Operations and Safety of Separated Bicycle Facilities at Single Lane Roundabouts

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Overview

• Introduction
• Typical Roundabout Design
• Separated Roundabout Design
• Operations Analysis
• Safety Assessment
• Conclusions

Stanford University, Palo Alto, CA
Bicycles at Roundabouts

Sprocket Bikeway
University of California, Davis, CA
Bicycles at Roundabouts

California Avenue/North Quad
University of California, Davis, CA
Bicycles at Roundabouts

Source: Google Images
Bicycles at Roundabouts

5th Street/Cantrill Drive
Davis, CA

Hutchinson Drive/Sage Street
University of California, Davis, CA
Bicycles at Roundabouts

Dutch example
Source: CROW via RoundaboutsUSA

Separated Bike Lane Planning & Design Guide
Massachusetts DOT

INDAABOUT DESIGN WITH SEPARATED BIKE LANE

- The bicycle crossing should be immediately adjacent to and parallel with the pedestrian crossing, and both should be at the same elevation.
- Consider providing supplemental yield lines at roundabout exits to indicate priority at these crossings.
- The decision of whether to use yield control or stop control at the bicycle crossing should be based on available sight distance.
- The separated bike lane approach to the bicycle crossing should result in bicyclists arriving at the queuing area at a perpendicular angle to approaching motorists.
- Curb radius should be a minimum of 5 ft. to enable bicyclists to turn into the queuing area.
- Channelizing islands are preferred to maintain separation between bicyclists and pedestrians, but may be eliminated if different surface materials are used.
- Place BICYCLE/PEDESTRIAN WARNINGS signs (W11-15) as close as practical to the bicycle and pedestrian crossings (see Section 4.1.9).

At crossing locations of multi-lane roundabouts or roundabouts where the exit geometry will result in faster exiting speeds by motorists thus reducing the likelihood that they will yield to bicyclists and pedestrians, additional measures should be considered to induce yielding such as providing an actuated device such as a Rapid Flashing Beacon or Pedestrian Hybrid Beacon.

EXHIBIT 48: Design for Roundabout with Separated Bike Lanes
Separated Bicycle Facility – “Cycle Track”

“...an exclusive bikeway that combines the user experience of a separated path with the on-street infrastructure of a conventional bike lane.”

-NACTO *Urban Bikeway Design Guide*

A one-way cycle track in Chicago, IL
Source: Chicago DOT
Mixing Zone

Merge bicyclists into bike lane or shared lane in advance of intersection

Washington, DC
Source: Streetsblog

New York, NY
Source: NACTO
Exclusive Turn Phase

- Provides separate signal phases for turning drivers and through bicyclists
- Potential capacity tradeoffs
Protected Intersection

Corner refuge islands provide key features for bicyclists:

• Advanced stop bars
• Set back crossings
• Two-stage left turns
• Free right-turns

Borrows from Dutch intersection designs

Conceptual design of a protected intersection
Source: Vimeo
Built in 2016

Salt Lake City, UT
Source: Streetsblog

Covell Boulevard/J Street
Davis, CA
Roundabout – Typical Design

Bicycle Options:

• Merge with motor vehicles and travel as motor vehicle on the circulating roadway

• Take ramp to shared-use path and travel as a pedestrian on crosswalks

Bicycle lane on circulating roadway not recommended due to right-hook conflict
Roundabout – Separated Design

Bicycles stay in own separate lane through roundabout that is between pedestrians and motor vehicles.

Bicycles yield to pedestrians, but motor vehicles yield to pedestrians and bicycles at crosswalks.
Operations Analysis Model

Vissim microsimulation networks

Typical Design

Separated Design
Model Assumptions

- Seeding interval of 15 minutes, peak 15 minutes of one hour period
- Peak hour factor of 0.95, 3 percent heavy vehicles
- Pedestrian volume of 20 per hour in crosswalks
- Average approach speeds: 35 mph for vehicles, 11.5 mph for bicycles, and 2.5 mph for pedestrians
- Average roundabout speeds: 20 mph for vehicles and 5.5 mph for bicycles on shared path
Model Calibration

Goal was to match HCM capacity curve

Minimum gap time in the Vissim priority rule function was adjusted

Although not an exact match, within variation in observed data for HCM model development
Turning Movement Volumes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Volume (vph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Vehicles</td>
<td>2,100</td>
</tr>
<tr>
<td>Bicycles</td>
<td>80</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>80</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,260</strong></td>
</tr>
</tbody>
</table>
Typical Design, 0% Bicycles on Path
Typical Design, 50% Bicycles on Path
Typical Design, 100% Bicycles on Path
Separated Design
# Results Summary

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Average Intersection Delay*</th>
<th>Average Network Delay for Bicycles</th>
<th>Total Travel Time for Bicycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical, 0% Path</td>
<td>26.5 sec/veh</td>
<td>5.20 sec/veh</td>
<td>1.57 hr</td>
</tr>
<tr>
<td>Typical, 25% Path</td>
<td>25.1 sec/veh</td>
<td>3.94 sec/veh</td>
<td>1.69 hr</td>
</tr>
<tr>
<td>Typical, 50% Path</td>
<td>23.5 sec/veh</td>
<td>2.98 sec/veh</td>
<td>1.77 hr</td>
</tr>
<tr>
<td>Typical, 100% Path</td>
<td>21.8 sec/veh</td>
<td>1.20 sec/veh</td>
<td>2.00 hr</td>
</tr>
<tr>
<td>Separated</td>
<td>23.9 sec/veh</td>
<td>1.83 sec/veh</td>
<td>1.57 hr</td>
</tr>
</tbody>
</table>

*Average intersection delay for motor vehicles and bicycles traveling through the roundabout
Safety Assessment: Speed

Figure 1. Risk of severe injury (left) and death (right) in relation to impact speed in a sample of 422 pedestrians aged 15+ years struck by a single forward-moving car or light truck model year 1989–1999, United States, 1994–1998. Risks are adjusted for pedestrian age, height, weight, body mass index, and type of striking vehicle, and standardized to the distribution of pedestrian age and type of striking vehicle for pedestrians struck in the United States in years 2007–2009. Dotted lines represent point-wise 95% confidence intervals. Serious injury is defined as AIS score of 4 or greater and includes death irrespective of AIS score.

Safety Assessment: Conflict Points

Conflict type
• crossing
• merging
• diverging

Conflict mode
• motor vehicle
• bicycle
• pedestrian
Typical Design
Typical Design
Typical Design
Separated Design

CONFLICT TYPE
- Pedestrian
- Vehicle
- Bicycle
- Crossing
- Merging
- Overtaking
Separated Design
## Conflict Point Summary

<table>
<thead>
<tr>
<th>Conflict Points Mode</th>
<th>Conflict Type</th>
<th>Typical Design</th>
<th></th>
<th>Separated Design</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Roadway</td>
<td>Shared Path</td>
<td></td>
</tr>
<tr>
<td><strong>Motor Vehicle</strong></td>
<td>Crossing</td>
<td>-</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Merging</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Diverging</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Bicycle</strong></td>
<td>Crossing</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Merging</td>
<td>4</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Diverging</td>
<td>4</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td><strong>Pedestrian</strong></td>
<td>Crossing</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Merging</td>
<td>-</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Diverging</td>
<td>-</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>32</td>
<td>40</td>
<td>24</td>
</tr>
</tbody>
</table>
Findings

• For typical design, delay is higher when more bicycles use the roadway and lower when more use the shared use path.

• For the test case (80 bicycles per hour), this shift between roadway and path routes yielded a range of about 5 seconds per vehicle for LOS C/D conditions and nearly 20 seconds per vehicle for LOS E/F conditions.

• Separated design had similar delay to the typical design with 50 percent bicycles.

• Separated design had lower bicycle delays and travel time for most design scenarios.

• Separated design reduces conflict points with other modes.

• Separated design keeps bicycles separate from other modes to provide a more comfortable experience.
Interactive Roundabouts Web Map

http://gis.fehrandpeers.com/Apps/RoundaboutApplication
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