HSM Freeway and Ramps Calibration For Pennsylvania
Reasons for Crash Prediction Models

Why PennDOT is using the HSM for safety analysis

- Data Driven Safety Analysis
- Accurately locates true safety needs
- Develop projects that have the best safety impact
- Can predict the safety impact a proposed project will have
- Allows for a impartial network screening of Highways
- Accounts for regression to the mean
Accomplishments to Date

- Regionalized SPFs for:
  - Two-Lane, Two-way Rural Roads
  - Multi-lane Divided & undivided Rural Roads
  - Urban/Suburban Arterial Roadways
  - Urban/Suburban Collector Roadways (March 2019)
- 1st network screening based on HSM methodology
  - Screened all 67 counties (about 20,000 locations)
- Publication 638 May 2019 Update
  - Requires HSM analysis for HSIP project applications
Predictive Analysis Uses

• HSIP program
  – Enhanced network screening based excess crash frequency values
  – All location specific project applications must now use HSM analysis to justify the safety need and show the project safety impacts
  – Now require BCAs for project applications

• Using HSM in Project Development
  – Purpose and Needs studies
  – Design exceptions
  – Design optimization
  – Routine traffic engineering and safety studies

• HOP evaluations
  – We now have Traffic Impact Studies that use HSM methodologies to quantify safety impacts of development
Where PennDOT Plans to Go

What Needs Done

• Incorporate other facility types into analysis by calibration or SPF development
  – Freeways & Ramps
  – Roundabouts
  – One-way streets
  – Others

• Need to expand network screening
  – More locations
  – More facility types

• Need to include analysis for Freeways and Ramps
  – Calibrate 2014 SPFs for Freeways, Ramps, and Ramp Terminals
  – Add to network screening

• Calibration was the best option for Freeways and Ramps
<table>
<thead>
<tr>
<th>Ch</th>
<th>Title</th>
<th>National Publication</th>
<th>Pennsylvania Status</th>
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</thead>
<tbody>
<tr>
<td>10</td>
<td>Rural Two-Lane Two-Way Roads</td>
<td>HSM 1st Edition, 2010</td>
<td>PA SPFs* created</td>
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<td>11</td>
<td>Rural Multilane Highways</td>
<td>HSM 1st Edition, 2010</td>
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<td>12</td>
<td>Urban and Suburban Arterials</td>
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<td>PA SPFs* created</td>
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<td>18</td>
<td>Freeways</td>
<td>HSM Supplement, 2014</td>
<td>PA calibration ongoing</td>
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<tr>
<td>19</td>
<td>Ramps</td>
<td>HSM Supplement, 2014</td>
<td>PA calibration ongoing</td>
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</tbody>
</table>

* Safety Performance Functions
What is Calibration

- Differences in safety performance (crash frequency) are known to occur from state-to-state
  - Weather
  - Police crash reporting thresholds
  - Driver population (behavior, demographics, etc.)
  - Current and historical design practices
  - Vehicle mix
  - Terrain
  - Other factors not accounted for in models

- Calibration uses a large sample of data to compute a state-specific “adjustment” (calibration factor) to make HSM procedures more reliable in a given state
Why Calibration

- More reliable results for alternatives analysis, design exceptions
- Different results for network screening

Annual Crashes, I-50 Segment 999

Safety Issue?

Predicted (uncalibrated HSM) | Observed
---|---

Predicted (with PA calibration) | Observed
---|---

Probably not...
HSM CH 18 and 19 Site Types

- Basic Freeway Segments
- Speed Change Lanes
- Ramp Terminal Intersections
- Ramps
- Collector-Distributor Roads (not enough in Pennsylvania for calibration)
Behind the Scenes

- Dozens of Safety Performance Functions (SPFs)
  - Rural vs. Urban
  - Different numbers of lanes
  - Different forms of control
  - Multiple SPFs for a given site, summed to get total crashes
    - PDO and fatal+injury
    - Single vehicle and multi-vehicle

- Calibration process groups some SPFs together to reduce data needs
Calibration Data Needs

• Crash Data
  – Minimum of 30 sites and 100 crashes for each group of calibration factors
  – In practice, having 100 crashes of the rarest type (such as single vehicle fatal+injury) determined sample size
  – Years 2013-2017 used for this project

• AADT

• Geometric and traffic control variables required by HSM models
Site Selection

- Equal number of sites selected from following geographic areas
  - Districts 1 and 2
  - Districts 3 and 4
  - Districts 5 and 8
  - District 6
  - Districts 9 and 10
  - Districts 11 and 12
- Within each district pair, sites randomly selected from RMS list
### Computing the Results

<table>
<thead>
<tr>
<th>Site</th>
<th>Observed Crashes (i.e. crash data)</th>
<th>Predicted Crashes (i.e. HSM Results)</th>
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</thead>
<tbody>
<tr>
<td>Site 1</td>
<td>5</td>
<td>4.3</td>
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<tr>
<td>Site 2</td>
<td>12</td>
<td>16.8</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
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<tr>
<td>Total</td>
<td>120</td>
<td>100</td>
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Calibration Factor = $C = \frac{120}{100} = 1.2$

Highway Safety Manual Second Edition will increase emphasis and information on calibration.
• Review of ramp crash narratives revealed assignment of crashes to wrong ramps within an interchange
• Every narrative from the crashes on 660 ramps reviewed, crashes reassigned as appropriate/possible
• PennDOT addressing the issue for crash data in future years
Assessing the Results

• The Calibrator (FHWA Tool)
  - Outlier identification with scaled residuals
    • Sites where observed and predicted crashes are substantially different relative to other sites
    • Could indicate data issues or highly unique sites
  - Statistical analysis of the quality of the data
    • Coefficient of Variation – are site-to-site differences greater than what would naturally be expected?
    • Indicates if results will be reliable
• Ramps
  – PennDOT curve database found to be inaccurate
  – Manual curve measurements being done

• Speed Change Lanes
  – Coefficient of Variation high
  – Calibration effort stopped
Pennsylvania Calibration Factors

<table>
<thead>
<tr>
<th>Site Type</th>
<th>Fatal+Injury Multi-Vehicle</th>
<th>Fatal+Injury Single-Vehicle</th>
<th>PDO Multi-Vehicle</th>
<th>PDO Single-Vehicle</th>
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</thead>
<tbody>
<tr>
<td>Basic Freeway Segment</td>
<td>1.64</td>
<td>1.13</td>
<td>0.87</td>
<td>1.15</td>
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<tr>
<td>Signalized Ramp Terminal</td>
<td>1.03</td>
<td></td>
<td></td>
<td>0.93</td>
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<tr>
<td>Stop-Controlled Ramp Terminal</td>
<td>1.71</td>
<td></td>
<td></td>
<td>1.35</td>
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Speed Change Lanes and Collector-Distributor Roads – No PA calibration factors (use 1.00)
How to use the results

- Interactive Highway Safety Design Module
  - Version with PA calibration factors pre-loaded will be available on PennDOT website
I-81 Improvement Strategy for South Central Pennsylvania

Application of Pennsylvania Statewide Calibration Factors To the HSM Predictive Method
• **Overview:** Key transportation planning partners in the region are working together on a no-borders evaluation of 100 miles of Interstate 81 (I-81) / Interstate 78 (I-78) in South Central Pennsylvania.

• **Goal:** Establish a strategy to address needs within the corridor related to safety, congestion, infrastructure condition, access, and relevant connecting roads.

• **Purpose:** Allow the strategy to serve as a playbook for prioritization for funding future projects via the Statewide Transportation Improvement Program and regional long-range transportation plans.
Project Team

• Metropolitan Planning Organizations
  – Tri-County Regional Planning Commission
  – Franklin County Planning Department
  – Lebanon County Planning Department

• Pennsylvania Department of Transportation

• Federal Highway Administration

• Michael Baker International, Inc.
• Performed a network screening for the I-81 / I-78 corridor.
• Utilized Highway Safety Manual predictive methods for:
  – Freeway Segments
  – Speed Change Lanes
  – Ramps
  – Ramp Terminals
• Applied Statewide Calibration Factors
• Created a custom application to complete the analysis
• Evaluated freeway segments, speed change lanes, ramps, and ramp terminals.

• Calculated predicted crashes and adjustment factors (Part C CMFs)

• Utilized PennDOT RMS data, PennDOT’s curve database, and PennDOT crash data.

• Manually collected data that was not readily available.

• Established an excess cost for ease of comparison.
Geographical Depiction of Safety Performance
Preliminary Results

A cursory review has revealed seemingly obvious safety issues.

EXAMPLE 1:
- Highest potential safety benefit of all speed change lanes
- Deficient acceleration length with shoulder reduction from 8 feet to 2 feet
Preliminary Results

EXAMPLE 2:
- Relatively high potential for safety improvement
- Deficient acceleration length
- Missing yield sign
Next Steps

- Investigate locations with high excess values.

- Modify the existing network in order to quantify safety benefit of potential projects.

- Utilize safety results (and other categories) to prioritize funding for future projects.
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<tr>
<th>Name</th>
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<tr>
<td>Ben Brubaker, PE, PTOE</td>
<td></td>
<td>Michael Baker International, Inc.</td>
<td>(717) 221-2084</td>
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