TRB ACS20(1)

Safety Analytical Methods Subcommittee

A subcommittee of the TRB Committee on Safety Performance and Analysis

TRB Annual Meeting 2024

First time attendees

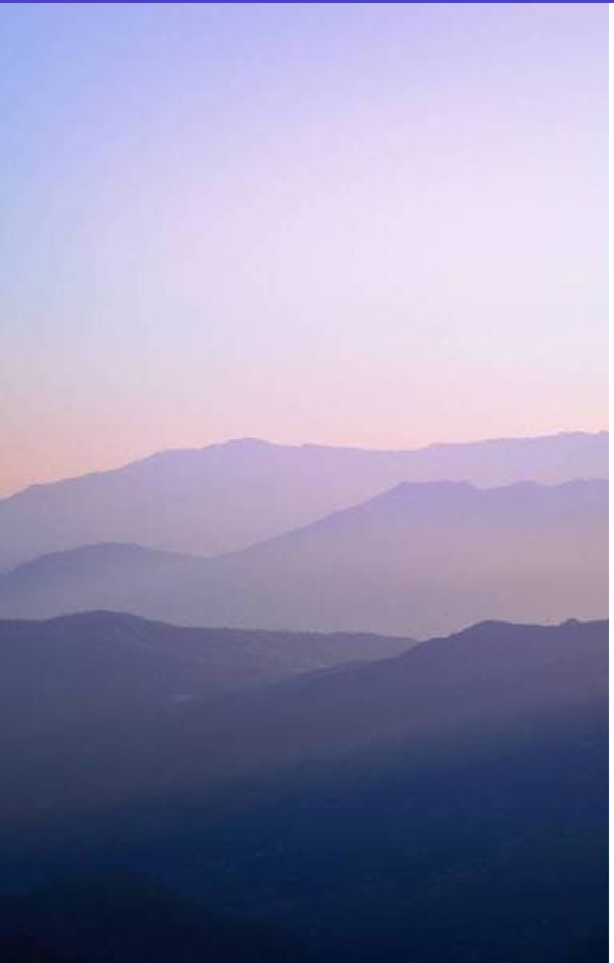
Attendance

Welcome!

Agenda

1. **Subcommittee scope, activities, leadership roles**
2. **Presentation and discussion of HSM Pooled Fund Project**: Applications of Data Driven Safety Analysis: Exploring the Validity of Combining Predictive Methods in the HSM, Scott Himes
3. **Research Needs** Statement (RNS) discussion
4. **Other**
    - Update on national efforts and initiatives (e.g., NCHRP projects)
    - Upcoming events
        - Events during TRB, other
    - Liaisons with other committees/subcommittees
    - Open floor
5. **Adjourn**

Leadership roles for the subcommittee



Secretary/ communications coordinator*	Taking and posting meeting agendas/minutes, maintaining the subcommittee contact list, and information distribution.
Research coordinator	Assisting with development and submission of research needs statement, identifying research topics for white papers and TRB E-circulars. - ***Bahar Dadashova (TTI)***
TRB event coordinator	Supporting paper review and planning for TRB sessions. – ***Jonathan Wood (Iowa State)***
Liaison Coordinator*	Promoting subcommittee activities through the connection with end-users, professionals and other committee/subcommittees.

*** Volunteers needed – contact Ida/ Xiao**

Applications of Data Driven Safety Analysis: Exploring the Validity of Combining Predictive Methods in the HSM

Scott Himes

Applications of Data Driven Safety Analysis

Exploring the Validity of Combining Predictive Methods

Scott Himes, PhD, PE

Acknowledgements

- HSM Implementation Pooled Fund Study
- Matt Hinshaw, FHWA
- Derek Troyer, FHWA
- Jerry Roche, FHWA
- Bonnie Polin, MassDOT
- Dan Carter, NCDOT
- Kevin Scopoline, WisDOT

Agenda

1. Background Motivation
2. Literature and Case Study Review
3. Recommended Approach
4. Example Case Study
5. Questions

Background Motivation

Research Questions

- HSM promotes Empirical Bayes (EB) method for analyzing project alternatives
  - HSM supplement clarifies EB method cannot be used for any alternatives if it is not applicable for all alternatives
  - This has led agencies to avoid EB method in general, including “future no-build” scenarios
  - Considering only predicted crash frequency treats locations as “average” locations
- Research questions
  - Is there an effective approach to consistently and reliably incorporate observed crash history?
  - What is the appropriate traffic volume (projected versus existing) for alternative analysis?
  - What role does calibration play in safety analysis?

Literature Review and Case Studies

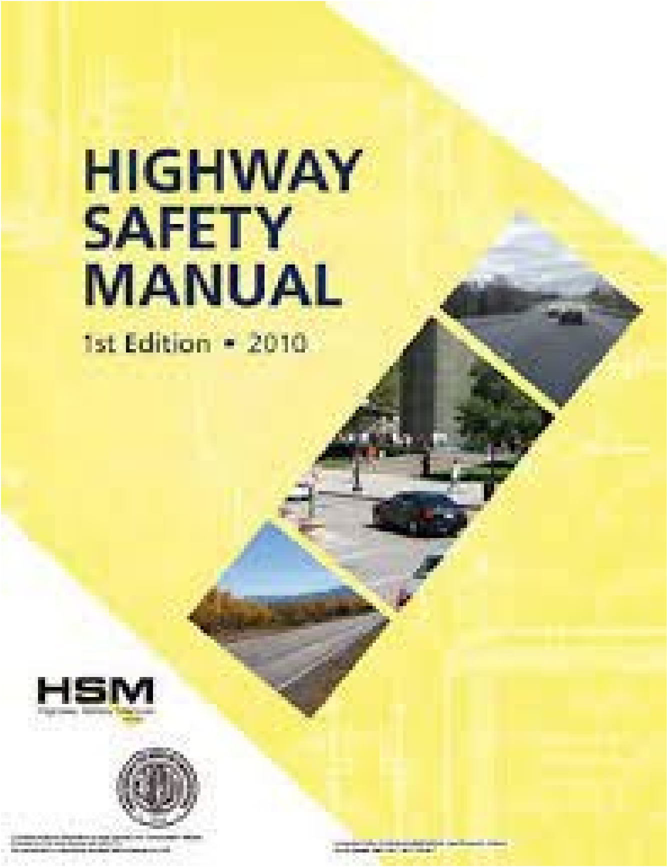
Literature Review

Safety Performance Function Sources

- ❑ National models – Highway Safety Manual

$$N_{predicted} = N_{spf,x} \times \left(\prod AF_{n,x}\right) \times C_x$$

- ❑ Jurisdiction-specific development
  - Substitute for HSM base SPFs
  - Jurisdiction-specific base SPF and adjustment factors



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Local Calibration

- ❑ Accounts for differences from one jurisdiction to another, or changes over time
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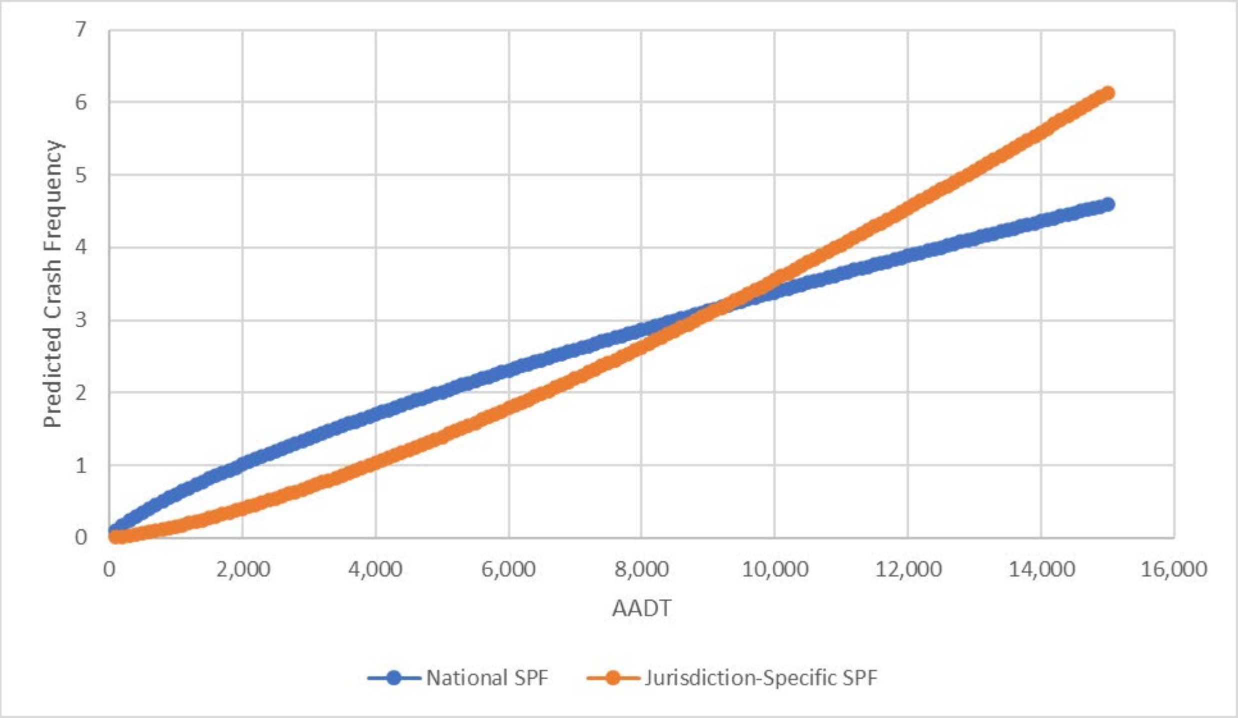

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HSM Single-State Calibration

- Prior to the release of HSM1, intersections calibrated to California and segments calibrated to Washington
  - The intention was to provide support for comparative analysis using predictive method across facility types
  - For example, widening a roadway from two-lanes to four-lanes

Literature Review Findings

SPF Calibration

- ❑ Research has shown need for calibration of HSM or jurisdiction-specific SPFs
- ❑ Calibration factors may not adequately address relationships
- ❑ Calibration factors can vary substantially by facility type
  - HSM single-State calibration may not be appropriate for many agencies
  - Having calibration for each facility type can help overcome this

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Literature Review Findings

Application of EB Method

- Much research has focused on the merits of the EB method at reducing bias
- Guidance is unclear on what constitutes a substantial change
  - Change in facility type is clear
  - How much proposed change within a facility type reduces the validity of historic crash data?
    - Widening shoulders from 0 ft to 10 ft
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- No research has focused on implications of using observed, predicted, or expected crash frequency among alternatives and alignment of methods to long-term project implementation

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Role of traffic volume in alternatives analysis

- HSM guidance suggests using AADT forecast estimates for future periods
- Part C explains practitioners should predict crash frequency under past or future traffic volumes, including for alternative designs
- Example applications are typically simplified – same AADT used in all alternatives
- The implication is that alternative-specific analysis year AADTs should be used; however, the full extent of the project trade-offs should be considered
  - Does the alternative generate changes in AADT on other facilities, and should those be considered?
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Case Studies

- Project team solicited data and case study examples from pooled fund States
- Three primary case study examples identified
  - NCDOT: Conversion of three-leg unsignalized intersection to Continuous Green-T
  - WisDOT: Conversion of four-leg unsignalized intersection to roundabout
  - HSM User Guide: Alternatives analysis of rural two-lane highway

Case Studies – NCDOT Example

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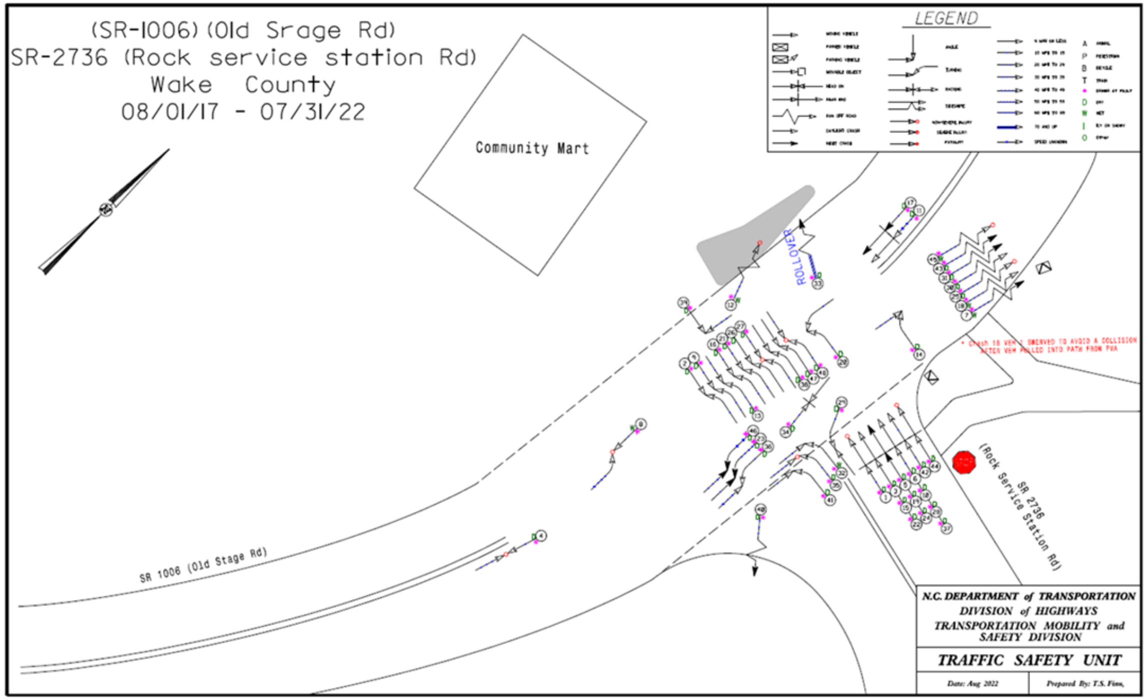
- Convenience store at the intersection impacts operations and safety
- Analysis methodology
  - Used historic crash data as baseline
  - Disaggregated crashes by type and severity
  - Applied crash type/severity CMFs
  - Used signal alternative as baseline for Continuous Green-T intersection
  - Future performance scaled based on a linear growth in AADT



Case Studies – WisDOT Example

- Existing four-leg unsignalized intersection identified in network screening
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- Crash data remained high for two years after screening with 65 percent FI
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- Calibrated models suggested 0.6 annual FI and 1.4 annual PDO crashes
- Observed data suggested 3.0 annual FI and 1.6 annual PDO crashes
- Analysis suggests that ignoring historic crash data, which may be high at this location for a specific reason, may undervalue the potential benefits, suggesting the project would not be economically justified

Case Studies – HSM User Guide

- Existing rural two-lane highway section (three segments)
- Project alternative 1 includes widening shoulder from 1 ft to 6 ft
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- 10.21 predicted crashes is 39 percent reduction
- 49.75 expected crashes is 9 percent reduction

Additional Review

- Project team reviewed State guidance on project alternative safety analysis
  - FDOT Safety Analysis Guidebook for PD&E Studies highlighted the importance of considering alternative-specific volumes and applicable study area
  - MassDOT Safety Alternatives Analysis Guide identified two-stage approach
    - Establish predicted crash frequency for no-build condition in the design year
    - Apply CMFs to no-build condition for project alternatives

Literature Review and Case Study Summary

- There is a demonstrated need for understanding potential biases, including when and how to use historic crash data when evaluating alternatives
  - Site specific attributes may contribute to higher crash counts, which may not be accounted for in predicted crash frequency which is a measure of "average"
  - Examples highlighted that higher crash counts, or higher proportion of severe crashes can hold over time (i.e., may not necessarily be regression-to-mean)
- There is no clear guidance on when historic crash data may no longer be applicable and may introduce bias when employing EB method
- There is a demonstrated need for a consistent and reliable approach for conducting project alternatives analysis

Literature Review and Case Study Summary

- Project alternatives analysis should consider alternative-specific traffic volumes and should consider the spatial and temporal impacts of the project alternative
- The HSM single-State calibration is a useful concept for estimating predicted crash frequency and severity for alternatives when facility types change
- However, State calibration efforts have shown that the HSM single-State calibration may not provide valid relationships from State to State
- Additionally, the single-State calibration may not capture the interactive influences of traffic volumes and geometric characteristics
- Jurisdiction-specific calibrations and utilizing calibration functions can support improved decision-making particularly when considering project alternatives of different facility types

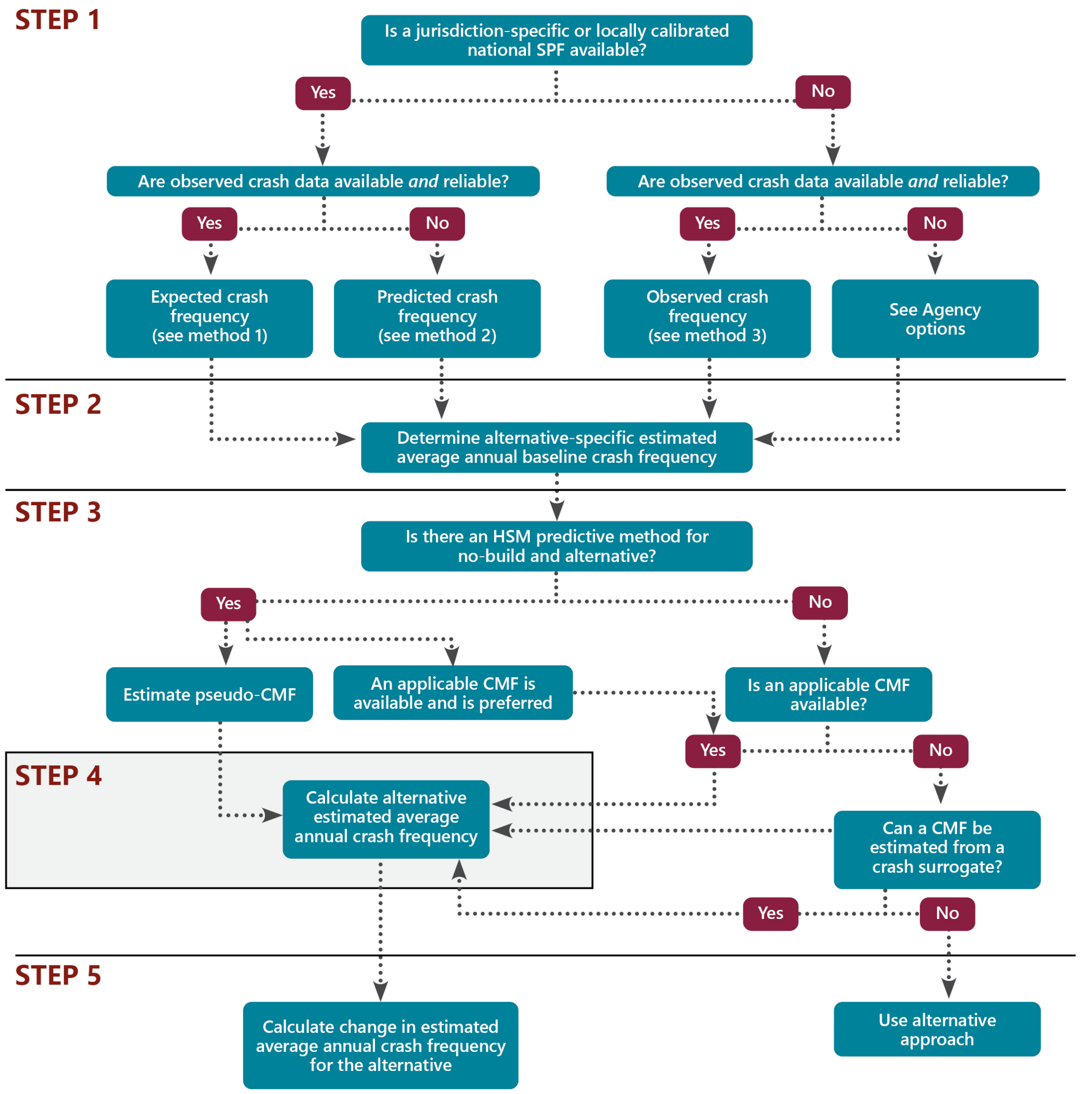
Recommended Approach

A Combined Method for Alternatives Analysis

- Project team explored reliability of methods for comparing project alternatives
  - Comparing expected crash frequency with observed or predicted crash frequency results in bias
  - Comparing predicted crash frequencies based on SPFs (and treating them as average locations) may result in a loss of information responsible for unique outcomes
  - There appears to be a disconnect when using baseline crash frequency and CMFs when comparing to using expected crash frequencies for project alternatives
- An approach, using baseline crash frequency and a relative assessment in estimated change in safety performance, is recommended for project alternatives analysis
  - Does not conflict with utilization of HSM Parts C or D
  - Allows the analyst to use the most reliable method available for assessing baseline measure
  - Provides for fair attribution of CMFs relative to Part C predictive method

Project Alternative Analysis Approach

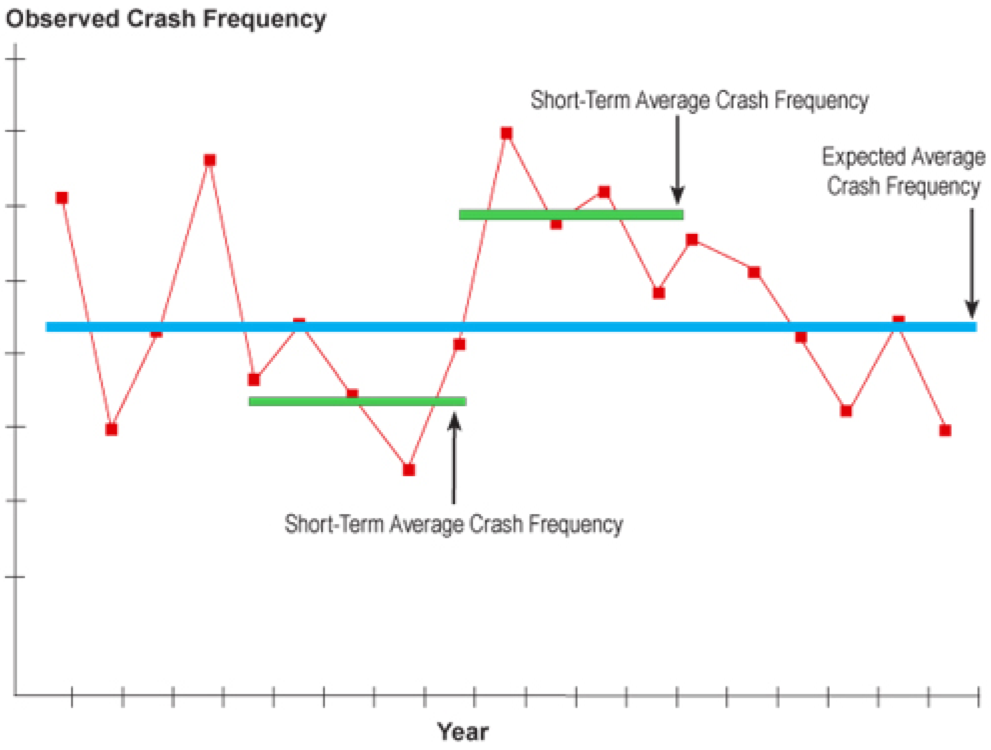
1. Establish baseline estimated average crash frequency for future no-build condition
2. Determine alternative-specific baseline average crash frequency
3. Identify the applicable method for estimating the safety effectiveness of project alternatives
4. Calculate the project alternative estimated crash frequency
5. Calculate expected change in crash frequency



Step 1: Baseline Average Crash Frequency

Establish baseline estimated average crash frequency for future no-build condition

a) Expected crash frequency
b) Predicted crash frequency
c) Observed crash frequency
d) Identify other options



Step 1: Identify Other Options

- At least two years of reliable observed crash data may not be available
- Locally calibrated SPFs or jurisdiction-specific SPFs may not be available
- Example options
  - Use one year of crash data if available
  - Identify a group of similar locations with reliable crash data
  - Use a predictive method for a similar facility type if available

Step 2: Alternative-Specific Baseline

- No-build condition may not serve as an applicable baseline for a project alternative
  - Example: Existing three-leg signalized intersection for a Continuous Green-T
  - An alternative-specific baseline (three-leg signalized intersection) may be required
- Alternative may require adjustment to baseline crash frequency if design year traffic volume differs
  - CMF may account for difference in traffic volume already
  - Example: road diet CMF may already account for change in traffic volume
- In most cases no adjustment is needed and results of Step 1 are used for Step 2

Step 3: Safety Effectiveness of Alternatives

- Several options exist for assessing project alternatives
- Each option has advantages and limitations
- Options are not considered as a hierarchy
  - Application of preferred CMFs
  - Application of pseudo-CMF
  - Application of safety surrogates

Step 3: Application of Preferred CMFs

- CMFs represent the relative effects of proposed countermeasures or enhancements
- HSM and CMF Clearinghouse contain CMFs to serve this purpose; however, context, crash type, and crash severity should be considered
- State agencies have developed preferred lists for consistent application
- HSM AFs can be applied together for multiple countermeasures
- NCHRP Report 991 should be considered when combining independent CMFs
- CMFs may not provide nuance for the complexity of proposed improvements
    - Example: CMF for widening rural two-lane to multilane roadway may be one CMF
    - Practitioner may wish to further consider the balance of median width, inside shoulder width, lane width, and outside shoulder width on safety performance

Step 3: Application of Pseudo-CMFs

- Relative comparison of predicted crash frequency from no-build to alternative

$$CMF_{pseudo} = \frac{N_{Alternative}}{N_{NoBuild}}$$

- May involve geometric changes within a facility type

$$CMF_{PM1} = \frac{AF_{i,A} \times \ldots \times AF_{n,A}}{AF_{i,NB} \times \ldots \times AF_{n,NB}}$$

- May involve geometric changes and traffic volume difference within a facility type

$$CMF_{PM2} = \frac{AADT_{A}^{\beta} \times AF_{i,A} \times \ldots \times AF_{n,A}}{AADT_{NB}^{\beta} \times AF_{i,NB} \times \ldots \times AF_{n,NB}}$$

- May involve a change in facility type

$$CMF_{pseudo} = \frac{N_{Alternative}}{N_{NoBuild}}$$

Step 3: Application of Pseudo-CMFs

- Allows for more nuanced assessment of geometric changes
- Allows for use of the predictive method when a CMF may not exist
- Assumes the predictive method for different facility types can be compared
  - Local calibration or jurisdiction-specific for all SPFs considered is required
  - Assumes single-State calibration is valid and applicable to jurisdiction if HSM models are directly applied

Step 4: Alternative Estimated Annual Crash Frequency

- Project alternative-specific estimated annual crash frequency

$$N_{estimated\ ,design\ ,alternative} = N_{baseline\ ,design\ ,alternative} \times CMF_{alternative}$$

- Can be compared to baseline crash frequency for the no-build condition or to other alternatives in the design year

Step 5: Change in Estimated Annual Crash Frequency

- Calculate the change in estimated annual crash frequency from the baseline in the design year under no-build conditions

$$N_{change,design,alternative} = N_{baseline,design} - N_{estimated,design,alterantive}$$

Example: HSM User Guide Case Study

Case Study – HSM User Guide

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Case Study – Steps 1 and 2

- Method 1 can be used since there is reliable crash data and locally calibrated HSM SPF
- No change in traffic volume anticipated
- Expected crash frequency calculated as shown in the original case study
- These serve as the estimated average annual baseline crash frequency for the no-build alternative
- No adjustments are needed in Step 2

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Case Study – Step 3

- Alternative 1: Shoulder widening from 1 ft to 6 ft: Pseudo-CMF = (1.0/1.23) = 0.81
- Alternative 2: Pseudo-CMF = (1.00 x 0.92 x 9.83 x 1.00) / (1.23 x 1.00 x 1.00 x 1.14) = 0.61

Feature	Conditions		Adjustment Factors	
	No-Build	Alternative 2	No-Build	Alternative 2
Shoulder Width	1 ft	6 ft	1.23	1.00
Lighting	Not Present	Present	1.00	0.92
Speed Enforcement	Not Present	Present	1.00	0.93
Roadside Rating	5	3	1.14	1.00

Case Study – Steps 4 and 5

- Estimated average annual crash frequency

Segment	No-Build	Alternative 1	Alternative 2
1	9.99	8.12	6.09
2	34.32	27.90	20.94
3	10.54	8.57	6.43
Total	54.85	44.59	33.46

- Change in estimated average annual crash frequency
  - Alternative 1: Reduction of 10.26 crashes
  - Alternative 2: Reduction of 21.39 crashes

Summary

- Recommended approach provides consistent method for project alternatives analysis
- Flexible to demands of analysis and availability of evaluation methods
- Recommended approach prioritizes using EB method, when data are available
- Consistent application of relative effects of safety improvements
- Additionally, historic crash data confined to no-build condition, removing question of applicability after changes are made
- Can be accomplished without local calibration, but calibration is recommended
- Flexible to incorporate alternative-specific traffic volumes
- More research is needed to identify the extent to which local calibration supports assessment of alternatives across facility types compared to a single-State calibration

Questions?

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Thank You!

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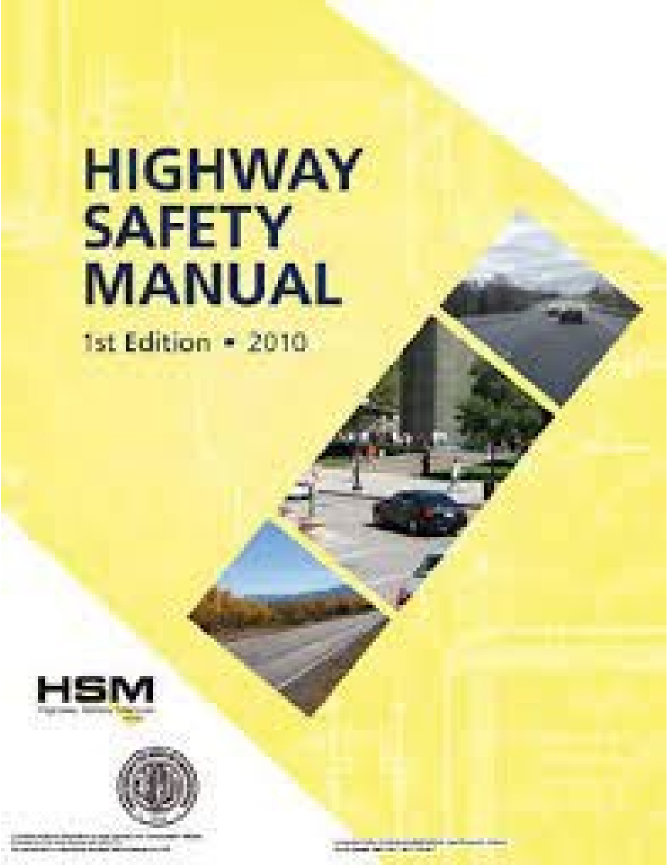

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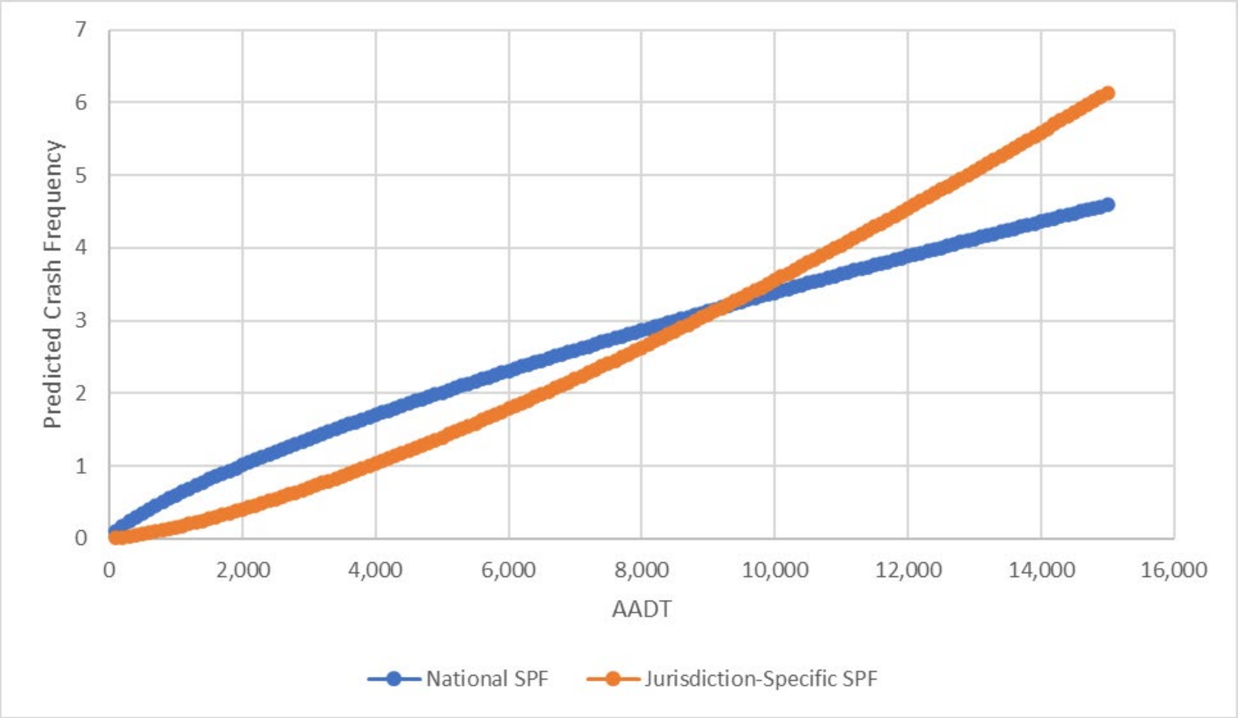

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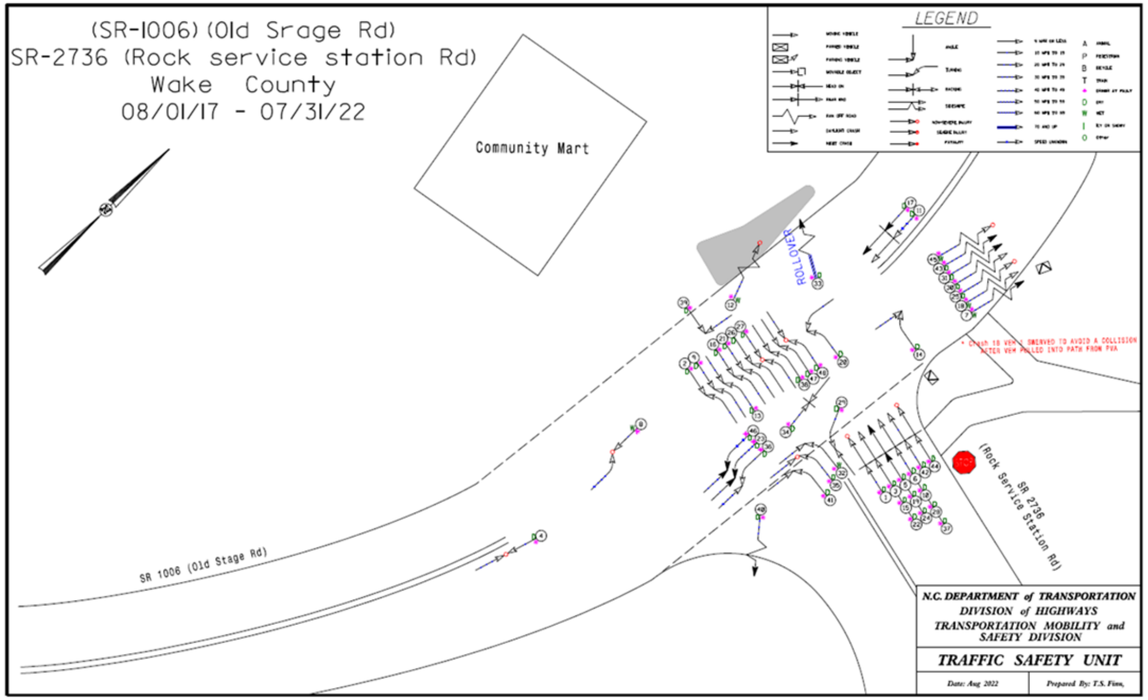

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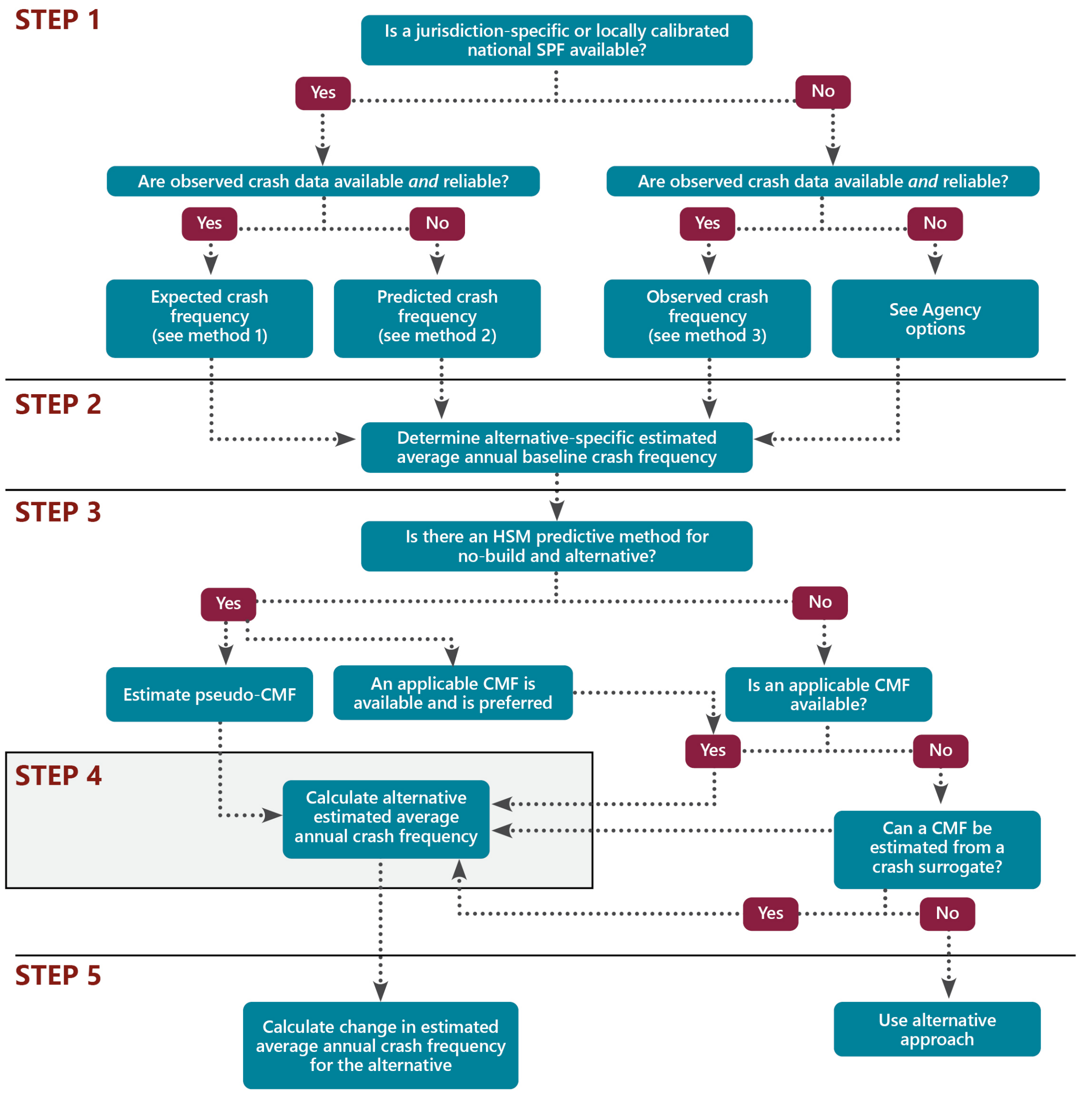
  - Provides for fair attribution of CMFs relative to Part C predictive method

Project Alternative Analysis Approach

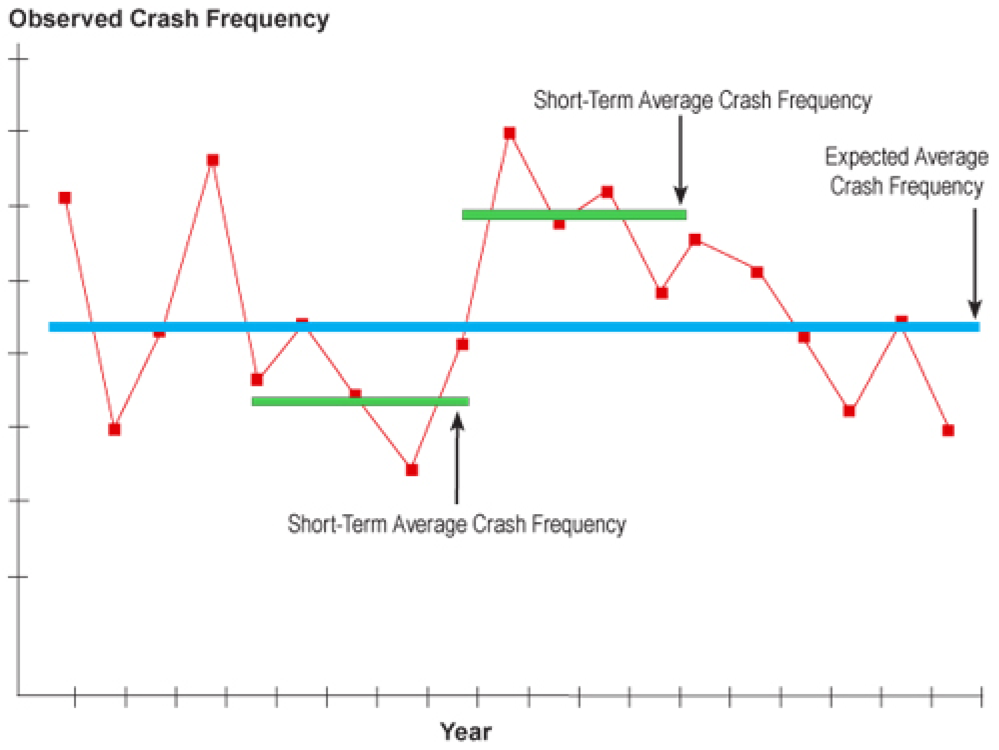
1. Establish baseline estimated average crash frequency for future no-build condition
2. Determine alternative-specific baseline average crash frequency
3. Identify the applicable method for estimating the safety effectiveness of project alternatives
4. Calculate the project alternative estimated crash frequency
5. Calculate expected change in crash frequency



Step 1: Baseline Average Crash Frequency

Establish baseline estimated average crash frequency for future no-build condition

a) Expected crash frequency
b) Predicted crash frequency
c) Observed crash frequency
d) Identify other options



Step 1: Identify Other Options

- At least two years of reliable observed crash data may not be available
- Locally calibrated SPFs or jurisdiction-specific SPFs may not be available
- Example options
  - Use one year of crash data if available
  - Identify a group of similar locations with reliable crash data
  - Use a predictive method for a similar facility type if available

Step 2: Alternative-Specific Baseline

- No-build condition may not serve as an applicable baseline for a project alternative
  - Example: Existing three-leg signalized intersection for a Continuous Green-T
  - An alternative-specific baseline (three-leg signalized intersection) may be required
- Alternative may require adjustment to baseline crash frequency if design year traffic volume differs
  - CMF may account for difference in traffic volume already
  - Example: road diet CMF may already account for change in traffic volume
- In most cases no adjustment is needed and results of Step 1 are used for Step 2

Step 3: Safety Effectiveness of Alternatives

- Several options exist for assessing project alternatives
- Each option has advantages and limitations
- Options are not considered as a hierarchy
  - Application of preferred CMFs
  - Application of pseudo-CMF
  - Application of safety surrogates

Step 3: Application of Preferred CMFs

- CMFs represent the relative effects of proposed countermeasures or enhancements
- HSM and CMF Clearinghouse contain CMFs to serve this purpose; however, context, crash type, and crash severity should be considered
- State agencies have developed preferred lists for consistent application
- HSM AFs can be applied together for multiple countermeasures
- NCHRP Report 991 should be considered when combining independent CMFs
- CMFs may not provide nuance for the complexity of proposed improvements
  - Example: CMF for widening rural two-lane to multilane roadway may be one CMF
  - Practitioner may wish to further consider the balance of median width, inside shoulder width, lane width, and outside shoulder width on safety performance

Step 3: Application of Pseudo-CMFs

- Relative comparison of predicted crash frequency from no-build to alternative

$$CMF_{pseudo} = \frac{N_{Alternative}}{N_{NoBuild}}$$

- May involve geometric changes within a facility type

$$CMF_{PM1} = \frac{AF_{i,A} \times \ldots \times AF_{n,A}}{AF_{i,NB} \times \ldots \times AF_{n,NB}}$$

- May involve geometric changes and traffic volume difference within a facility type

$$CMF_{PM2} = \frac{AADT_{A}^{\beta} \times AF_{i,A} \times \ldots \times AF_{n,A}}{AADT_{NB}^{\beta} \times AF_{i,NB} \times \ldots \times AF_{n,NB}}$$

- May involve a change in facility type

$$CMF_{pseudo} = \frac{N_{Alternative}}{N_{NoBuild}}$$

Step 3: Application of Pseudo-CMFs

- ❑ Allows for more nuanced assessment of geometric changes
- ❑ Allows for use of the predictive method when a CMF may not exist
- ❑ Assumes the predictive method for different facility types can be compared
  - Local calibration or jurisdiction-specific for all SPFs considered is required
  - Assumes single-State calibration is valid and applicable to jurisdiction if HSM models are directly applied

Step 4: Alternative Estimated Annual Crash Frequency

- Project alternative-specific estimated annual crash frequency

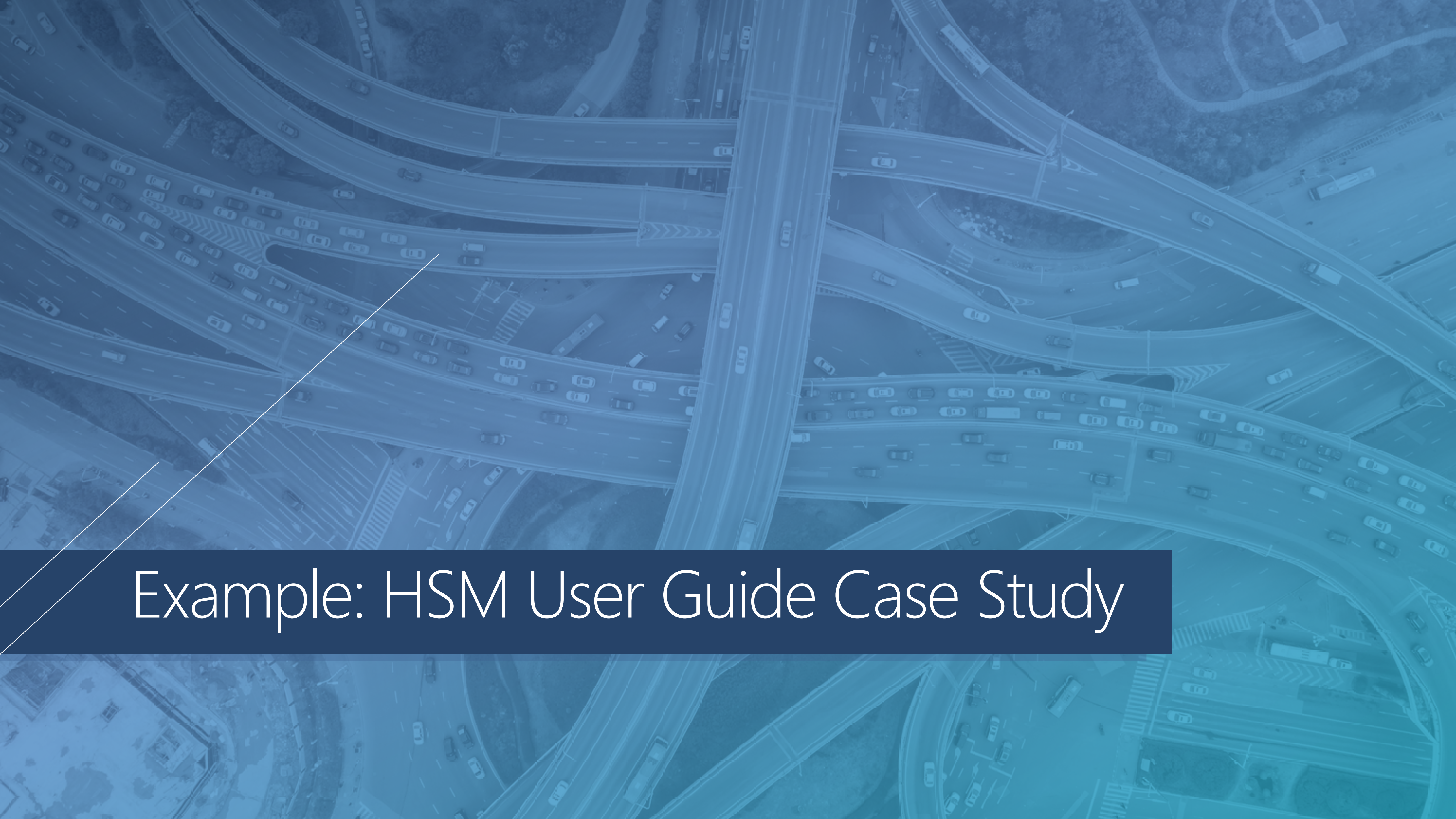
$$N_{estimated\ ,design\ ,alternative} = N_{baseline\ ,design\ ,alternative} \times CMF_{alternative}$$

- Can be compared to baseline crash frequency for the no-build condition or to other alternatives in the design year

Step 5: Change in Estimated Annual Crash Frequency

- Calculate the change in estimated annual crash frequency from the baseline in the design year under no-build conditions

$$N_{change,design,alternative} = N_{baseline,design} - N_{estimated,design,alterantive}$$



Example: HSM User Guide Case Study

Case Study – HSM User Guide

- Existing rural two-lane highway section (three segments)
- Project alternative 1 includes widening shoulder from 1 ft to 6 ft
- Project alternative 2 includes widening shoulder from 1 ft to 6 ft, installing roadway lighting, improving roadside hazard rating, and automated speed enforcement

Alternative	Segment	Predicted Crash Frequency	Observed Crash Frequency	Overdispersion Parameter	Weighted Adjustment	Expected Crash Frequency
No Build	1	4.94	11	0.202	0.167	9.99
No Build	2	3.58	40	0.303	0.156	34.32
No Build	3	8.24	11	0.121	0.167	10.54
No Build	Total	16.76	62	N/A	N/A	54.85
1	1	4.02	11	0.202	0.198	9.62
1	2	2.91	40	0.303	0.185	33.14
1	3	6.70	11	0.121	0.198	10.15
1	Total	13.63	62	N/A	N/A	52.91
2	1	3.01	11	0.202	0.248	9.02
2	2	2.18	40	0.303	0.232	31.21
2	3	5.02	11	0.121	0.248	9.52
2	Total	10.21	62	N/A	N/A	49.75

Case Study – Steps 1 and 2

- Method 1 can be used since there is reliable crash data and locally calibrated HSM SPF
- No change in traffic volume anticipated
- Expected crash frequency calculated as shown in the original case study
- These serve as the estimated average annual baseline crash frequency for the no-build alternative
- No adjustments are needed in Step 2

Alternative	Segment	Predicted Crash Frequency	Observed Crash Frequency	Overdispersion Parameter	Weighted Adjustment	Expected Crash Frequency
No Build	1	4.94	11	0.202	0.167	9.99
No Build	2	3.58	40	0.303	0.156	34.32
No Build	3	8.24	11	0.121	0.167	10.54
No Build	Total	16.76	62	N/A	N/A	54.85

Case Study – Step 3

- Alternative 1: Shoulder widening from 1 ft to 6 ft: Pseudo-CMF = (1.0/1.23) = 0.81
- Alternative 2: Pseudo-CMF = (1.00 x 0.92 x 9.83 x 1.00) / (1.23 x 1.00 x 1.00 x 1.14) = 0.61

Feature	Conditions		Adjustment Factors	
	No-Build	Alternative 2	No-Build	Alternative 2
Shoulder Width	1 ft	6 ft	1.23	1.00
Lighting	Not Present	Present	1.00	0.92
Speed Enforcement	Not Present	Present	1.00	0.93
Roadside Rating	5	3	1.14	1.00

Case Study – Steps 4 and 5

- Estimated average annual crash frequency

Segment	No-Build	Alternative 1	Alternative 2
1	9.99	8.12	6.09
2	34.32	27.90	20.94
3	10.54	8.57	6.43
Total	54.85	44.59	33.46

- Change in estimated average annual crash frequency
  - Alternative 1: Reduction of 10.26 crashes
  - Alternative 2: Reduction of 21.39 crashes

Summary

- Recommended approach provides consistent method for project alternatives analysis
- Flexible to demands of analysis and availability of evaluation methods
- Recommended approach prioritizes using EB method, when data are available
- Consistent application of relative effects of safety improvements
- Additionally, historic crash data confined to no-build condition, removing question of applicability after changes are made
- Can be accomplished without local calibration, but calibration is recommended
- Flexible to incorporate alternative-specific traffic volumes
- More research is needed to identify the extent to which local calibration supports assessment of alternatives across facility types compared to a single-State calibration

Questions?

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Thank You!

Research topics

Topics

Keep this in mind… evaluation criteria:

a) the overall importance of conducting research on this topic

b) do you believe that State DOTs will consider completion of research on this topic to be a key priority

Other items

- Update on national efforts and initiatives
- Upcoming events
- Subcommittee membership and task forces/working groups:
  - New methods/theories (e.g. white papers, e-circular, special issues, RNS)
  - Promotion of applications (e.g. workshops, training, RNS)
  - Ad hoc issues with the Highway Safety Manual (e.g., RNS)
- Liaisons with other committees/subcommittees
- Open floor

Thank you

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