
Andrew Ooms
November 2012

Outline

▷ Safety Overview
  ▪ Current practices
  ▪ Safety Fundamentals
▷ Introduction the Highway Safety Manual
  ▪ Part C Predictive Method
  ▪ Part D Crash Modification Factors
▷ Crash Prediction in Alternatives Evaluation
  ▪ Methodology
  ▪ Example Applications
  ▪ Calibration
▷ Applications in Alaska
Presentation Goals

- Provide overview of safety concepts
- Share new quantitative tools
  - Supplement current safety practices
  - Add reliability and capabilities to safety evaluation
  - Provide quantitative safety performance for existing and new facilities
  - Enhance message to decision makers
- Discuss crash prediction applications in Alaska

OVERVIEW OF SAFETY
What if,…

...you were asked to evaluate the safety performance of these seven alternatives?

![Image of alternatives table]

Current Common Safety Practices

- System Planning: Identify high-crash locations
  - Crash frequency, crash rate, or severity
  - Some combination of these performance measures

  - **Example: Oregon DOT SPIS List**
    - Weighted average of frequency, rate, and severity
    - Performance measure: highest ranked 5-10% of segments

  - **Example: ADOT&PF HSIP List**
    - Intersections
      - Critical crash method; safety ratio > 0.90
      - 1 fatality or 2 major injuries
    - Segments
      - 1 fatality or 2 major injuries
Current Common Safety Practices

- Project Planning through Design
  - Non-Safety Focused Projects
    - Design Standards as a Surrogate for Safety
    - Engineering Judgment
    - Peer Review Process
  - Safety Focused Projects
    - Crash Reduction Factors
    - Design Standards as a Surrogate for Safety
    - Engineering Judgment
    - Peer Review Process

- Operations and Maintenance
  - Signing and Pavement Marking Inventories/Maintenance
  - Pavement Quality Inventories/Maintenance

Why do something different?

- Able to measure safety objectively (i.e., quantitatively)

- New tools build on and enhance current practice
  - Improve reliability
  - Provide new capabilities (e.g., predicting crashes, new facilities)
  - Able to quantify safety and compare with other project advantages and disadvantages (e.g., costs, operations, ROW)

- Opportunities to incorporate new tools and methods in the near-term and plan for further integrating them in the long-term
  - No need to do everything at once
  - New tools/methods can provide value to decision making now
Integrating Safety

- Safety integration throughout project development process
  - Quantify safety performance
  - Comprehensively address safety issues
  - Cost-effectively reduce crashes

Overview of Tools and Methods

- Safety Analyst
- HiSafe
- FHWA Developing Quality CMFs
- FHWA CMF Clearinghouse
- Highway Safety Manual
- Transportation Safety Reviews
- IHSDM
- PlanSafe
- PBCAT (Pedestrian/Bicycle Focused)
- On-going FHWA and NCHRP Research/Reports
Safety Analysis Tools

- **SafetyAnalyst**
  - Roadway safety management tool
  - Applies HSM Part B procedures

- **HiSafe**
  - Crash prediction tool
  - Applies HSM Part C procedures

- **Interactive Highway Safety Design Model (IHSDM)**
  - Evaluates safety and operations of geometric design
  - Crash prediction parallels HSM Part C

- **FHWA CMF Clearinghouse**
  - Broader range of CMFs than HSM
  - Web-based, continually updated

- **ADOT&PF HSIP Handbook**
  - Provides critical crash rate parameters
  - Alaska-developed CRFs

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What is the HSM? It is...

**...Like the HCM**
- An analysis tool
- Assesses safety performance based upon exposure and roadway conditions
- Quantifies safety

**...NOT Like the MUTCD & Green Book**
- No requirements
- No mandates
- No warrants
- No standards
What can the HSM be used for?

- Quantifying Safety in Project Decisions
- Spending Limited Resources Wisely
- Guiding Improvements for...
  - Networks
  - Corridors
  - Intersections
- Managing Risk to Reduce Tort Liability

HSM Content

- Part A – Introduction and Fundamentals
  - 1: Introduction
  - 2: Human Factors
  - 3: Fundamentals
- Part B – Roadway Safety Management Process
  - 4: Network Screening
  - 5: Diagnosis
  - 6: Select Countermeasures
  - 7: Economic Evaluation
  - 8: Prioritization
  - 9: Safety Effectiveness Evaluation
- Part C – Predictive Method
  - 10: Two-Lane Rural Highways
  - 11: Multilane Rural Highways
  - 12: Urban and Suburban Arterials
- Part D – Crash Modification Factors
  - 13: Roadway Segments
  - 14: Intersections
  - 15: Interchanges
  - 16: Special Facilities
  - 17: Networks
- Glossary
SAFETY FUNDAMENTALS

Factors Influencing Crashes

Source: Treat 1979
Objective and Subjective Safety

» Objective – Measured
» Subjective - Perceived

SUBJECTIVE

“Downtown is difficult as it is without having a roundabout death trap in it.” - Chico Enterprise - Record Posted: 03/08/2011

OBJECTIVE

Converting a traffic signal in an urban area to a roundabout reduces injury/fatal crashes by about 60%. – HSM 2010

Nominal and Substantive Safety

Source: NCHRP 480
Crashes are Rare and Random Events

Crashes, as rare random events, tend to regress to long-term average – this is called “Regression to the Mean” (RTM)

Looking at short-term crash frequencies can be misleading
Regression to the Mean

How is RTM Compensated For?

Safety Performance Functions (SPFs)
- Predicts the average number of crashes per year
- It is generally a nonlinear regression equation
  - From HSIS Data
  - Crashes do NOT necessarily vary linearly with traffic volume

Data Inputs
- AADT (for major and minor approaches if analyzing intersection)
- Segment Length (if analyzing roadway segment)
- Coefficients from tables or equations given in the HSM
How is RTM Compensated For?

- **Empirical Bayes**
  - A process to develop a *weighting between observed and predicted crashes*
  - A means to calculate a refined prediction called the *expected number of crashes*

<table>
<thead>
<tr>
<th>Observed Number of Crashes</th>
<th>Expected Number of Crashes</th>
<th>Predicted Number of Crashes</th>
</tr>
</thead>
</table>

**HSM PART C PREDICTIVE METHOD**
### Overview of Methods for Estimating and Predicting Crashes

#### Why estimate or predict crashes?
- Identifying potential countermeasures
- Designing new roadway and want to consider safety quantitatively
- Modifying existing roadway and want to consider safety quantitatively

#### What types of projects could this apply to?
- Corridor studies
- Intersection studies
- Access Management activities
- Capacity enhancements
- Development review process
- "Upgrades to an urban cross-section"

#### Traditional Approach
- Surrogates for Safety (e.g., standards, speed, number of conflict points)
  - Advantage – Simple and familiar
  - Disadvantage – Indirect measures, need an existing condition
- Crash Reduction Factors
  - Advantages – Simple and limited data required, can account for local conditions
  - Disadvantages – Unreliable results (does not account for RTM), not always able to account for variability in results

#### New Approaches
- HSM Predictive Method
  - Advantages – More reliable results (accounts for RTM), do not need an existing condition
  - Disadvantages – Slightly more expertise and data needed
- Crash Modification Factors
  - Advantages – More reliable, able to account for variability in results
  - Disadvantages – Slightly more expertise and data needed
Fundamentally, what is the Predictive Method?

Your Site’s Predicted Crashes = \left( \text{Default Prediction for Generic Sites} \right) \times \left( \text{Adjustment Factors for Local Conditions} \right) \times \left( \text{Calibration Factor} \right)

N_p = \left( \text{Safety Performance Function} \right) \times \left( \text{Crash Modification Factors} \right) \times \left( \text{Calibration Factor} \right)

N_p = \left( N_{spf} \right) \times \left( CMF_1 \times CMF_2 \ldots CMF_n \right) \times C
Safety Performance Functions

SPFs are regression models used to estimate predicted crash frequency.

- The SPF for multiple-vehicle nondriveway collisions is:

\[ N_{brmv} = e^{(a+b \times \ln(AADT) + \ln(L))} \]

- AADT = average annual daily traffic volume (vehicles/day) on roadway segment;
- L = length of roadway segment (mi); and
- a, b = regression coefficients for a specific facility type
- For a four-lane divided arterial: a = -12.34, b = 1.36

HSM PART D CRASH MODIFICATION FACTORS
HSM Content

Part A – Introduction and Fundamentals
- 1: Introduction
- 2: Human Factors
- 3: Fundamentals

Part B – Roadway Safety Management Process
- 4: Network Screening
- 5: Diagnosis
- 6: Select Countermeasures
- 7: Economic Evaluation
- 8: Prioritization
- 9: Safety Effectiveness Evaluation

Part C – Predictive Method
- 10: Two-Lane Rural Highways
- 11: Multilane Rural Highways
- 12: Urban and Suburban Arterials

Part D – Crash Modification Factors
- 13: Roadway Segments
- 14: Intersections
- 15: Interchanges
- 16: Special Facilities
- 17: Networks

Glossary

What is a CMF?

Ratio showing the change in the number of crashes between two conditions
Usually a comparison of a proposed condition to an existing condition
- Existing Lane Width of 11 feet
- Proposed Lane Width of 12 feet

\[
CMF = \frac{\text{Crash frequency for proposed condition } 'p'}{\text{Crash frequency for existing condition } 'e'} = \frac{E_p}{E_e}
\]
Sources of Crash Modification Factors

- Part C contains CMFs applied in the predictive method

- Part D presents CMFs for:
  - Chapter 13: Roadway Segments
  - Chapter 14: Intersections
  - Chapter 15: Interchanges
  - Chapter 16: Special Facilities and Geometric Situations
  - Chapter 17: Road Networks

- FHWA CMF Clearinghouse
  - [http://www.cmfclearinghouse.org/](http://www.cmfclearinghouse.org/)

- ADOT&PF HSIP Handbook

CMF Availability in Part D Chapters
CMFs in Part D Chapters

Table

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting</th>
<th>Traffic Volume</th>
<th>Crash Type</th>
<th>CMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>All</td>
<td>0.99*</td>
<td>0.1</td>
<td>0.40</td>
<td>0.1</td>
</tr>
<tr>
<td>(one or less</td>
<td>All</td>
<td>0.33</td>
<td>0.05</td>
<td>0.32</td>
<td>0.06</td>
</tr>
<tr>
<td>lanes)</td>
<td>All</td>
<td>0.32</td>
<td>0.06</td>
<td>0.23</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Graph

Formula

\[ CMF = (0.98)^{nprohib} \]

CMF Standard Error in Part D Chapters

- CMF Standard Error

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting</th>
<th>Traffic Volume</th>
<th>Crash Type</th>
<th>CMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian and</td>
<td>Unspecified</td>
<td></td>
<td>1.09*</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Bicycle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(All severities)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pedestrian</td>
<td>Unspecified</td>
<td></td>
<td>1.57</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>(All severities)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicycle</td>
<td>Unspecified</td>
<td></td>
<td>1.80</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>(All severities)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right-turn</td>
<td>Unspecified</td>
<td></td>
<td>1.00</td>
<td>0.09</td>
<td>0.01</td>
</tr>
<tr>
<td>(Injury)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right-turn</td>
<td>Unspecified</td>
<td></td>
<td>1.00</td>
<td>0.09</td>
<td>0.01</td>
</tr>
<tr>
<td>(Non-injury)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All types</td>
<td>Unspecified</td>
<td></td>
<td>1.07</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Base Condition: A signalized intersection with prohibited right-turn-on-red operation.


Bold: Used for the most reliable CMFs. These CMFs have a standard error of 0.1 or less.

Italic: Less Reliable

Bold: More Reliable
CMF Standard Error in Part D Chapters

- CMF Standard Error

\[ CI (95\%) = CMF_x \pm 2 \times SE_x \]

\( CI \) = confidence interval

\( CMF_x \) = CMF for condition \( x \)

\( SE_x \) = Standard error for condition \( x \)

- Analysis result will yield a range with 95% confidence

Other CMF Sources

- FHWA CMF Clearinghouse

- ADOT&PF HSIP Handbook (CRFs)

\[ CMF = 1 - \frac{CRF}{100} \]
Crash Prediction in Alternative Evaluation

- **SPFs**
  - Predict the future no-build and alternative conditions

- **CMFs**
  - Modify SPFs for desired conditions
  - Represent difference in crash frequency

- **Results**
  - Number of predicted crashes for each study condition
  - Crash costs then utilized in benefit/cost

- Safety performance of alternatives quantified
- Comparable to operations, right-of-way, construction costs, etc.
### Methods for Comparing Alternative Conditions

<table>
<thead>
<tr>
<th>Method</th>
<th>Condition 1</th>
<th>Condition 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Part C SPF</td>
<td>Part C SPF</td>
</tr>
<tr>
<td>2</td>
<td>Part C SPF</td>
<td>Part D CMF</td>
</tr>
<tr>
<td>3</td>
<td>Independent SPF</td>
<td>Part D CMF</td>
</tr>
<tr>
<td>4</td>
<td>Observed Crash Frequency</td>
<td>Part D or Independent CMF</td>
</tr>
</tbody>
</table>

#### Methods for Comparing Alternative Conditions

- **Method 1: SPF vs. SPF**
  - Requires SPF for each study condition
  - Calibration preferred
  - Applicable to new facilities and future conditions

- **Method 2: SPF vs. SPF x CMF**
  - Requires SPF for base condition
  - Calibration preferred
  - Applicable to new facilities and future conditions

- **Method 3: Independent SPF vs. SPF x CMF**
  - Requires local SPF
  - Applicable to new facilities and future conditions

- **Method 4: Existing Frequency vs. Frequency x CMF**
  - Requires only crash history and applicable CMFs
  - Not applicable to new facilities or future conditions
**Predictive Method for Urban and Suburban Arterials**

\[
N_i = SPF \times (CMF_{1i} \times CMF_{2i}) \times C_i
\]

**Considerations**

- Incorporates many, but not all geometric features – absence does not mean a feature does not have an effect
- These models do not explain cause
- Weather and driver behavior is not explicitly addressed in these models
Russell Street Corridor, Missoula, Montana

1. 1.5 Mile-long Study Area
2. 1 of 5 Bridge Crossings for Community of Missoula
3. 2/3 lane cross section
4. ADT volumes of 25,000 (north end) to 20,000 (south end)
5. Important route for bicycle commuters
6. Earmark secured for initial funding of project
Alternatives

Data Collection

- Much of it is standard for a traffic study
- Additional data:
  - Fixed object density & offset
  - Driveway information
  - Alcohol sales establishments w/in 1,000 feet of signalized intersection
- Data collected from
  - Field measurements,
  - Scaled aerials,
  - Google Streetview, and
  - Concept plans
### Predictive Method Analysis

\[ N_i = \text{SPF} \times (\text{CMF}_{1i} \times \text{CMF}_{2i}) \]

- Calculated predicted average crash frequency for each scenario and two no-build scenarios (3-lane and 5-lane volumes)
- **Steps involved**
  - Data collection of existing conditions
  - Calculation of predicted crashes
  - Report results
- **Challenge: Local calibration data not available**
  - Cannot report expected average crash frequency data
  - **Response:** Calculate predicted average crash frequencies for each scenario and compare on a relative basis to the respective no-build scenario (3-lane or 5-lane)

### Analysis Tools

- **Excel Spreadsheet**
- **HiSafe**
  - Applicable for planning, traffic operations, and functional design level analyses
Results

<table>
<thead>
<tr>
<th></th>
<th>3-Lane Volume Scenario</th>
<th>5-Lane Volume Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of Crashes Compared to No-Build Scenario (Alternative 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Alt 1</strong></td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Alt 2</strong></td>
<td>67%</td>
<td>70%</td>
</tr>
<tr>
<td><strong>Alt 3</strong></td>
<td>65%</td>
<td>63%</td>
</tr>
<tr>
<td><strong>Option 6</strong></td>
<td>85%</td>
<td>73%</td>
</tr>
</tbody>
</table>

- Alternatives 2, 3, and 5-R were rated as having “good” performance, Alternative 4 and Options 6 and 7 were rated as having “fair” performance, and Alternative 1 (no-build) was rated as “poor”
  - Roundabouts, medians, and left-turns make up the biggest differences
  - The predicted proportion of fatality/injury crashes is lower in alternatives with roundabouts

Challenges

- Local calibration data not available
  - Resolution: Calculate predicted average crash frequencies for each scenario and compare on a relative basis to the respective no-build scenario (3-lane or 5-lane)
- Unable to predict ped/bike crashes at roundabouts
  - Resolution: Did not include pedestrian/bicyclist crashes in results (used multimodal level of service instead)
- CMF for right-in/right-out restriction not available
  - Resolution: Restricted public street intersections are treated as driveways in the respective median-controlled segment analysis
- SPF for two-lane median-divided roadways not available
  - Resolution: Predicted head-on and sideswipe, opposite direction, crashes are removed from the multiple-vehicle, non-driveway predicted crashes
- SPF for three-lane undivided roadway not available
  - Resolution: Applied SPF for a four-lane undivided roadway
Russell Street Conclusions

- HSM analysis was effective for evaluating the relative impacts of different design features
- Using relative results made it difficult to compare between 3-lane and 5-lane volume scenarios
- Results did not surprise engineers, but helped communicate points to elected officials and citizens
Calibrating SPFs

- HSM SPFs should be calibrated to local conditions
  - Apply locally developed factor to account for conditions not explicitly captured in SPF models

- Calibration methodology provided in Appendix to Part C
  - 30-50 similar sites
  - 100 or more crashes/year for all sites
  - By facility: ratio of observed to HSM prediction for calibration sites

- If no calibration factor, can do relative analysis

Calibration of HSM Crash Prediction Models

- Uncalibrated models can be used for relative comparison of safety to “no build”

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>No Build</th>
<th>Concept #1</th>
<th>Concept #2</th>
<th>Concept #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury/Fatal Crashes</td>
<td>-</td>
<td>+10%</td>
<td>-20%</td>
<td>-8%</td>
</tr>
<tr>
<td>PDO Crashes</td>
<td>-</td>
<td>+12%</td>
<td>-16%</td>
<td>-4%</td>
</tr>
<tr>
<td><strong>Change in Total Crashes</strong></td>
<td>-</td>
<td><strong>+11.5%</strong></td>
<td><strong>-17.4%</strong></td>
<td><strong>-5.2%</strong></td>
</tr>
</tbody>
</table>
Calibration of HSM Crash Prediction Models

- Calibration allows for prediction of number of crashes per year

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>No Build</th>
<th>Concept #1</th>
<th>Concept #2</th>
<th>Concept #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Injury/Fatal Crashes</td>
<td>3</td>
<td>1.5</td>
<td>2.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Number of PDO Crashes</td>
<td>12</td>
<td>6.0</td>
<td>9.9</td>
<td>6.9</td>
</tr>
<tr>
<td><strong>Total Number of Crashes</strong></td>
<td><strong>15</strong></td>
<td><strong>7.5</strong></td>
<td><strong>12.1</strong></td>
<td><strong>8.9</strong></td>
</tr>
</tbody>
</table>

Oregon DOT Calibration Factors

Table 7.1: Recommended Oregon HSM Calibration Factors (based on locally derived crash proportions)

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Observed Crashes</th>
<th>Predicted Crashes</th>
<th>Calibration Factor, C</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEGMENTS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td>2-lane undivided</td>
<td>377</td>
<td>610</td>
</tr>
<tr>
<td>Rural Multilane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MRU</td>
<td>Undivided</td>
<td>364</td>
<td>906</td>
</tr>
<tr>
<td>MRD</td>
<td>Divided</td>
<td>58</td>
<td>75</td>
</tr>
<tr>
<td>U2U</td>
<td>2-lane undivided</td>
<td>177</td>
<td>267</td>
</tr>
<tr>
<td>UST</td>
<td>1-lane with TWTL</td>
<td>215</td>
<td>267</td>
</tr>
<tr>
<td>U4D</td>
<td>4-lane divided</td>
<td>101</td>
<td>114</td>
</tr>
<tr>
<td>U4U</td>
<td>4-lane undivided</td>
<td>906</td>
<td>803</td>
</tr>
<tr>
<td>U5T</td>
<td>5-lane with TWTL</td>
<td>772</td>
<td>1216</td>
</tr>
<tr>
<td>INTERSECTIONS</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Rural Two-Lane</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>R1ST</td>
<td>3-leg, minor STOP</td>
<td>108</td>
<td>144</td>
</tr>
<tr>
<td>R4ST</td>
<td>4-leg, minor STOP</td>
<td>204</td>
<td>655</td>
</tr>
<tr>
<td>R4SG</td>
<td>4-leg, signalized</td>
<td>142</td>
<td>318</td>
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<tr>
<td>Rural Multilane</td>
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<tr>
<td>MR3ST</td>
<td>3-leg, minor STOP</td>
<td>37</td>
<td>239</td>
</tr>
<tr>
<td>MR4ST</td>
<td>4-leg, minor STOP</td>
<td>178</td>
<td>455</td>
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<tr>
<td>MR4SG</td>
<td>4-leg, signalized</td>
<td>157</td>
<td>1053</td>
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<tr>
<td>Urban and Suburban arterials</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>U1ST</td>
<td>3-leg, minor STOP</td>
<td>103</td>
<td>291</td>
</tr>
<tr>
<td>U4ST</td>
<td>4-leg, minor STOP</td>
<td>105</td>
<td>231</td>
</tr>
<tr>
<td>U5ST</td>
<td>5-leg, signalized</td>
<td>321</td>
<td>439</td>
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<tr>
<td>U6ST</td>
<td>6-leg, signalized</td>
<td>490</td>
<td>654</td>
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### Florida DOT Calibration Factors

#### FDOT Segment Calibration Factors

<table>
<thead>
<tr>
<th></th>
<th>R2U</th>
<th>R4D</th>
<th>U2U</th>
<th>U32LT</th>
<th>U4U</th>
<th>U4D</th>
<th>U52LT</th>
</tr>
</thead>
<tbody>
<tr>
<td>KABC</td>
<td>1.00</td>
<td>0.68</td>
<td>1.02</td>
<td>1.04</td>
<td>0.73</td>
<td>1.63</td>
<td>0.70</td>
</tr>
</tbody>
</table>

#### FDOT Intersection Calibration Factors

<table>
<thead>
<tr>
<th></th>
<th>R2 3ST</th>
<th>R2 4ST</th>
<th>R2 4SG</th>
<th>RM 4SG</th>
<th>U 3SG</th>
<th>U 4SG</th>
</tr>
</thead>
<tbody>
<tr>
<td>KABC</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

### Calibration of Predictive Models from HSM in Tumalo, Oregon
Project Background and Purpose

- Project Purpose:
  - Evaluate design alternatives on US 20
  - Quantify safety in decision making process
- Project Considerations
  - Apply predictive method
  - Apply calibrated SPF

Calibration Procedure

1. Select Calibration Sites
2. Summarize Observed Crashes
3. Calculate Uncalibrated Predicted Crashes
4. Calculate Ratio of Observed to Predicted Crashes
Calibration Procedure

Select Calibration Sites

Summarize Observed Crashes

Calculate Uncalibrated Predicted Crashes

Calculate Ratio of Observed to Predicted Crashes
Calibration Procedure

Number of crashes per year over study period (5 years of data)

<table>
<thead>
<tr>
<th>Segment ID</th>
<th>Fatal &amp; Injury</th>
<th>Property Damage Only</th>
<th>Total Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1-2</td>
<td>0.2</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>S1-3</td>
<td>0.2</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>S1-4</td>
<td>0.2</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>S2-3</td>
<td>0.6</td>
<td>0.4</td>
<td>1.0</td>
</tr>
<tr>
<td>S4-1</td>
<td>0.2</td>
<td>1.2</td>
<td>1.4</td>
</tr>
</tbody>
</table>

\[ N_i = N_{SPF} \times (CMF_1 \times CMF_2) \]

\[ N_{spf} = \text{AADT} \times L \times 10^{-6} \times e^{-0.312} \]

<table>
<thead>
<tr>
<th>Segment ID</th>
<th>Fatal &amp; Injury</th>
<th>Property Damage Only</th>
<th>Total Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1-1</td>
<td>0.2</td>
<td>0.4</td>
<td>0.7</td>
</tr>
<tr>
<td>S1-2</td>
<td>0.4</td>
<td>0.9</td>
<td>1.3</td>
</tr>
<tr>
<td>S1-3</td>
<td>0.3</td>
<td>0.7</td>
<td>1.1</td>
</tr>
<tr>
<td>S1-4</td>
<td>0.5</td>
<td>1.0</td>
<td>1.4</td>
</tr>
<tr>
<td>S2-3</td>
<td>0.5</td>
<td>1.1</td>
<td>1.7</td>
</tr>
<tr>
<td>S4-1</td>
<td>0.7</td>
<td>1.4</td>
<td>2.1</td>
</tr>
</tbody>
</table>
**Calibration Procedure**

1. Select Calibration Sites
2. Summarize Observed Crashes
3. Calculate Uncalibrated Predicted Crashes
4. Calculate Ratio of Observed to Predicted Crashes

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Observed Crash Frequency</th>
<th>Uncalibrated Predicted Crash Frequency</th>
<th>Calibration Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadway Segments</td>
<td>7.8</td>
<td>15.3</td>
<td>0.51</td>
</tr>
<tr>
<td>Three-Leg Unsignalized Intersections</td>
<td>7.6</td>
<td>14.79</td>
<td>0.51</td>
</tr>
<tr>
<td>Four-Leg Unsignalized Intersections</td>
<td>10.6</td>
<td>25.75</td>
<td>0.41</td>
</tr>
</tbody>
</table>

**Calibration Procedure**

- Select Calibration Sites
- Summarize Observed Crashes
- Calculate Uncalibrated Predicted Crashes
- Calculate Ratio of Observed to Predicted Crashes

![Calibration Procedure Diagram](image-url)
APPLICATION IN ALASKA

Corridor Studies/Intersection Design Applications

- Provide engineers and designers with quantitative safety performance to evaluate alternatives
- Increase the reliability of safety assessments
- Offer capability to evaluate new or substantially modified facilities
- Supply input for benefit/cost
- Better inform decision makers and the public of the impacts of design decisions
Example: Integration into ADOT&PF HSIP

Existing HSIP Process
1. Critical crash rate + severity screening
2. Identify treatments, apply CRFs to existing crash frequency
3. Benefit/Cost ranking
4. Project Evaluation

Possible Modified HSIP Process
1. Alternate Screening Method (RTM)
2. Calibrated SPF + CMF to predict future crash frequency
3. Benefit/Cost ranking
4. Project Evaluation

Summary

The HSM helps the safety practice evolve from reactive to predictive

The HSM allows for quantitative evaluation of safety impacts

The HSM allows a quantitative comparison of design, operations, and management alternatives

The profession now has the ability to begin to more fully integrate operations and safety into the design decision process
Further Questions

Andrew Ooms
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(907) 646-7995