NCHRP 3-65: Applying Roundabouts in the United States

Operations

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Presentation Outline

- Analytical Computation
- Driver Behavior and Geometry
- Model Comparison/Calibration
- Model Selection
## Capacity Models Tested

### Empirical Models

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>NAME</th>
<th>TYPE</th>
<th>VARIABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>British</td>
<td>RODEL/Kimber</td>
<td>Linear</td>
<td>geometry</td>
</tr>
<tr>
<td>French</td>
<td>GIRABASE/Louah</td>
<td>Exponential</td>
<td>geometry + tf/ tc</td>
</tr>
<tr>
<td>Swiss</td>
<td>Lausanne</td>
<td>Linear</td>
<td>geometry</td>
</tr>
<tr>
<td>Israel</td>
<td>Polus</td>
<td>Exponential</td>
<td>speed</td>
</tr>
<tr>
<td>FHWA</td>
<td>Simplified British</td>
<td>Linear</td>
<td>NA</td>
</tr>
</tbody>
</table>

### Analytical Models

- German Wu tf/tc
- Australian SIRDA/Troutbeck tf/tc limited geometry
- HCM tf/tc
Analysis of Exiting Models

- All international models (including SIDRA and RODEL) predict capacities higher than observed.
# Field Measured Gap Acceptance Parameters

## ‘Average’ approach critical gap and follow-up times

<table>
<thead>
<tr>
<th>Model</th>
<th>1 Lane</th>
<th>2 Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>tf</td>
<td>tc</td>
</tr>
<tr>
<td>Field Right lane</td>
<td>2.6-4.3</td>
<td>4.2-5.9</td>
</tr>
<tr>
<td>Field Left lane</td>
<td>2.7-4.7</td>
<td>4.2-4.4</td>
</tr>
<tr>
<td>HCM</td>
<td>3.1</td>
<td>4.6</td>
</tr>
<tr>
<td>German</td>
<td>3.2</td>
<td>4.4</td>
</tr>
<tr>
<td>French</td>
<td>2.1</td>
<td>NA</td>
</tr>
<tr>
<td>Akçelik Dominant</td>
<td>1.8-2.7</td>
<td>1.4-4.9</td>
</tr>
<tr>
<td>Akçelik SubDom</td>
<td>2.2-4.0</td>
<td></td>
</tr>
</tbody>
</table>
Influence of Flow & Geometry on Driver Behavior

- Entry lane width = entry width / #lanes

\[ y = -0.047x + 3.408 \]
\[ R^2 = 0.0336 \]

\[ y = -0.0079x + 4.8345 \]
\[ R^2 = 0.0003 \]
Influence of Flow & Geometry on Driver Behavior

- **Radius**

![Graph showing relationship between radius and gap parameters]

- For all tf:
  - \( y = -0.0074x + 4.9528 \)
  - \( R^2 = 0.0154 \)

- For all tc:
  - \( y = -0.0131x + 3.4573 \)
  - \( R^2 = 0.166 \)
Influence of Flow & Geometry on Driver Behavior

- Entry Angle

\[ y = 0.0006x + 3.1536 \]
\[ R^2 = 0.0007 \]

\[ y = 0.0066x + 4.6343 \]
\[ R^2 = 0.0308 \]
Influence of Flow & Geometry on Driver Behavior

- **Splitter Width**

\[ y = -0.0792x + 3.6508 \]

\[ R^2 = 0.3873 \]

\[ y = -0.023x + 4.9384 \]

\[ R^2 = 0.0075 \]
# One Lane Calibration

<table>
<thead>
<tr>
<th>MODEL</th>
<th>None (All veh/hr)</th>
<th>pcus</th>
<th>geometry &amp; F (1L sites only)</th>
<th>geometry &amp; F (All sites)</th>
<th>geometry tf; tc mup&lt;6</th>
<th>Include exit + 100% conflicting mup&lt;6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kimber</td>
<td>795</td>
<td>773</td>
<td>421</td>
<td>167</td>
<td>169</td>
<td>-</td>
</tr>
<tr>
<td>Akcelik</td>
<td>593</td>
<td>545</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>160</td>
</tr>
<tr>
<td>Kreisel</td>
<td>294</td>
<td>215</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>143</td>
</tr>
<tr>
<td>French</td>
<td>1191</td>
<td>1234</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>258</td>
</tr>
<tr>
<td>Swiss</td>
<td>376</td>
<td>343</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>323</td>
</tr>
<tr>
<td>HCM Upper</td>
<td>326</td>
<td>322</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>145</td>
</tr>
<tr>
<td>HCM Lower</td>
<td>180</td>
<td>176</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FHWA</td>
<td>240</td>
<td>224</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
One Lane Calibration

- British – All single lane approaches

![Graph showing conflicting flow vs. max entering flow. The graph includes data points for Raw Data, British (Kimber/RODEL), and British Calibrated.]
One Lane Calibration

- Australian – All single lane approaches

![Graph showing conflicting flow vs max entering flow with data points for Australian (Akcelik/SIDRA), Australian-Calibrated, and Raw Data categories.]
One Lane Calibration

- German – All single lane approaches

![Graph showing Max Entering Flow vs Conflicting Flow for German-calibrated data, German (Wu/Kriesel) data, and Raw Data.](image-url)
One lane Calibration

- HCM – All single lane approaches

![Graph showing calibration results for HCM with different flow rates.](image-url)
One Lane Calibration

- **Port Orchard north (average entry flow)**

![Graph showing the relationship between Conflicting Flow (pcus/hr) and Max Entering Flow (veh/hr) for WA04-N (Port Orchard). The graph includes data points for All Raw Data, Raw Data WA04-N, HCM (calibrated), Australian (calibrated), and British (calibrated).]
One Lane Calibration

- Kennewick south (high entry flow)

![Graph showing conficting flow vs max entering flow with categories](file)
One lane Calibration

- Linear or exponential regression

- \( RMSE = 160 \)
Critical Gap and Follow-up time estimates

- Average critical gap and follow-up time similar to using regression
Multi-Lane Calibration

- Several sites exhibit strong queuing in only one lane
  - Turning movement effects
  - Other possible constraints (path overlap, etc.)

<table>
<thead>
<tr>
<th>Site</th>
<th>Left Lane</th>
<th>Right Lane</th>
<th>L</th>
<th>T</th>
<th>R</th>
<th>U</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>WA09-e</td>
<td>18%</td>
<td>82%</td>
<td>9%</td>
<td>86%</td>
<td>5%</td>
<td>1%</td>
<td>10% of Throughs in LL</td>
</tr>
<tr>
<td>MD04-E</td>
<td>55%</td>
<td>45%</td>
<td>72%</td>
<td>28%</td>
<td>1%</td>
<td>0%</td>
<td>20% of Lefts in RL</td>
</tr>
<tr>
<td>MD05-SW-NW</td>
<td>0%</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MD05-SW-W</td>
<td>0%</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VT03-E</td>
<td>45%</td>
<td>55%</td>
<td>30%</td>
<td>49%</td>
<td>21%</td>
<td>0%</td>
<td>50% of Lefts in RL; 15% of Throughs in LL</td>
</tr>
<tr>
<td>VT03-S</td>
<td>33%</td>
<td>67%</td>
<td>28%</td>
<td>39%</td>
<td>31%</td>
<td>3%</td>
<td></td>
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<tr>
<td>VT03-W</td>
<td>35%</td>
<td>65%</td>
<td>19%</td>
<td>32%</td>
<td>46%</td>
<td>4%</td>
<td></td>
</tr>
</tbody>
</table>
## Multi-Lane Calibration

### Multi-Lane Summary

<table>
<thead>
<tr>
<th>MODEL</th>
<th>LANE</th>
<th># Obs</th>
<th>None (All veh/hr)</th>
<th>pcus</th>
<th>geometry &amp;F (All Sites)</th>
<th>geometry tf; tc</th>
<th>mup&lt;6</th>
</tr>
</thead>
<tbody>
<tr>
<td>British</td>
<td>Right</td>
<td>385</td>
<td>478</td>
<td>480</td>
<td>-</td>
<td>-</td>
<td>163</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>120</td>
<td>480</td>
<td>488</td>
<td>-</td>
<td>-</td>
<td>189</td>
</tr>
<tr>
<td>German</td>
<td></td>
<td>143</td>
<td>385</td>
<td>323</td>
<td>-</td>
<td>-</td>
<td>257</td>
</tr>
<tr>
<td>French</td>
<td></td>
<td>128</td>
<td>821</td>
<td>692</td>
<td>-</td>
<td>-</td>
<td>230</td>
</tr>
<tr>
<td>Swiss</td>
<td></td>
<td>143</td>
<td>528</td>
<td>444</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>HCM Lower</td>
<td></td>
<td>143</td>
<td>272</td>
<td>320</td>
<td>-</td>
<td>-</td>
<td>372</td>
</tr>
<tr>
<td>HCM Upper</td>
<td></td>
<td>143</td>
<td>368</td>
<td>426</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>FHWA</td>
<td></td>
<td>71</td>
<td>953</td>
<td>857</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
Multi Lane Calibration

- Australian - All multilane approaches
- Lane based model

![Graph showing conflicting flow vs maximum entering flow for all right and all left approaches in Australia.](image)
Multilane Calibration

- British – All multilane approaches
- Total approach model
Multilane Calibration

- Single lane entry – correlation to entry width
Multilane Calibration

- Critical lane model - Capacity of critical lane of two-lane approach

\[ y = -0.4235x + 979.49 \]
\[ R^2 = 0.4876 \]
\[ RMSE = 145 \]

\[ y = 1227.3e^{-0.0009x} \]
\[ R^2 = 0.5747 \]
\[ RMSE = 144 \]
Delay

- HCM delay tested against field data
- Data collection limits true understanding of delay for high v/c;
- For v/c > 0.9; HCM difficult to estimate because initial queue is unknown
- Variation large; correlation factor = 0.44
- Recommendation: HCM delay equation appears to be reasonably valid
Delay

1-lane (C=q/x measured)

2-lane RL (C=q/x measured)
HCM Draft Chapter Recommendations

- 1-Lane: HCM Model (revised parameters)
- Multi-Lane: Simple regression model for critical lane
- Delay: HCM Formulae
- Additional effort to explain findings in the HCM chapter:
  - Description of first order parameters
  - Description of the lack of correlation to geometry