237x + 6.0316 \]

\[ R^2 = 0.3491 \]
Implications for design

- Tangential or nearly tangential exits do not appear to cause excessive vehicle exit speeds if the following conditions are met:
  - The speed of circulation (V2 and V4) is kept low
  - The distance between the start of the exit path and the point of interest (e.g., crosswalk) is kept short

- Entry speed appears to be limited by drivers’ anticipation of the speed needed for circulation
  - However, recommend continued reliance on entry path curvature as a primary method to control entry speed
Additional findings regarding design and safety

- The single-lane sites included in the study have better crash frequencies and crash rates than the multilane sites in the study.
- The majority of the multilane sites were designed before the concept of path overlap was included in any documentation (FHWA Roundabout Guide).
Additional findings regarding design and safety

- Narrow lane widths (entry and circulating) at multilane roundabouts appear to have a detrimental effect on safety

- Entry width:
  - Aggregated entry width (number of lanes) has a clear safety and operational effect
  - Variations of lane width appear to be second-order effects
Additional findings regarding design and safety

- **Angle between legs:**
  - *Found to be a significant effect in US data*
  - *As angle to next leg decreases, number of entry-circulating crashes increases*

- **Splitter island width**
  - *No strong effect between splitter island width and entry capacity found*
Multilane path overlap

- Apparent contributor to high crash frequencies at multilane roundabouts
- Anecdotal evidence suggests that its correction can substantially improve safety performance
Non-motorized Users

- Examination of observed field behaviors for two groups:
  - Pedestrians
  - Bicyclists

- Pedestrian data:
  - 10 approaches at 7 sites; 769 events

- Bicyclist data:
  - 14 approaches at 7 sites; 690 events

- Geographic diversity:
  - California, Florida, Maryland, Nevada, Oregon, Utah, Vermont, Washington
How do motorists behave when encountering pedestrians?

- **Motorists failing to yield to pedestrians**
  - All sites: 30 percent
  - Entry leg: 23 percent
  - Exit leg: 38 percent
  - 1-lane approaches: 17 percent
  - 2-lane approaches: 43 percent
Are there conflicts between motorists and pedestrians?

- Only 4 conflicts observed out of 769 pedestrian crossings (0.5%)
- Conflict rate: 2.3 conflicts per 1000 opportunities
### How do behaviors at roundabouts compare to other forms of control?

<table>
<thead>
<tr>
<th>Crossing control</th>
<th>Percent of “normal” crossings</th>
<th>Percent of non-yielding vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncontrolled</td>
<td>70%</td>
<td>48%</td>
</tr>
<tr>
<td>Roundabout</td>
<td>85%</td>
<td>32%</td>
</tr>
<tr>
<td>Signal-controlled</td>
<td>90%</td>
<td>15%</td>
</tr>
<tr>
<td>Stop-controlled</td>
<td>100%</td>
<td>4%</td>
</tr>
</tbody>
</table>

- No practical differences in walking speed
What are the roundabout characteristics that tend to cause problems or tend to be safer?

- Motorists less likely to yield on 2-lane approaches compared to 1-lane approaches
- Motorists less likely to yield on exit leg compared to entry leg
- Pedestrians more likely to hesitate when starting crossing from exit leg
- Review of geometric features did not yield additional insights
How do motorists and bicyclists interact?

- **Lane position on approach:**
  - Edge of lane/bike lane: 73%
  - Claim lane: 15%
  - Sidewalk: 12%

- **Lane position on exit:**
  - Edge of lane: 61%
  - Claim lane: 16%
  - Sidewalk: 23%

- **Little observed interaction between modes**
  - Bikes tended to wait for gaps in circulating traffic
Are there conflicts between motorists and bicyclists?

- Only 4 conflicts observed in 690 bicyclist events (0.5%)
- Small number of observed events of wrong-way riding (7)
Conclusions

- Adjustments to speed model improve predictive ability
- Statistical and anecdotal evidence that various geometric factors influence safety
- Little observed safety problem for pedestrians and bicyclists, although some roundabout characteristics make use more challenging