New Conflict Point Crash Prediction Method

NCDOT Webinar

Presenters: Thomas Chase
Chris Cunningham
Taehun Lee

NCDOT Moderators: Joseph Hummer, Daniel Carter
NCDOT Research Engineer: Lisa Penny

09/23/2020
Overview

• Introduction
• Existing Methodologies
• Concept and Framework
• Model Development
• Results
• Hands-on Exercise
• Summary and Conclusions
NCDOT Research Project

2018-20: Reasonable Alternatives for Grade Separated Intersections

Objective: Identify alternatives to interchange designs for separation at arterial intersections and

Research Goal: To develop the operational and safety performance evaluation methods for grade-separated intersection designs
Motivation

Safety Analysis

• Design Alternatives
• Countermeasure Effectiveness
• Hotspot Identification
• System Performance
• Benefit Cost Analysis
# Planning Level Safety

**Simplified Methods:** Detailed analysis and data collection are not needed at this scale of safety analysis.

**Combine Judgement and Data:** Selection of alternatives to compare can be done manually—consider both published results and learned experience.

**Project Specific:** If a particular component of safety is the purpose of the project, be sure to address that component.

<table>
<thead>
<tr>
<th>Intro</th>
<th>Existing</th>
<th>Concept</th>
<th>Development</th>
<th>Results</th>
<th>Hands-on</th>
<th>Conclusions</th>
</tr>
</thead>
</table>

http://www.itre.ncsu.edu
Before and After Safety Study

**Rigorous:** Data collection and analysis methods are strictly established and replicable

**Quantifiable:** Outcomes are measured with well-defined Measures of Effectiveness

**Targeted:** Methods and MOEs are selected to best capture the countermeasure or improvement
Existing Planning-Level Safety Methods for Intersections
Safety Analysis – Conflict Points

Traditional Planning Level Method: Comparison of Conflict Points

A simple conflict point (CP) comparison method assumes that the number of total CPs is directly correlated to safety performance.

<table>
<thead>
<tr>
<th>Conflict Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing</td>
<td>16</td>
</tr>
<tr>
<td>Merging</td>
<td>8</td>
</tr>
<tr>
<td>Diverging</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
</tr>
</tbody>
</table>

Conventional
Safety Analysis – Conflict Points

Traditional Planning Level Method: Comparison of Conflict Points

- This method does not account for the individual conflict point types or perform any crash prediction.

<table>
<thead>
<tr>
<th>Conflict Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing</td>
<td>12</td>
</tr>
<tr>
<td>Merging</td>
<td>8</td>
</tr>
<tr>
<td>Diverging</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>28</strong></td>
</tr>
</tbody>
</table>

Displaced Left Turn
Safety Analysis – Conflict Points

Traditional Planning Level Method: Comparison of Conflict Points

• While the method is very simplified, the comparison can be performed for any intersection type including proposed designs which have not been built.

<table>
<thead>
<tr>
<th>Conflict Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing</td>
<td>2</td>
</tr>
<tr>
<td>Merging</td>
<td>6</td>
</tr>
<tr>
<td>Diverging</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
</tr>
</tbody>
</table>

Restricted Crossing U-Turn

Intro | Existing | Concept | Development | Results | Hands-on | Conclusions
--- | --- | --- | --- | --- | --- | ---
Safety Analysis – Weighted Conflicts

Weighted Conflict Points - VJuST (Virginia DOT)

- Research shows that crash severities are higher at crossing conflict points compared to diverging and merging conflicts.

<table>
<thead>
<tr>
<th>Crashes</th>
<th>Number of Crashes</th>
<th>FI Rate (%)</th>
<th>Average Crash Rate (crashes/year·million entering veh)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>FI</td>
<td>PDO</td>
</tr>
<tr>
<td>Total</td>
<td>1,838</td>
<td>566</td>
<td>1,272</td>
</tr>
<tr>
<td>NCP</td>
<td>1,275</td>
<td>321</td>
<td>954</td>
</tr>
<tr>
<td>CP Crashes</td>
<td>563</td>
<td>245</td>
<td>318</td>
</tr>
<tr>
<td>- Crossing</td>
<td>410</td>
<td>205</td>
<td>205</td>
</tr>
<tr>
<td>- Diverging</td>
<td>101</td>
<td>28</td>
<td>73</td>
</tr>
<tr>
<td>- Merging</td>
<td>52</td>
<td>12</td>
<td>40</td>
</tr>
</tbody>
</table>

* Note: the statistics in the table are based on the crash data collected for later model development
Weighted Conflict Points - VJuST (Virginia DOT)

- The VDOT accounted for the different crash severity for CP types by weighting system.

- This method still cannot account for different crash rates for CP types and the impact of traffic volume on crash frequency.

[ VJuST Safety Evaluation Process, Virginia DOT]
CMFs – Crash Modification Factors

- The Highway Safety Manual defines Safety Performance Functions (SPFs) which estimate crashes given geometry and AADT.

- For intersections, these functions differ based on number of approaches and control types.

- SPFs estimate base crash rates for the conditions and must be adjusted for any countermeasures.
### CMFs – Crash Modification Factors

- Crash Modification Factors are multipliers to the base estimated crashes.
- CMFs can only be developed once a crash history exists.
- Not all CMFs are created equal!
  - Sample Size
  - Comparison Sites or Control
  - Potential Bias
  - Diverse Geography
- Projects with multiple countermeasures – be wary of directly applying all CMFs!
CMFs – Crash Modification Factors

The Crash Modification Factors Clearinghouse provides a searchable database of CMFs along with guidance and resources on using CMFs in road safety practice.

WHAT ARE CMFs?
A crash modification factor (CMF) is used to compute the expected number of crashes after implementing a countermeasure on a road or intersection.

GETTING STARTED
Learn more about how to use this site in our User Guide section.

CHANGE AHEAD
The CMF Clearinghouse will transition to the CMF rating criteria developed as part of the NCHRP 57-72 project for the 2nd edition of the Highway Safety Manual.

Intro | Existing | Concept | Development | Results | Hands-on | Conclusions

http://www.itre.ncsu.edu
Movement-based Safety Performance Functions - Concepts

<table>
<thead>
<tr>
<th>Intro</th>
<th>Existing</th>
<th>Concept</th>
<th>Development</th>
<th>Results</th>
<th>Hands-on</th>
<th>Conclusions</th>
</tr>
</thead>
</table>

http://www.itre.ncsu.edu
**Movement-Based Safety Performance Functions (MB-SPFs)**

<table>
<thead>
<tr>
<th>Concept</th>
<th>Safety Performance Functions (SPFs)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conflict Point Analysis (VJuST)</strong></td>
<td><strong>Can account for the impact of traffic volume</strong></td>
</tr>
<tr>
<td>• Can compare the safety between ALIs&lt;br&gt;• Cannot account for the impact of traffic volume</td>
<td><strong>Not applicable to the safety evaluation of ALIs</strong></td>
</tr>
<tr>
<td><strong>Movement-Based SPFs (MB-SPFs)</strong></td>
<td></td>
</tr>
<tr>
<td>• Classifies crashes into CP and NCP crashes and estimates to models: CP-SPF &amp; NCP-SPF&lt;br&gt;• Predicts the CP and NCP crashes separately, and then sums them to predict the intersection total crashes.&lt;br&gt;• Can account for the impact of traffic volume and the different crash risk for CP types&lt;br&gt;• Applicable to any intersection geometry for safety performance evaluation&lt;br&gt;• Can be used to analyze safety impacts of intersections not currently in service.</td>
<td></td>
</tr>
</tbody>
</table>
MB-SPF Concepts

Conflict Point (CP) vs Non-Conflict Point (NCP) Crashes

Grandiflora

Westgate

Intro | Existing | Concept | Development | Results | Hands-on | Conclusions

http://www.itre.ncsu.edu
MB-SPF Concepts

Assigning CP Crashes

<table>
<thead>
<tr>
<th>Intro</th>
<th>Existing</th>
<th>Concept</th>
<th>Development</th>
<th>Results</th>
<th>Hands-on</th>
<th>Conclusions</th>
</tr>
</thead>
</table>

http://www.itre.ncsu.edu
MB-SPF Concepts

Estimating Total Crashes

- Conflict Point #1 Crashes
- Conflict Point #N Crashes
- Total Conflict Point Crashes
- Non-Conflict Point Crashes
- Total Intersection Crashes
- Model Runs
- Sum

<table>
<thead>
<tr>
<th>Intro</th>
<th>Existing</th>
<th>Concept</th>
<th>Development</th>
<th>Results</th>
<th>Hands-on</th>
<th>Conclusions</th>
</tr>
</thead>
</table>

http://www.itre.ncsu.edu
MB-SPF Model Development
MB-SPF Model Development

MB-SPF Data Needs

• Conventional and Alternative Intersections

• Specific Movement Types
  – Crossover
  – Channelized Lane
  – Ramp Merge
  – U-Turn

• Distribution of Congestion Level
Data Collection

• The crash and traffic volume data are collected from 35 sites\(^1\) in NC

- Crash data
  - Crash Type & Location
  - Vehicle Maneuver
  - Crash Severity

- Traffic Volume
  - Turning Movement Counts\(^2\)
  - AADT

1) Each intersection may include multiple signalized zones in an alternative intersection. In this study, we considered each zone as a site.

2) TM counts are observed for 11 ~ 16 hours a day (avg = 13.7 hours). (6AM-7PM: 14 sites, 6AM-10PM: 14 sites, 7AM-6PM: 4 sites, 7AM-7PM: 7 sites)
MB-SPF Model Results
Safety Analysis – Analysis Results

Model Estimation Results

- The models are estimated for crash severities, TOT (Total), FI (Fatal & Injury), and PDO (Property Damage Only) crashes, using the Negative Binomial (NB) regression model.

- The results for CP-SPF show the impact of crossing CP on the crash frequency is significantly higher than the other two (diverging and merging) in all three severity models.

<table>
<thead>
<tr>
<th>MB-SPFs</th>
<th>TOT Model</th>
<th>FI Model</th>
<th>PDO Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP-SPF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \alpha_{\text{Crossing}} )</td>
<td>-8.501 ***</td>
<td>-8.267 ***</td>
<td>-10.160 ***</td>
</tr>
<tr>
<td>( \alpha_{\text{Diverging}} )</td>
<td>-9.873 ***</td>
<td>-10.464 ***</td>
<td>-11.073 ***</td>
</tr>
<tr>
<td>( \alpha_{\text{Merging}} )</td>
<td>-9.316 ***</td>
<td>-9.706 ***</td>
<td>-10.571 ***</td>
</tr>
<tr>
<td>( \beta_{\text{CMV Major}} )</td>
<td>0.689 ***</td>
<td>0.663 ***</td>
<td>0.749 ***</td>
</tr>
<tr>
<td>( \beta_{\text{CMV Minor}} )</td>
<td>0.109 *</td>
<td>0.015</td>
<td>0.166 **</td>
</tr>
<tr>
<td>NCP-SPF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \alpha )</td>
<td>-10.874 ***</td>
<td>-6.885 ***</td>
<td>-13.618 ***</td>
</tr>
<tr>
<td>( \beta_{\text{AADT Major}} )</td>
<td>0.792 ***</td>
<td>0.531 **</td>
<td>0.828 ***</td>
</tr>
<tr>
<td>( \beta_{\text{AADT Minor}} )</td>
<td>0.521 ***</td>
<td>0.229 ***</td>
<td>0.742 ***</td>
</tr>
</tbody>
</table>

Statistical Significance Codes: ‘***’ < 0.001, ‘**’ < 0.01, ‘*’ < 0.05, ‘.’ < 0.1
Model Estimation Results

- One major concern with fitting safety data is over-fitting or biasing the model to a set of predictor variables.
Safety Analysis – Analysis Results

Safety Performance Comparison

- Overall, the contra-RCUT and RCUT (R-U) showed good performance, and the DL-Downstream and Quadrant Left (SE) showed poor performance than others.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Approach Volume</th>
<th>Conflict Points</th>
<th>Base</th>
<th>Direct Left Downstream</th>
<th>Direct Left Upstream</th>
<th>Single Point</th>
<th>RCUT</th>
<th>Contra-RCUT</th>
<th>RCUT (Right then U-turn)</th>
<th>Quadrant (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EBN-WBN</td>
<td>EB: 50% WB: 50%</td>
<td>36</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EBT-WBL</td>
<td>EB: 60% WB: 40%</td>
<td>7.876</td>
<td>2.23</td>
<td>2.06</td>
<td>2.04</td>
<td>1.52</td>
<td>1.46</td>
<td>1.50</td>
<td>2.45</td>
<td></td>
</tr>
<tr>
<td>EBN-WBN</td>
<td>EB: 50% WB: 50%</td>
<td>7.936</td>
<td>2.28</td>
<td>2.08</td>
<td>2.05</td>
<td>1.54</td>
<td>1.47</td>
<td>1.50</td>
<td>2.33</td>
<td></td>
</tr>
<tr>
<td>EBT-WBL</td>
<td>EB: 60% WB: 40%</td>
<td>7.683</td>
<td>2.17</td>
<td>2.03</td>
<td>2.00</td>
<td>1.48</td>
<td>1.42</td>
<td>1.48</td>
<td>2.29</td>
<td></td>
</tr>
</tbody>
</table>

Low CP Crashes                  High CP Crashes
Hands-On Examples

capxnc.itredatalab.org
Recommendations

• For new intersection designs, CMFs are not yet available
• Current practice is to measure number of conflict points, VJuST uses weighting factors
• Proposed Movement-Based Safety Performance Functions enable safety screening with planning-level data
• MB-SPF need daily turning movement data
• Definition of conflict point order based on geometry
• MB-SPF has preliminary validation underway but many planned improvements
• MB-SPF method can be applied to existing designs as well for planning-level comparison
Opportunities for Improvement

- Control Type for CP
- Extra Travel Distance for All
- Larger Crash Database
- Pedestrian/Bicycle Crash Prediction
- Time of Day
- Clearly Defining CP vs NCP Crash Types
- Interchange, One-way streets, Roundabouts
Acknowledgements

Research Team
• Thomas Chase
• Christopher Cunningham
• Shannon Warchol
• Chris Vaughan
• Taehun Lee

NCDOT Steering Committee
• Joseph Hummer (chair)
• Lisa Penny
• Stephen Bolyard
• Kevin Lacy
• Katie Hite

• Jim Dunlop
• Brian Mayhew
• Mike Reese
• Daniel Carter
• Brian Murphy
Reference Links

NCDOT Research Project 2018-20

NCDOT Safety and Mobility Initiatives

VJuST Tool and Innovative Intersection Website – Good Graphics

ITRE DataLab- Research Tools and Datasets
Questions?