User-Rated Comfort and Preference of Separated Bike Lane Intersection Designs

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Background


- In general, separated / protected bike lanes are associated with increased safety (*Marshall and Ferenchak* 2019; *Harris et al.* 2013; *Teschke et al.*, 2012; *Lusk et al.* 2013)

- Intersections are the weak link for both actual safety (reported crashes and observed conflicts) and perceived safety (comfort)
Measuring Comfort

• How to measure?
  • Hypothetical/imagined photos or video, in-person or online
  • Simulated environments
  • Naturalistic (i.e. people bicycling)

• What to measure?
  • Survey answers of stated comfort
  • Bio-physiological parameters

• Some evidence of bias
  • Imagined environments less comfortable compared to actual experience (Fitch and Handy, 2018)

• Important to consider sample demographics, cycling experience, attitudes and other variables
## Designs Considered

<table>
<thead>
<tr>
<th>Bike Signal*</th>
<th>Protected / Bend-out*</th>
<th>Bend In*</th>
<th>Maintain Path</th>
<th>Mixing Zone*</th>
<th>Lateral Shift*</th>
</tr>
</thead>
</table>

* FHWA Separated Bike Lane Planning and Design Guide (2015)

Scope: One-way configurations and focus on the right-turning interaction with cars
Collecting and Curating Sample Clips

10 locations from:
• Denver, CO
• Portland, OR
• Salt Lake City, UT
• Seattle, WA
Mixing Zones

Salt Lake City
300S at 200E

Portland
NE Multnomah
Seattle Dexter at Harrison

Bicycle Signal

Clip 5
Right Turn Arrow
Bicycle Signal
Waiting to turn

Denver Arapahoe at 18th

Mixing Zone
Protected / Bend Out

Salt Lake City
200W at 300S

Maintain

Portland
Multnomah and 11th
Controls:
Off Street Path

Springwater Corridor Trail, Portland, OR
Avg. Rating = 4.77

Separated / Protected Bike Lane Segment

NE Multnomah Protected Lane, Portland, OR
Avg. Rating = 4.54
Example clip - Interaction

Clip 25

https://youtu.be/VrFGgoBrqaA
Example clip – Turn Visible

Clip 13
In Person Survey

- 277 individuals
- 26 clips rating each on a 1-5 comfort scale (including neither) some on riding with children
- 7,166 total ratings
Who took the survey?

- **Female**: 56%
- **Male**: 44%
- **White, non-Hispanic**: 70%
- **Black or African-American**: 4%
- **Asian or Pacific Islander**: 10%
- **Hispanic and/or latina/o**: 10%
- **Hispanic and/or latina/o**: 10%
- **other**: 2%
- **Multi-racial**: 4%

**Age Distribution**
- **18 to 24**: 23%
- **25 to 34**: 27%
- **35 to 54**: 25%
- **55 +**: 25%
Who took the survey?

- Primarily Car: 16%
- Mostly Car: 31%
- Mix: 21%
- Primarily Bike: 12%
- Primarily Transit: 20%

- 90% have driver’s license
- 58% had a working bicycle
- 45% had a transit pass
- 57% had a car or truck

Travel behavior categories:

- Last month: 36%
- Last 5 yrs: 15%
- Last year: 13%
- More than 5 yrs: 10%
- Never: 26%

Most recent biking for transportation:
Results
COMFORT BY GENDER IDENTITY

Men
- 18% Very comfortable
- 31% Somewhat comfortable
- 17% Neither uncomfortable nor comfortable
- 5% Somewhat uncomfortable
- 10% Very uncomfortable

Women
- 12% Very comfortable
- 29% Somewhat comfortable
- 25% Neither uncomfortable nor comfortable
- 10% Somewhat uncomfortable
- 9% Very uncomfortable

COMFORT BY RACE/ETHNICITY

Hispanic or non-white
- 12% Very comfortable
- 25% Somewhat comfortable
- 25% Neither uncomfortable nor comfortable
- 9% Somewhat uncomfortable
- 6% Very uncomfortable

White, non-Hispanic
- 16% Very comfortable
- 33% Somewhat comfortable
- 21% Neither uncomfortable nor comfortable
- 6% Somewhat uncomfortable
- 5% Very uncomfortable
<table>
<thead>
<tr>
<th>Design Type</th>
<th>Very comfortable</th>
<th>Somewhat comfortable</th>
<th>Neither uncomfortable nor comfortable</th>
<th>Somewhat uncomfortable</th>
<th>Very uncomfortable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bike Signal</td>
<td>31%</td>
<td>35%</td>
<td>11%</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Protected</td>
<td>30%</td>
<td>36%</td>
<td>11%</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>Bend in</td>
<td>14%</td>
<td>32%</td>
<td>20%</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Maintain</td>
<td>14%</td>
<td>29%</td>
<td>23%</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Mix</td>
<td>10%</td>
<td>27%</td>
<td>26%</td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td>Shift</td>
<td>9%</td>
<td>27%</td>
<td>26%</td>
<td>11%</td>
<td></td>
</tr>
</tbody>
</table>

**COMFORT BY DESIGN TYPE**
Mean comfort score with and without turning interactions

### Mean comfort score (1-5)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>No interaction</th>
<th>Interaction with turning vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicycle Signal (*)</td>
<td>3.77</td>
<td></td>
</tr>
<tr>
<td>Protected Intersection</td>
<td>3.95</td>
<td></td>
</tr>
<tr>
<td>Bend-in</td>
<td>3.47</td>
<td></td>
</tr>
<tr>
<td>Maintain separation / straight path</td>
<td>3.63</td>
<td></td>
</tr>
<tr>
<td>Mixing zone</td>
<td>3.03</td>
<td>3.04</td>
</tr>
<tr>
<td>Lateral Shift</td>
<td>3.14</td>
<td>2.8</td>
</tr>
</tbody>
</table>

### Percentage Comfortable

<table>
<thead>
<tr>
<th>Scenario</th>
<th>No interaction</th>
<th>Interaction with turning vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicycle Signal (*)</td>
<td>67%</td>
<td></td>
</tr>
<tr>
<td>Protected Intersection</td>
<td>72%</td>
<td></td>
</tr>
<tr>
<td>Bend-in</td>
<td>54%</td>
<td></td>
</tr>
<tr>
<td>Maintain separation / straight path</td>
<td>59%</td>
<td></td>
</tr>
<tr>
<td>Mixing zone</td>
<td>37%</td>
<td>37%</td>
</tr>
<tr>
<td>Lateral Shift</td>
<td>40%</td>
<td>40%</td>
</tr>
</tbody>
</table>

- Green bar indicates no interaction.
- Light green bar indicates interaction with turning vehicle.

## Notes
- (*) Indicates a specific scenario.
- The comfort scores range from 1 to 5, with 1 being the least comfortable and 5 being the most comfortable.
Percent comfortable by exposure distance

Percent Comfortable

Exposure distance (loss of buffer to far side of street) (ft)
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline - protected bike lane</td>
<td>89%</td>
</tr>
<tr>
<td>Bend in</td>
<td>70%</td>
</tr>
<tr>
<td>Protected Intersection</td>
<td>68%</td>
</tr>
<tr>
<td>Maintain separation - straight</td>
<td>51%</td>
</tr>
<tr>
<td>Lateral shift, post delineated</td>
<td>31%</td>
</tr>
<tr>
<td>Short mix zone</td>
<td>25%</td>
</tr>
</tbody>
</table>

Would ride with a 10 year old in this location?
Would you prefer to ride through intersection A or B on a bicycle?

Of those who chose A, reasons include*:
- Preferred the yield sign/markings (19%)
- Not having to cross a car lane (18%)
- Being able to stay to the right (10%)

Of those who chose B, reasons include*:
- Liking the separation from vehicles (35%)
- Clear lane marking (31%)
- Like the green color (21%)
Would you prefer to ride through intersection C or D on a bicycle?

Of those who chose C, reasons include*:
- Protection and separation from vehicles (43%)
- Improved visibility and turning angle (34%)
- Clear markings (17%)
- Slows down drivers, time to react (13%)

Of those who chose D, reasons include*:
- Less confusing design (34%)
- Better visibility and alertness (16%)
Now, compare your preference from A/B to your preference from C/D. Which would you prefer to ride through on a bicycle?

A (Mixing zone design): 6%
B (Lateral shift design): 10%
C (Protected intersection design): 73%
D (Bend-in design): 11%
Cluster Groupings
Exploring “types of cyclists”

K-Means Cluster Analysis, based on attitudes and perceptions toward bicycling

<table>
<thead>
<tr>
<th>“Bike Inclined”</th>
<th>“Interested but Concerned”</th>
<th>“Indifferent to Bicycling”</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Feel that destinations were within bikeable distances</td>
<td>• Interested in biking more</td>
<td>• Less interested in bicycling</td>
</tr>
<tr>
<td>• Not deterred by traffic</td>
<td>• Traffic keeps them from riding more</td>
<td>• Don’t view destinations as bikeable</td>
</tr>
<tr>
<td>• Saw people like them riding in their neighborhoods</td>
<td>• More likely to be female</td>
<td>• Don’t see people like themselves riding in their neighborhood.</td>
</tr>
<tr>
<td>• Most likely to bike for transport</td>
<td></td>
<td>• Least likely to have ridden a bike for transport or have a transit pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Most likely to take most trips by car.</td>
</tr>
</tbody>
</table>
Percentage Comfortable by Design Type

<table>
<thead>
<tr>
<th>Design Type</th>
<th>Bike Inclined</th>
<th>Interested but Concerned</th>
<th>Indifferent to Bicycling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal</td>
<td>73%</td>
<td>66%</td>
<td>61%</td>
</tr>
<tr>
<td>Protected Intersection</td>
<td>72%</td>
<td>60%</td>
<td>61%</td>
</tr>
<tr>
<td>Maintain separation</td>
<td>45%</td>
<td>25%</td>
<td>39%</td>
</tr>
<tr>
<td>Bend in</td>
<td>50%</td>
<td>33%</td>
<td>35%</td>
</tr>
<tr>
<td>Lateral Shift</td>
<td>42%</td>
<td>24%</td>
<td>31%</td>
</tr>
<tr>
<td>Mixing zone</td>
<td>49%</td>
<td>26%</td>
<td>37%</td>
</tr>
</tbody>
</table>

Legend:  
- No interaction
- Interaction
Conclusions (1)

• Separation matters:
  • Protected intersections / bend out and bike signal were found to provide the best expected rider comfort.
  • Designs that keep a separate bike lane (bend-in, straight-path) were rated as comfortable by more than half of all respondents but were sensitive to the presence of turning vehicles.
  • Designs that move bicyclists and motor vehicles into shared space (mixing zones or lateral shifts) were viewed as least comfortable.

• Exposure distance is a significant predictor of comfort. Shortening exposure distance is a good design objective.
Conclusions (2)

• “Interested but Concerned”
  • As found in past research finding, this group tends to be the most responsive to changes in the design environments.
  • Less than 30% of would feel comfortable with any form of mixing before the intersection.
  • However, about 67% would feel comfortable at a bike signal and protected intersection.

• “Riding with children”
  • Responses provide valuable insights but should be interpreted with caution as they are each based on a single video clip, without any interaction with a turning vehicle.
Acknowledgements

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