2019 ITE Workshop
Introduction to Performance Based Safety Analysis
April 9, 2019
Agenda

- Overview of PBSA
- Current motivation for this topic
- How do we conduct PBSA?
- Benefits of PBSA
- Common PBSA Applications
Overview of PBSA
Performance Based Safety Analysis
What are we trying to accomplish?

Identify **cost-effective** safety alternatives to mitigate crashes

- **The Safety Part:** Compare the safety performance of the project with and without safety alternatives

- **The Economic Part:** compare the monetized safety improvement to the added cost of the project with the improvement
Performance Based Safety Analysis
The Safety Part

Evaluate future safety performance of base condition and each safety mitigation alternative

- Implement HSM methodologies
- Allows the change of crash frequency and severity with mitigation alternatives to be quantified
- Predictive crash modeling used when applicable
Performance Based Safety Analysis

The Economic Part

- Quantify monetary change of crash frequency and severity changes
- Quantify benefit-cost of proposed safety mitigation alternatives
- Allows understanding of the cost-effectiveness of safety improvements

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Current motivation for this topic
Renewed Focus on Efficient Asset Management

- Blend financial realities with analysis to prioritize improvements
- Goal is to be more efficient with transportation dollars
- Eliminate nonessential project design elements
- Focus on data-driven decision making
- Performance-Based Practical Design (PBPD) approach to system preservation
Performance-Based Practical Design

- Breaks from traditional design by “fixing only what is broken”
- Substandard ≠ Deficient
- Uses data to drive the decision making process
- Focus on cost-effective solutions
- Safety: relies on substantive safety instead of nominal safety
Substantive Safety vs Nominal Safety

- Automatically follow “standards”?
- Widen narrow shoulders?
- Offset left turn lanes?
- Expand curve radius?

FHWA PowerPoint (Every Day Counts) “Data-Driven Safety Analysis –Nominal vs. Substantive Safety” by John McFadden, P.E.
New policy to implement PBPD for safety improvements

- Consistent application of safety analysis
- Increase reliability of safety analysis
- Mitigation alternatives focused on crash history
- Apply crash modeling to predict future crashes
- Apply economic analysis tools
- Documentation
- Assist in defining Purpose and Need of project
How do we conduct PBSA?

- Crash Prediction/Modeling
- Economic Analysis
Tools for Crash Modeling

HSM-based IHSDM software

• FHWA software for applying quantitative safety evaluation

• HSM methods

Inputs include facility type/location, geometric, and operational characteristics
Tools for Crash Modeling

Uses System Performance Functions (SPF) = Mathematical relationship between crash frequency per unit of time (and road length) and traffic volumes (AADT)
Tools for Crash Modeling
Crash Modeling output

- # and severity of crashes
- Tables describing predicted or expected crash frequency and severity
- Compare safety performance among alternatives

<table>
<thead>
<tr>
<th>Table 2. Expected Highway Crash Rates and Frequencies (Section 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Year of Analysis</strong></td>
</tr>
<tr>
<td><strong>Last Year of Analysis</strong></td>
</tr>
<tr>
<td><strong>Evaluated Length (mi)</strong></td>
</tr>
<tr>
<td><strong>Average Future Road AADT (vpd)</strong></td>
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<tr>
<td><strong>Expected Crashes</strong></td>
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<tr>
<td><strong>Total Crashes</strong></td>
</tr>
<tr>
<td><strong>Fatal and Injury Crashes</strong></td>
</tr>
<tr>
<td><strong>Property-Damage-Only Crashes</strong></td>
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<tr>
<td><strong>Percent of Total Expected Crashes</strong></td>
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<tr>
<td><strong>Percent Fatal and Injury Crashes (%)</strong></td>
</tr>
<tr>
<td><strong>Percent Property-Damage-Only Crashes (%)</strong></td>
</tr>
<tr>
<td><strong>Expected Crash Rate</strong></td>
</tr>
<tr>
<td><strong>Crash Rate (crashes/ mi/yr)</strong></td>
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<tr>
<td><strong>Fatal and Injury Crash Rate (crashes/ mi/yr)</strong></td>
</tr>
<tr>
<td><strong>Property-Damage-Only Crash Rate (crashes/ mi/yr)</strong></td>
</tr>
<tr>
<td><strong>Expected Travel Crash Rate</strong></td>
</tr>
<tr>
<td><strong>Total Travel (million veh-mi)</strong></td>
</tr>
<tr>
<td><strong>Travel Crash Rate (crashes/ million veh-mi)</strong></td>
</tr>
<tr>
<td><strong>Travel Fatal and Injury Crash Rate (crashes/ million veh-mi)</strong></td>
</tr>
<tr>
<td><strong>Travel Property-Damage-Only Crash Rate (crashes/ million veh-mi)</strong></td>
</tr>
</tbody>
</table>
Tools for Economic Analysis

- Facilitated by IHSDM software or spreadsheets
- Both use standard economic analysis techniques

IHSDM
Interactive Highway Safety Design Model

WisDOT Highway Safety Benefit-Cost Tool spreadsheet
What is accounted for in Economic Analysis

- **Alternative Costs**
  - Construction – costs of materials and construction
  - Right of Way

- **Change in safety performance – Monetized**
  - Change in frequency/severity of crashes with improvement
  - Output from crash modeling process – Fatal/Injury and PDO crashes

<table>
<thead>
<tr>
<th>Crash Severity (WisDOT terminology)</th>
<th>KABCO Abbreviation (Most severe injury in crash)</th>
<th>HSM Terminology</th>
<th>Wisconsin Adjusted National Economic Crash Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>K</td>
<td>Fatal</td>
<td>$10,897,580</td>
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<tr>
<td>Suspected Serious Injury</td>
<td>A</td>
<td>Serious Injury or Disabling</td>
<td>$613,781</td>
</tr>
<tr>
<td>Suspected Minor Injury</td>
<td>B</td>
<td>Evident Injury or Non-disabling</td>
<td>$194,022</td>
</tr>
<tr>
<td>Possible Injury</td>
<td>C</td>
<td>Possible Injury</td>
<td>$110,830</td>
</tr>
<tr>
<td>Property Damage Only (PDO)</td>
<td>O</td>
<td>No Injury</td>
<td>$10,173</td>
</tr>
</tbody>
</table>
Economic Analysis output

- Present value of crash costs
- Present value of construction/ROW costs
- Compare net present values in B/C

**Analysis Output Summary**

*Analysis Type: Benefit/Cost*

<table>
<thead>
<tr>
<th>Is Base Case</th>
<th>Title</th>
<th>Present Value of Crash Cost ($)</th>
<th>Present Value of Other Cost ($)</th>
<th>Net Present Value of Benefits (B) ($)</th>
<th>Net Present Value of Costs (C) ($)</th>
<th>Present Value of Net Benefit (B-C) ($)</th>
<th>Benefit Cost Ratio (B/C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Base</td>
<td>3,668,872.47</td>
<td>1,000,000.00</td>
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<td></td>
<td></td>
<td>1.5656</td>
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<tr>
<td>Mitigation</td>
<td></td>
<td>3,477,460.33</td>
<td>1,250,000.00</td>
<td>391,412.13</td>
<td>250,000.00</td>
<td>141,412.13</td>
<td></td>
</tr>
</tbody>
</table>
Benefits of PBSA
Benefits of PBSA

- Provides additional selection justification by safety improvement
- Allows metric for cost effectiveness of an alternative
- Concentrates on long-term average crashes rather than short-term trends (Accounts for Regression-to-the-mean (RTM) bias)
- Allows Empirical Bayes method
Additional Selection Metrics
Regression-to-the Mean (RTM) Bias

- Site Selected for Treatment due to Short-Term Trend
- Perceived Effectiveness of Treatment
- Actual Reduction due to Treatment

- Observed Crash Frequency
- Expected Average Crash Frequency (without Treatment)
- Years
Snapshot of Empirical Bayes

- $N_{\text{observed}, T, B}$ (Observed Frequency)
- $N_{\text{expected}, T, B}$ (EB Expected Frequency)
- $N_{\text{predicted}, T, B}$ (Predicted Frequency)

Crashes / Year vs. Traffic Volume

SPF
Common PBSA Applications
PBSA Applications – Example #1

- 2-lane, rural highway
- ADT = 1,000 vpd
- 55 mph posted speed limit
- Five ROR crashes in past five years
  - All occurred at horizontal curve
  - 2 A-injury, 2 B-injury, 1 PDO

Public says the curve is too sharp and wants a change...

Should the curve radius be increased?
PBSA Applications – Example #1

What crash prediction model to use?

• Can HSM modeling be used with the given inputs?
• Are at least two years of crash data available?
• Is the mitigation alternative significantly different than existing?

Crash estimation (CMFs)
Crash prediction (IHSDM)
Crash expectancy (IHSDM with EB)
Using Empirical Bayes method, site is expected to have 0.91 crashes per year
5 crashes / 5 years = 1.0 crashes per year

Using crash prediction, site is predicted to have 0.5 crashes per year
• EB considers both predicted and observed crashes
PBSA Applications – Example #2

- TWSC suburban intersection
- Major ADT = 14,000 vpd
- Minor ADT = 2,800 vpd
- Exclusive turn lanes present
- Fourteen crashes in past five years
  - 1 Fatal, 2 B-injury, 3 C-injury, 8 PDO

A roundabout or traffic signal are possibilities...

Which intersection control is preferred?
PBSA Applications – Example #2

What crash prediction model to use?

- Can HSM modeling be used with the given inputs?
- Are at least two years of crash data available?
- Is the mitigation alternative significantly different than existing?

Crash estimation (CMFs)

Crash prediction (IHSDM)

Crash expectancy (IHSDM with EB)
Appendix A of HSM: EB is **not** applicable

“at intersections at which the basic number of intersection legs or type of traffic control is changed as part of the project”

Previous crash patterns are not indicative to crash patterns of improvement alternatives
PBSA Applications – Example #2

What crash prediction model to use?

- Can HSM modeling be used with the given inputs?
- Are at least two years of crash data available?
- Is the mitigation alternative significantly different than existing?

- Crash estimation (CMFs)
  - No
- Crash prediction (IHSDM)
  - Yes
- Crash expectancy (IHSDM with EB)
  - No
PBSA Applications – Example #2

Total predicted crashes:

As a TWSC: 1.04 crashes / year
As a signal: 2.07 crashes / year
As a RAB: 1.08 crashes / year

Is a RAB recommended?

Remember, crash prediction is one part of your analysis...
PBSA Applications – Example #3

- Two-lane urban freeway segment
  - NB freeway mainline ADT = 35,500 vpd
  - Entrance ramp ADT = 2,100 vpd
- 175’ entrance ramp taper
- 28 crashes in past five years
- Extending entrance ramp or adding a 0.75-mile auxiliary lane are feasible options...

Which entrance ramp to design?
PBSA Applications – Example #3

What crash prediction model to use?

- Can HSM modeling be used with the given inputs?
- Are at least two years of crash data available?
- Is the mitigation alternative significantly different than existing?

Crash estimation (CMFs)

Crash prediction (IHSDM)

Crash expectancy (IHSDM with EB)
Total expected crashes:

Existing: 3.98 crashes / year
Extend ramp: 2.28 crashes / year
Add aux lane: 3.40 crashes / year

Remember, crash prediction is one part of your analysis...
Thank you very much!

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