NCHRP 3-65: Applying Roundabouts in the United States

Preliminary Safety Findings

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Purpose

- Develop roundabout level accident models
- Develop approach level accident models
- Conduct a before-after study of roundabouts converted from signal or stop control
Overview

- Model development process
- Roundabout level models
  - Data Summary
  - Models
  - Applications
- Approach level models
  - Data Summary
  - Models
  - Applications
- Speed Models
- Before-After Study
- Summary
Model Development Process
Model development process

- Assemble volume, geometric and crash data
  - *Required variation in characteristics*
  - *Needed large enough sample size of crashes*

- Postulate model forms and identify possible variables from literature review

- Use PROC GENMOD of SAS software
  - *Negative binomial error structure*

- Model form: \( \text{Accidents} = \alpha (\text{AADT})^\beta \exp(\delta_1 X_1 + \ldots) \)

- Also estimates dispersion parameter of negative binomial distribution that is used in accident prediction
Roundabout Level Models
Roundabout Level Volume and Geometric Data

- **AADT Range**
  - Minimum – 2,700 vpd
  - Maximum – 58,600 vpd
  - Mean – 16,725 vpd
Roundabout Level SPF –
Total Crashes Per Year – Three Approaches

Total Crashes -
Roundabouts with Three Approaches

Average Daily Traffic

Total Crashes Per Year

One Lane  Two Lanes
Roundabout Level SPF
Total Crashes Per Year – Four Approaches

Total Crashes -
Roundabouts with Four Approaches
Roundabout Level Model Applications

- Intended for estimating the expected number of collisions per year at a roundabout.

- Primarily intended for doing a comparative analysis of the safety performance of a roundabout to other roundabouts or other intersection types.

- The models can be used in estimating the expected safety of a contemplated roundabout.
Approach Level Models
## Summary of Approach Level Geometric Data (120-139 arms)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inscribed Circle Diameter (ft.)</td>
<td>36</td>
<td>300</td>
<td>142.3</td>
</tr>
<tr>
<td>Entry Width (ft.)</td>
<td>7.5</td>
<td>49</td>
<td>22.0</td>
</tr>
<tr>
<td>Approach Half Width (ft.)</td>
<td>10</td>
<td>49</td>
<td>20.0</td>
</tr>
<tr>
<td>Circulating Width (ft.)</td>
<td>11.5</td>
<td>45</td>
<td>25.8</td>
</tr>
<tr>
<td>Angle To Next Leg</td>
<td>27</td>
<td>180</td>
<td>89.3</td>
</tr>
<tr>
<td>AADT</td>
<td>220</td>
<td>19,593</td>
<td>4,637</td>
</tr>
</tbody>
</table>
Other variables considered for candidate models

- Effective Flare Length (ft.)
- Entry Radius (ft.)
- Entry Angle
- Exit Width (ft.)
- Departure Width (ft.)
- Exit Radius (ft.)
- Central Island Diameter (ft.)
- 1/Entry Path Radius (1/ft.)
- 1/Circulating Path Radius (1/ft.)
- 1/Exit Path Radius (1/ft.)
- 1/Left-Turn Path Radius (1/ft.)
- 1/Right-Turn Path Radius (1/ft.)
**Approach Level Crash Data – Total Number of Crashes**

The chart illustrates the total number of approach crashes at roundabouts, categorized by crash type and lane type (Single Lane vs. Multi-Lane). The chart shows:

- **Entering Circulating**
- **Exiting/Circulating**
- **Rear End on Approach**
- **Loss of Control**
- **Pedestrian**
- **Bicycle**

The y-axis represents the total number of crashes, ranging from 0 to 200, while the x-axis categorizes the crash types and distinguishes between Single Lane and Multi-Lane conditions.
Approach Level Model Results

- Several candidate models with logical variables
  - *none with more than a few variables*
  - *estimated effects in the expected direction*

- Specific collision types (TOTAL collisions only)
  - *entering/circulating*
  - *exiting/circulating*
  - *approaching*
Approach Level Safety Performance Functions

- **Entering/Circulating Crashes Per Year**

\[ e^{-7.2158} (\text{EnteringAADT})^{0.702} (\text{CirculatingAADT})^{0.132} e^{(0.051\text{EntryWidth} - 0.028\text{AngletoNextLeg})} \]

- **Exiting/Circulating Crashes Per Year**

\[ e^{-11.6805} (\text{ExitingAADT})^{0.280} (\text{CirculatingAADT})^{0.253} e^{(0.022\text{InscribedCircleDiameter} + 0.111\text{CirculatingWidth})} \]

- **Approaching Crashes Per Year**

\[ e^{-5.1527} (\text{EnteringAADT})^{0.461} e^{(0.03\text{ApproachHalfWidth})} \]
Recommended approach level models for crashes/year

**Entering/Circulating** = \( \exp(-7.2158) \)
\((\text{Entering AADT})^{0.702}(\text{Circulating AADT})^{0.132}\)
\(\exp(0.051 \times \text{Entry Width} - 0.028 \times \text{Angle to Next Leg})\)

**Exiting/Circulating** = \( \exp(-11.6805) \)
\((\text{Exiting AADT})^{0.280}(\text{Circulating AADT})^{0.253}\)
\(\exp(0.022 \times \text{ICD} + 0.111 \times \text{Circulating Width})\)

**Approaching** = \( \exp(-5.1527) \)
\((\text{Entering AADT})^{0.461}\)
\(\exp(0.03 \times \text{Approach Half Width})\)
Approach Level Model Applications

- To understand the impacts of geometric design decisions on various collision types.
  - IHSDM applications
  - HSM applications

- Not intended as predictive models

- If so used, it is desirable to calibrate a multiplier to reflect local conditions.
% change in crashes from candidate approach level models per unit change in variable

<table>
<thead>
<tr>
<th>Variable</th>
<th>Entering/ Circulating</th>
<th>Exiting/ Circulating</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry Radius (ft.)</td>
<td>1% reduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entry Width (ft.)</td>
<td>5% increase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approach Half Width (ft.)</td>
<td></td>
<td></td>
<td>3% increase</td>
</tr>
<tr>
<td>Inscribed Circle Diameter (ft.)</td>
<td></td>
<td></td>
<td>2.2% increase</td>
</tr>
<tr>
<td>Central Island Diameter (ft.)</td>
<td>0.5 to 0.8% reduction</td>
<td>1.4% increase</td>
<td></td>
</tr>
<tr>
<td>Circulating Width (ft.)</td>
<td></td>
<td></td>
<td>12% increase</td>
</tr>
<tr>
<td>Angle To Next Leg (degree)</td>
<td>3% reduction</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Speed Based Models
Speed Based Models for Approach Level

- **Hypothesis:**
  
  *Speed profile – design model*
  
  *PLUS*
  
  *Crash - speed profile model*
  
  ➔ *Alternative crash prediction model*

- Crash models developed with AADT and observed speeds at approach, entry point, exiting point

- Models not recommended – more data needed
Before-After Study
### BEFORE-AFTER RESULTS – ALL SITES (55)

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crashes recorded in after period</td>
<td>726</td>
<td>72</td>
</tr>
<tr>
<td>EB estimate of accidents expected after without roundabouts</td>
<td>1122</td>
<td>296</td>
</tr>
<tr>
<td>Reduction (Standard error)</td>
<td>35.4% (3.4)</td>
<td>75.8% (3.2)</td>
</tr>
</tbody>
</table>
## RESULTS BY CONTROL TYPE BEFORE CONVERSION

<table>
<thead>
<tr>
<th>CONTROL BEFORE</th>
<th>All</th>
<th>Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGNALS (9)</td>
<td>48%</td>
<td>78%</td>
</tr>
<tr>
<td>TWO WAY STOP (34)</td>
<td>44%</td>
<td>82%</td>
</tr>
<tr>
<td>ALL-WAY STOP (10)</td>
<td>Insignificant increase</td>
<td></td>
</tr>
</tbody>
</table>
Results by setting and number of lanes

ALL CRASH SEVERITIES

<table>
<thead>
<tr>
<th></th>
<th>SINGLE LANE</th>
<th>MULTILANE</th>
</tr>
</thead>
<tbody>
<tr>
<td>RURAL</td>
<td>72% (9)</td>
<td>No sample</td>
</tr>
<tr>
<td>URBAN/ SUBURBAN</td>
<td>56% (16)</td>
<td>18% (11)</td>
</tr>
</tbody>
</table>
Before after study - Additional insights

- Safety benefit appears to decrease with increasing AADT
  - irrespective of control type before, number of lanes and setting

- No apparent relationship to inscribed or central island diameter.
CONCLUSIONS

- Models are reasonable and usable, but could be better
- Speed-based safety models promising but require additional data and research effort
- Solid before-after crash benefits support us being here at this conference!