Safety Performance Functions for Rural Two-Lane County Road Segments

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Background: Current SPF Limitations

- HSM SPFs for rural two-lane segments (2U) based off data from 1,331 sites on state-maintained segments in MN and WA
- Predictive accuracy varies from state to state
  - Differences in geography, design, driver behavior, etc.
- HSM recommends recalibration or full re-estimation of SPFs using local data
- Neither HSM nor state specific SPFs use data from county-maintained roadways
  - Rural, low-volume, gravel, non-federal aid
Background: Michigan Rural Road Statistics

- All 83 counties in Michigan maintain road network
- 84,000 miles of rural highway
  - 69% of Michigan’s total roadway mileage
- > 72,000 miles of county owned rural highways
  - 86% of Michigan’s rural highway mileage
  - 60% of Michigan’s total roadway mileage
  - 4th largest county road system in US
- 60% of rural crashes occur on county roads
Objective

- Develop fully-specified SPFs for county-maintained highway segments in Michigan
  - Rural, 55 mph
  - Paved and gravel
  - Federal aid (FA) and non-federal aid (non-FA)
  - Broad statewide geographic distribution
Data Collection: Geographic Scope

- 29 counties
- All regions of the state
- Excluded all incorporated areas and census designated places
- Min. segment length: 0.2 mi
# Data Collection: Data Sources

<table>
<thead>
<tr>
<th>Data</th>
<th>Fed Aid Segments</th>
<th>Non-Fed Aid Segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>AADT</td>
<td>MDOT database</td>
<td>County road commissions, RPCs</td>
</tr>
<tr>
<td>Lane Width</td>
<td>Manual review (Google Earth)</td>
<td></td>
</tr>
<tr>
<td>Shoulder Width</td>
<td>Manual review (Google Earth)</td>
<td></td>
</tr>
<tr>
<td>Driveway Counts</td>
<td>Manual review (Google Earth)</td>
<td></td>
</tr>
<tr>
<td>Horizontal Curvature</td>
<td>MSU database</td>
<td></td>
</tr>
<tr>
<td>Crashes</td>
<td>Michigan State Police database</td>
<td></td>
</tr>
</tbody>
</table>
## Summary Statistics

### AADT

<table>
<thead>
<tr>
<th></th>
<th>Paved FA</th>
<th>Paved Non-FA</th>
<th>Low Volume Non-FA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Paved</td>
</tr>
<tr>
<td>Min</td>
<td>251</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Max</td>
<td>12,781</td>
<td>12,628</td>
<td>399</td>
</tr>
<tr>
<td>Mean</td>
<td>1,789</td>
<td>572</td>
<td>133</td>
</tr>
</tbody>
</table>

### Annual Midblock Segment Crashes (per Mile)

<table>
<thead>
<tr>
<th></th>
<th>Paved FA</th>
<th>Paved Non-FA</th>
<th>Low-Volume Non-FA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Paved</td>
</tr>
<tr>
<td>Non-Deer PDO Crashes</td>
<td>0.43</td>
<td>0.15</td>
<td>0.07</td>
</tr>
<tr>
<td>Non-Deer FI Crashes</td>
<td>0.17</td>
<td>0.06</td>
<td>0.03</td>
</tr>
<tr>
<td>Deer Crashes</td>
<td>1.10</td>
<td>0.37</td>
<td>0.17</td>
</tr>
<tr>
<td>Total Crashes</td>
<td>1.70</td>
<td>0.58</td>
<td>0.27</td>
</tr>
<tr>
<td>Deer Crashes, % of Total</td>
<td><strong>64.7%</strong></td>
<td><strong>63.8%</strong></td>
<td><strong>63.2%</strong></td>
</tr>
</tbody>
</table>

HSM Data from Washington State included 12% animal crashes.
Summary Statistics

Paved FA

- Major Collector: 88%
- Minor Arterial: 12%
- Average Segment Length: 0.52 mi
- Total Length: 3,616 mi

Paved Non-FA

- Local Road: 80%
- Minor Collector: 19%
- Average Segment Length: 0.58 mi
- Total Length: 1,398 mi

Low Volume Non-FA (Paved and Gravel)

- Local Road: 94%
- Minor Collector: 6%
- Average Segment Length: 0.57 mi
- Total Length: 1,984 mi
Analytical Method

- Crashes are non-negative integers
- Poisson assumption: Variance equals mean
  - Crash data typically over-dispersed -> Negative binomial
  \[ \lambda_{ij} = \exp(\beta X_{ij} + \epsilon_{ij}) \]
  - \(X_i\) = vector of estimable parameters
  - \(\beta\) = parameter estimate
  - \(\epsilon\) = gamma distributed term with mean 0 and variance \(\alpha\)

- Multiple counties with different design standards
  - County-specific random effect (panel data)
  \[ \lambda_{ij} = \exp(\beta X_{ij} + \epsilon_{ij} + \eta_{ij}) \]
  - \(j\) = county panel indicator
  - \(\eta\) = gamma distributed term with mean 0 and variance \(\alpha\)
Model Interpretation

- Estimation of crashes from RENB takes the form:

\[ N = \exp(\beta_o + \beta_i X_i) \]

Where:
- \( \beta_o \) = intercept term,
- \( X_i \) = vector of estimable parameters,
- \( \beta_i \) = parameter estimate

- This can be simplified to the following:

\[ N = e^{\beta_o} \times \text{Segment Length} \times AADT^{\beta_1} \times CMF_i \]

Where:
- \( CMF_i = \exp(\beta_i) \)

- Interpretation of CMFs:
  - CMF>1: Increase in crashes
  - CMF<1: Decrease in crashes

  - Percent reduction in crashes: \( 100 \times (1 - CMF) \)
  - Percent increase in crashes: \( 100 \times (CMF - 1) \)
SPF Functional Form: Paved Federal Aid Segments

\[ N\downarrow_{\text{MIDDE tot}} = e^{\uparrow - 5.99} \times (\text{Segment Length}) \times \text{AADT}^{\uparrow 0.71} \times \text{CMF} \]

\[ N\downarrow_{\text{MIDDE FI}} = e^{\uparrow - 7.43} \times (\text{Segment Length}) \times \text{AADT}^{\uparrow 0.759} \times \text{CMF} \]

Where:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>KABCO CMF</th>
<th>FI CMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence of curve with design speed &lt; 55 mph</td>
<td>1.56</td>
<td>1.54</td>
</tr>
<tr>
<td>Lane width &gt;12 ft</td>
<td>Not Significant</td>
<td>0.73</td>
</tr>
<tr>
<td>10 to 15 driveways per mile</td>
<td>1.07</td>
<td>Not Significant</td>
</tr>
<tr>
<td>15 driveways per mile or greater</td>
<td>1.15</td>
<td>Not Significant</td>
</tr>
</tbody>
</table>
Results: Paved Federal Aid Segments

KABCO Crashes

- Curve
- 15+ driveways
- 10-15 driveways
- Base

FI Crashes

- Curve
- Base
- Lane Width >12 ft

Estimated Mean Non-Deer Midblock Crashes per Mile vs. AADT
SPF Functional Form:
Paved Non Federal Aid Segments

\[ N_{\text{MIDDE\_tot}} = e^{\uparrow -6.23 \times (\text{Segment Length}) \times AADT \uparrow 0.73} \times CMF \]

\[ N_{\text{MIDDE\_FI}} = e^{\uparrow -7.94 \times (\text{Segment Length}) \times AADT \uparrow 0.787} \times CMF \]

Where:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>KABC0 CMF</th>
<th>FI CMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence of curve with design speed &lt; 55 mph</td>
<td>1.45</td>
<td>1.76</td>
</tr>
</tbody>
</table>
Functional Form of SPF: Low Volume Non Federal Aid Segments

\[ N_{\text{MIDDE} \_ \text{tot}} = e^{\uparrow-5.55 \times (\text{Segment Length}) \times \text{AAD} \times 0.674} \times \text{CMF} \]

\[ N_{\text{MIDDE} \_ \text{FI}} = e^{\uparrow-6.19 \times (\text{Segment Length}) \times \text{AAD} \times 0.584} \times \text{CMF} \]

Where:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>KABCO CMF</th>
<th>FI CMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence of curve with design speed &lt; 55 mph</td>
<td>1.96</td>
<td>2.03</td>
</tr>
<tr>
<td>Paved surface</td>
<td>0.67</td>
<td>0.58</td>
</tr>
</tbody>
</table>
Comparison of Base SPFs

Mean Estimated KABCO Non-Deer Crashes per Mile vs. AADT

- HSM
- FA
- MDOT
- Non-FA
Curve CMF

Mean Estimated KABC Non-Deer Crashes per Mile

- FA Curve
- Non-FA Curve
- MDOT Curve
- FA Base
- MDOT Base
- Non-FA Base

AADT
Pavement Surface CMF (Low Volume)

Mean Estimated KABCO Non-Deer Crashes per Mile vs. AADT

- Gravel
- Paved
- HSM
- MDOT
Conclusions

- Paved non-FA segments performed the best
  - FA segments showed similar performance
  - HSM models more linear than county models
    - Over-predict at high volumes, under-predict at low volumes
  - MDOT models under-predict relative to county models

- Gravel roads showed the highest crash occurrence rates, particularly for PDO crashes and curved segments
  - Reduced surface friction
  - Poorer maintenance
  - Less aggressive snow removal
  - Reduced roadside clear zone
  - Lower speeds?
Conclusions

- Presence of a horizontal curve <55 mph was positively correlated with crashes across all segment types
  - Speeds too fast
  - Limited sight distance
- Driveways increased total crash occurrence on FA
  - 10-15 ➔ 7% increase
  - 15+ ➔ 15% increase
- Effects of lane width and shoulder width were mostly inconclusive
  - Lane width significant for FI crashes on federal aid segments (most similar to state highways)
Limitations

- Dataset limited to Michigan
  - Gathering data was a laborious process – not feasible for most states to develop their own county SPFs
    - Calibration is a possibility
- Roadside data unavailable
  - Clear zone, foreslope, etc.
- Inconsistent design and maintenance practices between counties
- Cross-sectional study
  - Use pavement type CMF with caution (not B&A)
  - Crash reductions reflect equal AADTs
    - If a gravel road is paved, will traffic migrate to this road?
Questions?

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- MDOT report available by Googling “MDOT SPR 1645”