New Conflict Point Crash Prediction Method

NCDOT Webinar

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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

Introduction

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

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

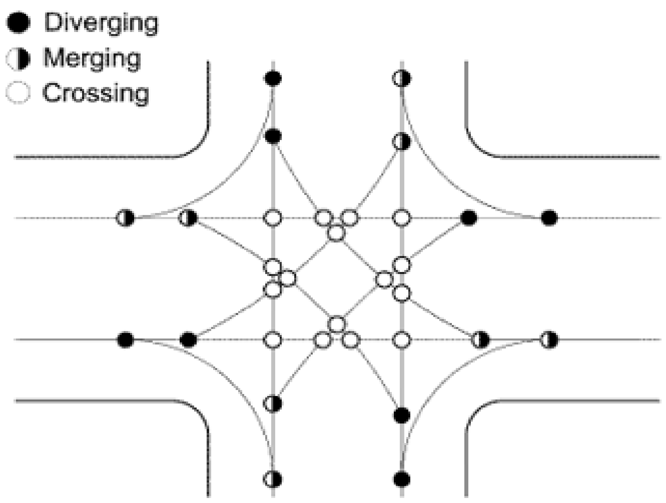
Targeted: Methods and MOEs are selected to best capture the countermeasure or improvement

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.



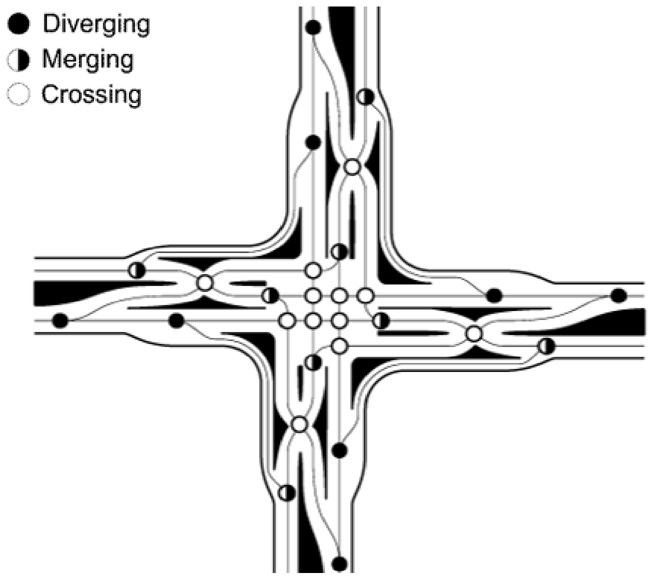
Conventional

Conflict Type	Count
Crossing	16
Merging	8
Diverging	8
Total	**32**

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.



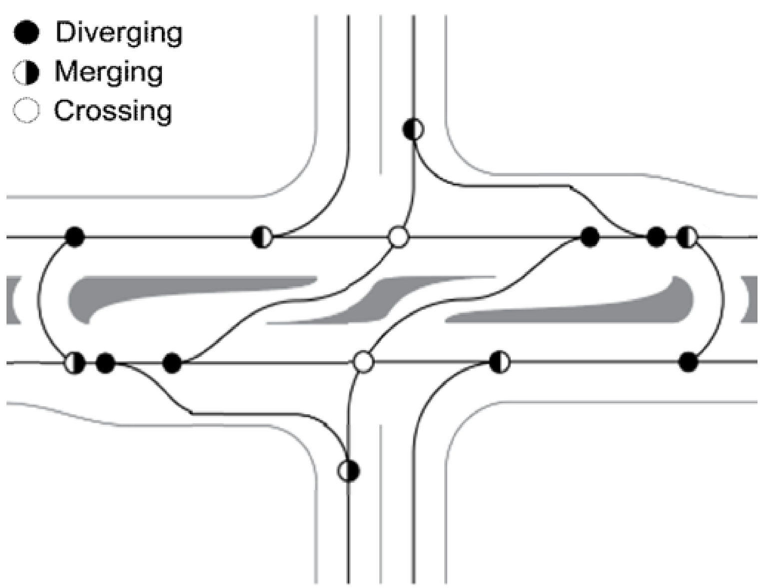
Displaced Left Turn

Conflict Type	Count
Crossing	12
Merging	8
Diverging	8
Total	**28**

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.



Restricted Crossing U-Turn

Conflict Type	Count
Crossing	2
Merging	6
Diverging	6
Total	**14**

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.

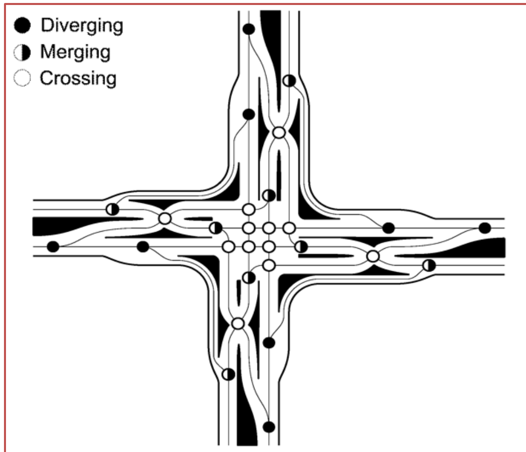
Crashes	Number of Crashes			FI Rate (%)	Average Crash Rate (crashes/year·million entering veh)		
	Total	FI	PDO		Total	FI	PDO
Total	1,838	566	1,272	30.8	0.651	0.225	0.426
NCP	1,275	321	954	25.2	0.434	0.125	0.309
CP Crashes	563	245	318	43.5	0.217	0.100	0.117
- Crossing	410	205	205	50.0	0.183	0.097	0.085
- Diverging	101	28	73	27.7	0.019	0.005	0.014
- Merging	52	12	40	23.1	0.047	0.012	0.035

* Note: the statistics in the table are based on the crash data collected for later model development

Safety Analysis – Weighted Conflicts

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.



Conflict Type	Count
Crossing	12
Merging	8
Diverging	8
Total	**28**

Step 1
Count the Conflict Points

Conflict Type	Weight
Crossing	2
Merging	1
Diverging	1

Step 2
Weight x CPs

Weighted Total Conflict Points

40

Step 3
Weighted Total Conflict Points

[VJuST Safety Evaluation Process, Virginia DOT]

Safety Analysis – Crash Modification Factors

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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

Safety Analysis – Crash Modification Factors

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!

Safety Analysis – Crash Modification Factors

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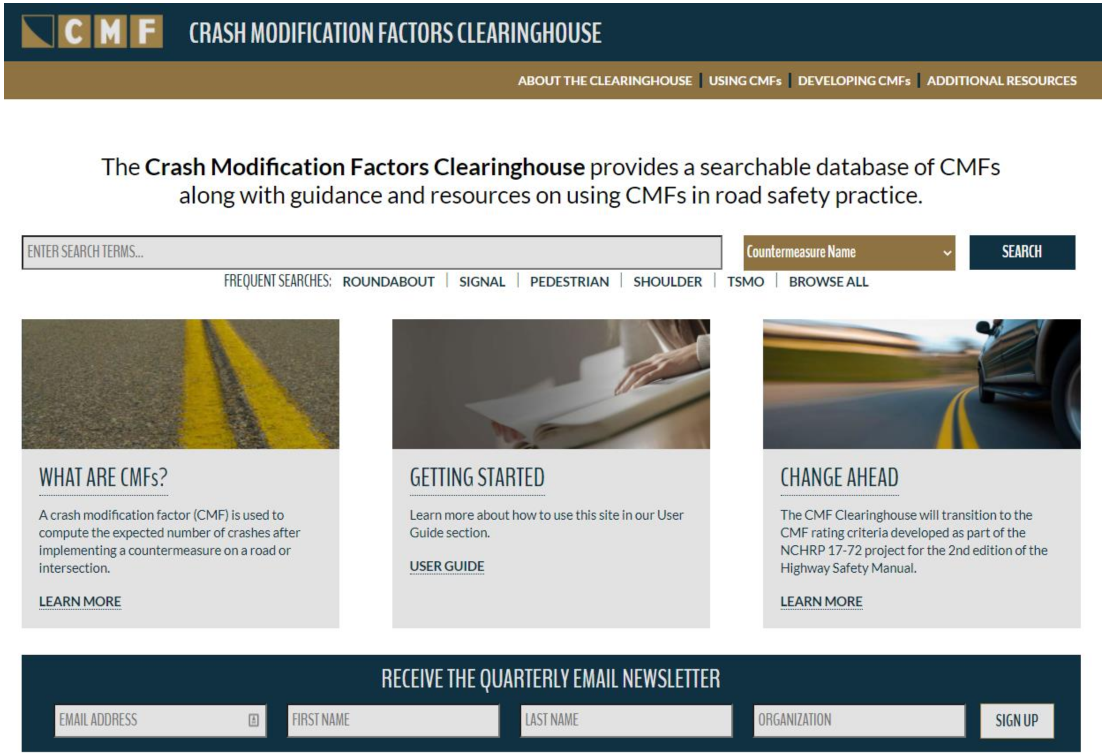
CMFs – Crash Modification Factors



Movement-based Safety Performance Functions - Concepts

MB-SPF Concepts

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Movement-Based Safety Performance Functions (MB-SPFs)

Conflict Point Analysis (VJuST)

- Can compare the safety between AIIs
- Cannot account for the impact of traffic volume

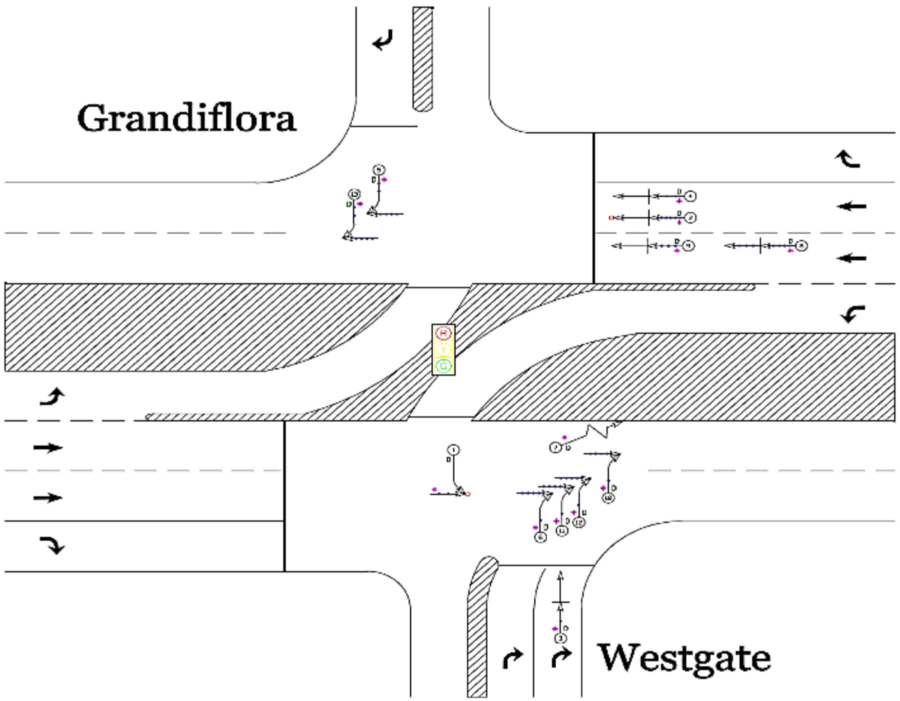
Safety Performance Functions (SPFs)

- Can account for the impact of traffic volume
- Not applicable to the safety evaluation of AIIs

Movement-Based SPFs (MB-SPFs)

- Classifies crashes into CP and NCP crashes and estimates to models: CP-SPF & NCP-SPF
- Predicts the CP and NCP crashes separately, and then sums them to predict the intersection total crashes.
- Can account for the impact of traffic volume and the different crash risk for CP types
- Applicable to any intersection geometry for safety performance evaluation
- Can be used to analyze safety impacts of intersections not currently in service.

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



MB-SPF Concepts

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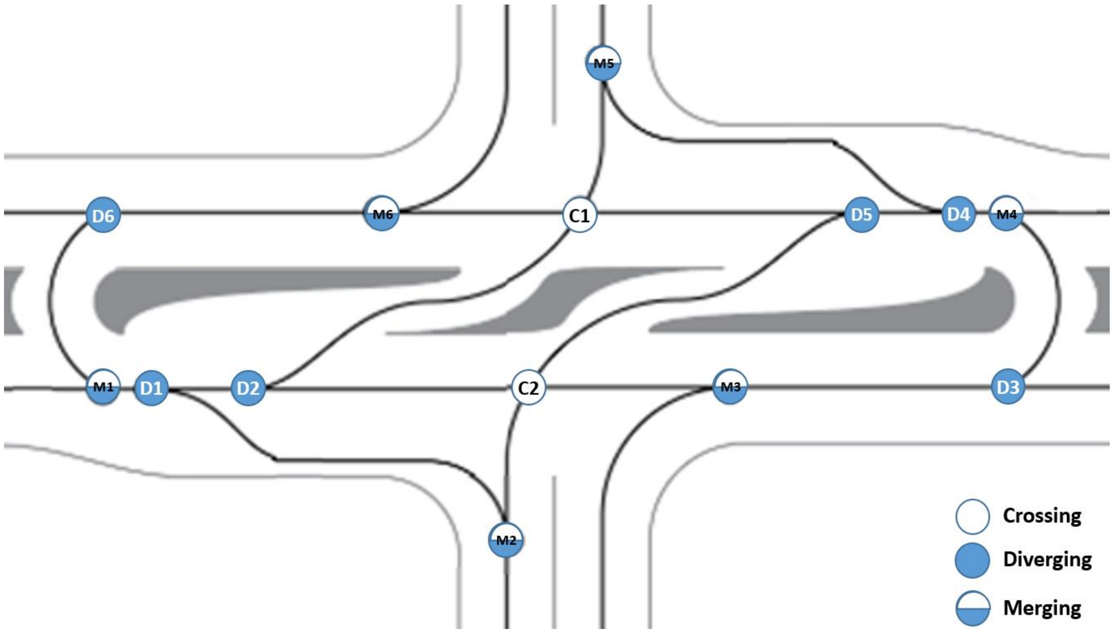
Assigning CP Crashes



MB-SPF Concepts

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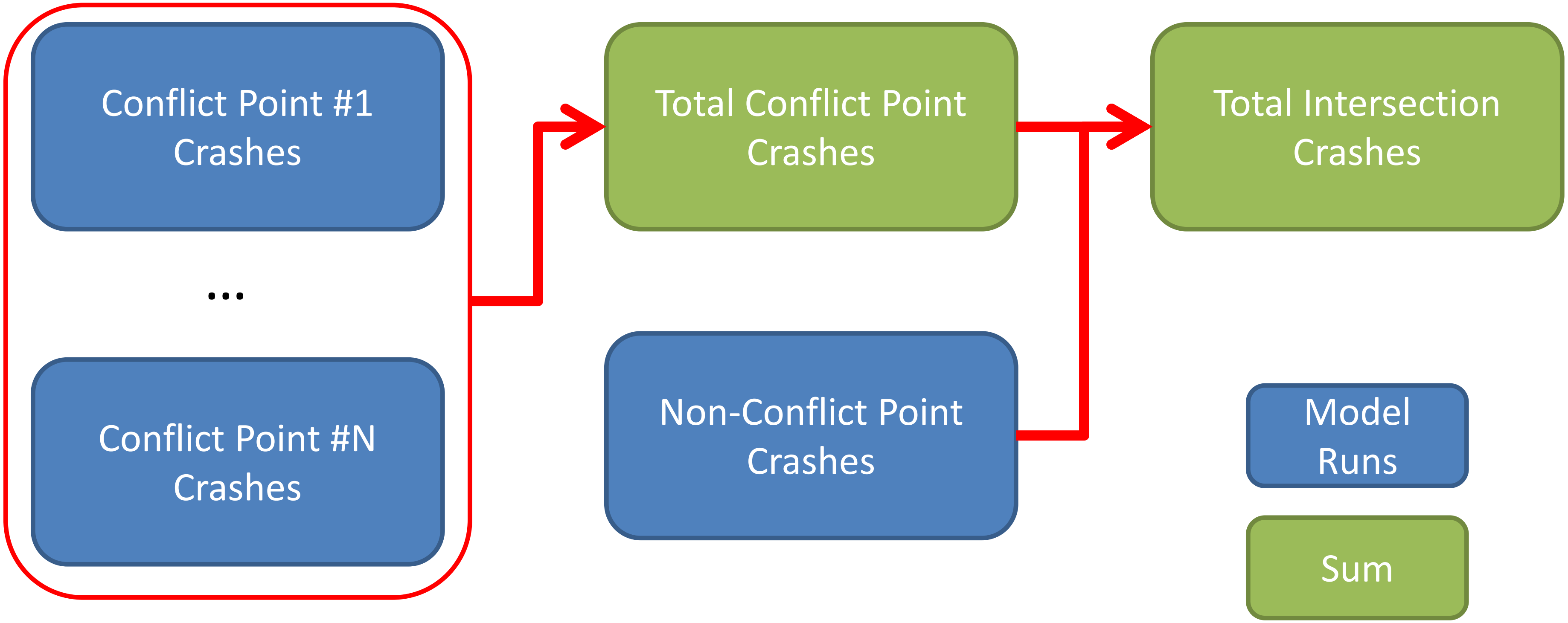
Estimating Total Crashes



MB-SPF Model Development

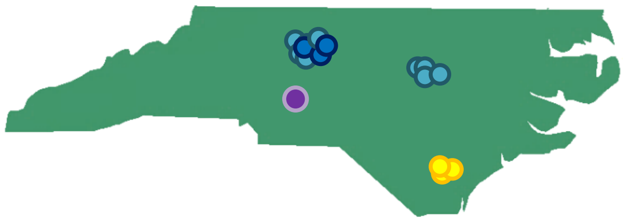
MB-SPF Model Development

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



- 15 Conventional Intersections (4SG)
- 6 Conventional with Channelized Lane (4SG)
- 11 Partial Restricted Crossing U-Turn (RCUT)
- 3 Diverging Diamond Interchange (DDI)

- **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.

MB-SPFs	TOT Model		FI Model		PDO Model	
CP-SPF	**Coefficient**	**Sig.**	**Coefficient**	**Sig.**	**Coefficient**	**Sig.**
$\alpha_{Crossing}$	-8.501	***	-8.267	***	-10.160	***
$\alpha_{Diverging}$	-9.873	***	-10.464	***	-11.073	***
$\alpha_{Merging}$	-9.316	***	-9.706	***	-10.571	***
$\beta_{CMV_{Major}}$	0.689	***	0.663	***	0.749	***
$\beta_{CMV_{Minor}}$	0.109	*	0.015		0.166	**
NCP-SPF	**Coefficient**	**Sig.**	**Coefficient**	**Sig.**	**Coefficient**	**Sig.**
α	-10.874	***	-6.885	***	-13.618	***
$\beta_{AADT_{Major}}$	0.792	***	0.531	**	0.828	***
$\beta_{AADT_{Minor}}$	0.521	***	0.229	***	0.742	***

Statistical Significance Codes: '***' < 0.001, '**' < 0.01, '*' < 0.05, '.' < 0.1

Safety Analysis – Analysis Results

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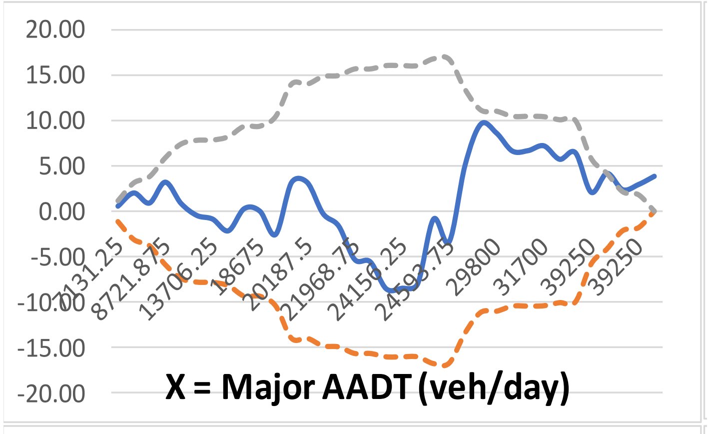
Model Estimation Results

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



CP-SPF Model Estimation Results Cumulative Residuals

Safety Analysis – Analysis Results

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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.

Conflict Points		36	10	10	10	8	8	8	9
Scenario	Approach Volume	Base Conventional	Direct Left Downstream	Direct Left Upstream	Single Point	RCUT	Contra-RCUT	RCUT (Right then U-turn)	Quadrant (SE)
EBN-WBN	EB: 50% WB: 50%	7.815	2.19	2.06	2.02	1.51	1.45	1.50	2.13
EBT-WBL		7.936	2.28	2.08	2.05	1.54	1.47	1.50	2.33
EBN-WBN	EB: 60% WB: 40%	7.683	2.17	2.03	2.00	1.48	1.42	1.48	2.29
EBT-WBL		7.876	2.23	2.06	2.04	1.52	1.46	1.50	2.45

Low CP Crashes High

Hands-On Examples

capxnc.itredatalab.org

Safety Analysis - Recommendations

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

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- Daniel Carter
- Brian Murphy

Reference Links

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[NCDOT Research Project 2018-20]

[NCDOT Safety and Mobility Initiatives]

[VJuST Tool and Innovative Intersection Website – Good Graphics]

[ITRE DataLab- Research Tools and Datasets]

Intro	Existing	Concept	Development	Results	Hands-on	Conclusions

Questions?