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Quantitative Safety Analysis: A Discussion on Practical Applications and Options in Project-Decision Making

Thursday, May 14, 2020 (12:30pm – 5:00pm ET)

Agenda

- 1:00 pm Begin Time
- Kick Off – Amy Causseaux (FDOT)
- Opening Remarks and Introductions – Kevin Burgess (FHWA)
- Overview – Mark Doctor (FHWA)
- Options – Dave Petrucci (FHWA)
- 2:45 – 3:15 pm BREAK
- Implications – George Merritt (FHWA)
- 4:45 – 5:00 pm WRAP UP / Questions

The “Parking Lot”

- Questions that come up that can be covered later in the course will be “parked”
- We will review these questions at the end to make sure they were answered
- Chat Questions
- Open Discussion


Source: Alex@flickr

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Meeting Kick Off

Amy Causseaux – Florida Department of Transportation (FDOT)

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Opening Remarks & Introductions

Kevin Burgess – FHWA Florida Division

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Overview

Mark Doctor – FHWA Resource Center

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Options

Dave Petrucci – FHWA Resource Center

Presentation Content

- Background
- AASHTO Highway Safety Manual (HSM) Fundamentals
- Crash Prediction Workflow Considerations
- Examples
- Conclusions
- Take Home Material
  - Maturity Matrix
  - Resources

BACKGROUND

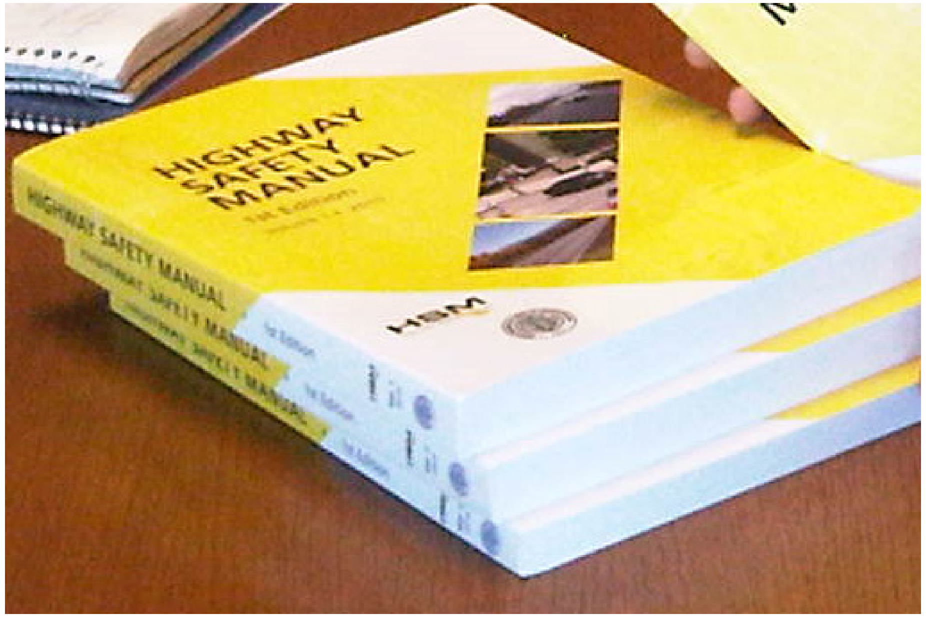
Data-Driven Safety Analysis

- Applying newer, evidence-based tools to evaluate safety performance in planning and project development
- Includes reactive and proactive applications of predictive and systemic analysis tools and methods
- Evolution from just nominal to substantive approaches
- The AASHTO HSM is an ~~the~~ example of such a tool

https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/ddsa_resources/

The AASHTO HSM…

- Original purpose was to serve as a single, authoritative document for quantitatively estimating ‘safety’
- A tool for safety analysis
- Encourages a ‘science-based’ approach
- A synthesis & compilation of previous research
- Describes relationships between certain roadway conditions and safety outcomes (i.e. crash frequency, severity, types)



http://www.highwaysafetymanual.org/Pages/default.aspx

The AASHTO HSM is NOT …

- Itself a standard, policy, nor a best practice document
- The Highway Safety Performance Function Manual
- The Highway Crash Severity Estimation Model
- A Replacement for Professional Engineering Judgement
- Boundless
- Free
- Perfect
- ….

HSM 1st Edition Content and Structure

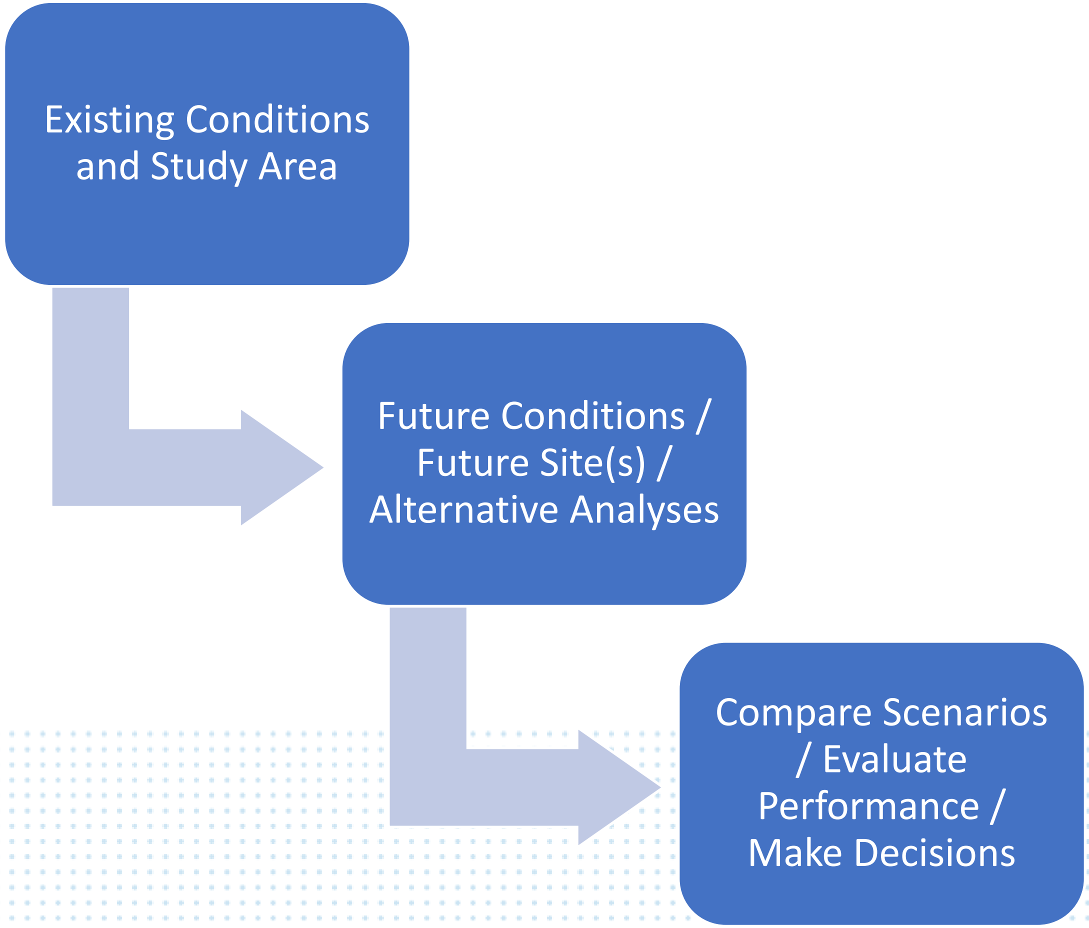
- Part A - (Introduction, Human Factors and Fundamentals)
- Part B - (Roadway Safety Management Process)
- Part C - (Predictive Methods)
- Part D - (Crash Modification Factors or CMF’s)

** Note that a 2nd Edition has been under development. As of today, a publication date is unknown, but is likely several years from now.*

http://www.highwaysafetymanual.org/Documents/HSM2_GeneralUpdate_20191113.pdf

https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3874

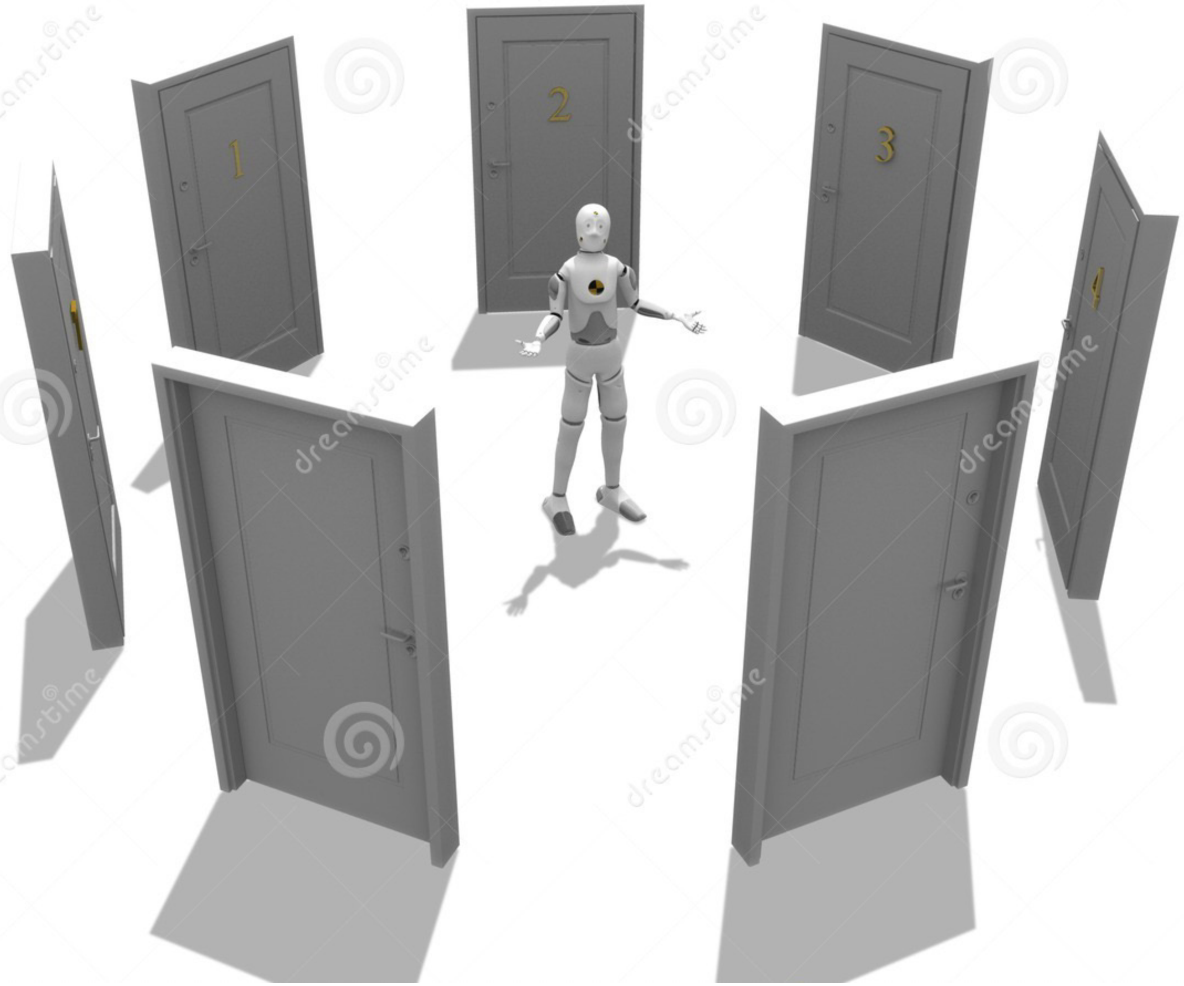
Typical Beginnings of Safety Analysis



Key Considerations:

- Purpose / Needs / Goals
- Applicable Policy / Rules
- Expertise
- Available tools
- Scope, schedule, budget

Tool and Resource Overload



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HSM FUNDAMENTALS

HSM Fundamentals

1. Crashes are a fundamental indicator of ‘safety performance’
2. Differences between objective and subjective safety concepts
3. Crashes are rare and random events
4. Crashes are the result of a convergence of events / conditions
5. Contributing factors influence crashes
6. Roadway design and operation impact users
7. Crash estimation methods are evolving

1. Crashes = Fundamental Indicators

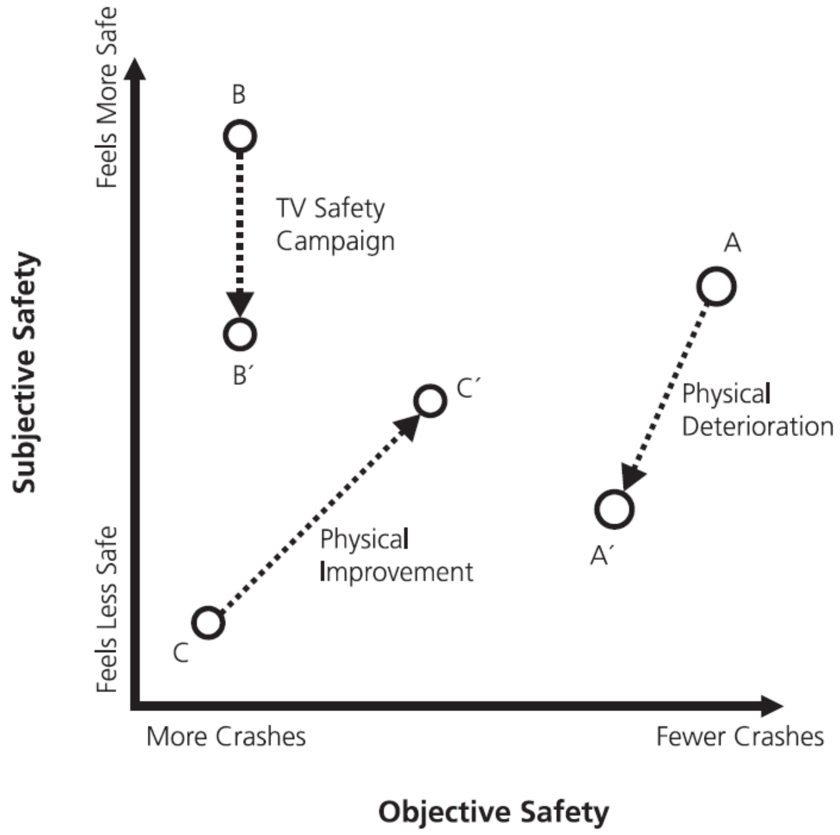
- Crash frequency is used as a fundamental indicator of 'safety' in the evaluation and estimation methods in the HSM
- The term 'safety' is interchangeable with crash frequency or severity, or both, as well as collision type
- Injury & property damage have societal and economic costs

Severity	Comprehensive Crash-Level Cost (2017 dollars)
K	$11,637,947
A	$674,353
B	$204,143
C	$129,001
O	$12,108

SOURCE: FHWA Guide, *Crash Costs for Highway Safety Analysis*

2. Objective and Subjective Safety

- Objective Safety = application of a quantitative measure, would be repeatable.
  - *Objective Safety* = f(models, science)
- Subjective Safety = perception and opinion, based on the individual, assessments may vary.
  - *Subjective Safety* = f(user, bias, experiences, knowledge, expertise, environment, objective safety)



Source: NCHRP 17-27

Figure 3-1. Changes in Objective and Subjective Safety

"The traveling public, the transportation professional and the statisticians may all have diverse but valid opinions about whether a site is "safe" or "unsafe."

SOURCE: AASHTO HSM Chapter 3 Page 3-2

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2. Objective and Subjective Safety

- "…**Engineering judgment** must be applied when developing designs for roadway improvement projects. Successful projects involve a transparent and consensus-based decision process that outlines what is important and how it will be measured or estimated. Implementing such a process and making a good decision requires full knowledge of the quantitative and qualitative effects of the many identified values and issues, including safety…."

SOURCE ITE Integration of Safety in the Project Development Process and Beyond: A Context Sensitive Approach – Page 2

https://www.ite.org/pub/?id=e4edb88b-bafd-b6c9-6a19-22e98fedc8a9

Safety Analysis Options

As we progress through this presentation, the goal of this recurring slide is to construct the foundational items covered thus far so that the user can understand and relate various options for both quantitative and qualitative safety analysis that may or may not be appropriate for a given project.

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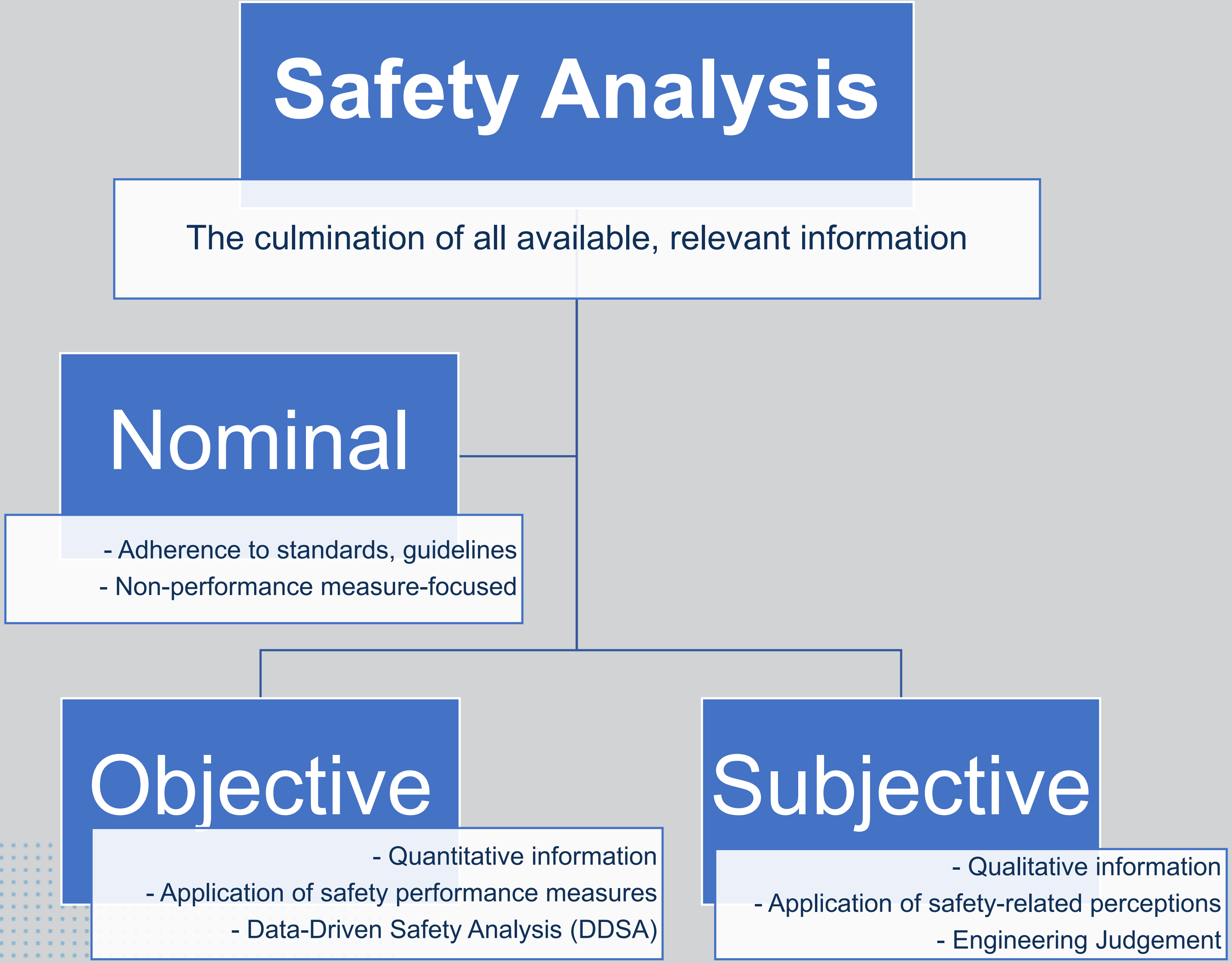


3. Crashes = Rare and Random

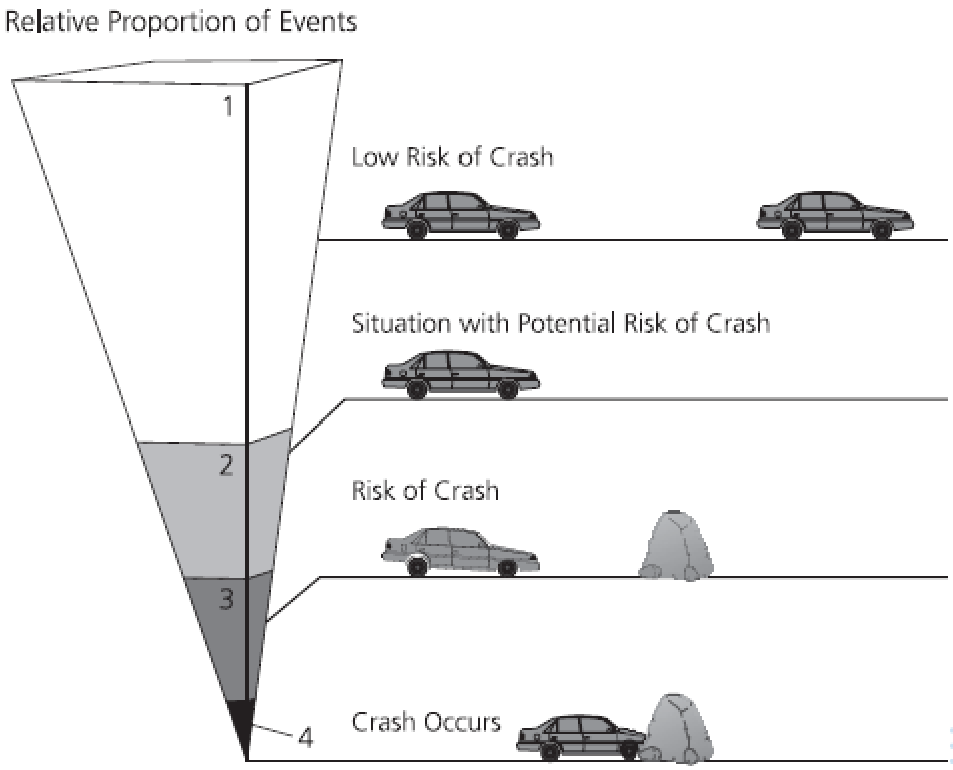


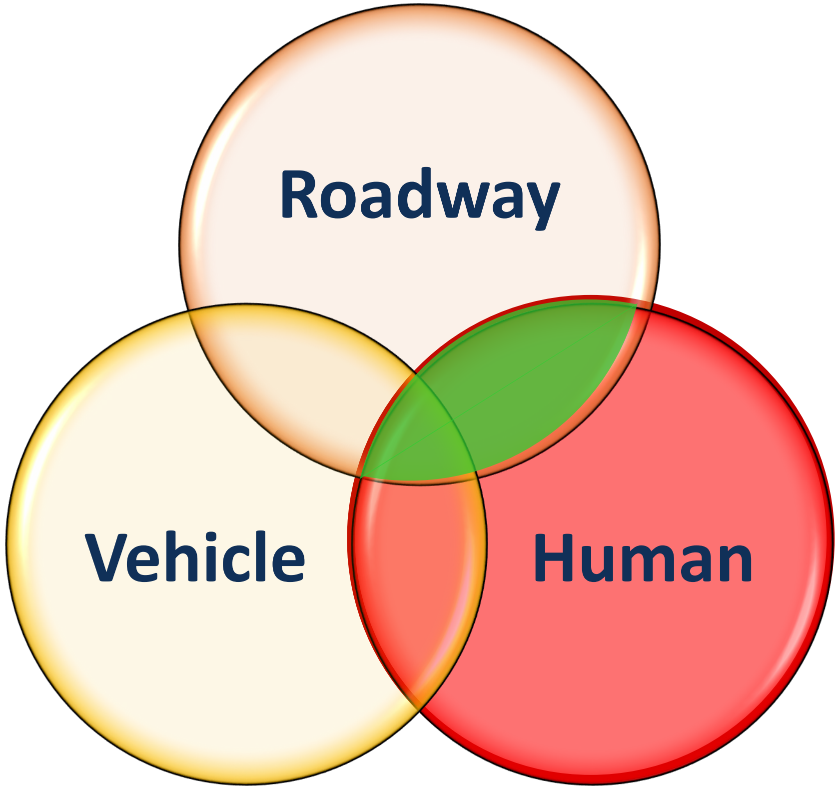
Figure 3-2. Crashes Are Rare and Random Events

SOURCE: HSM Chapter 3.2.1 Page 3-2

- A crash is one possible outcome of a continuum of events with changing risk
- Crashes represent only a fraction of these events
- Many more near misses and evasive maneuvers
- How do we predict random events?

4. Crashes = Convergence of Events

- Judgment errors
- Distractions
- Information overload
- Driver expectation violations
- Rules of the road violations
- Mistakes / errors lead to crashes
- **Crashes have been associated with various measurable design, exposure and traffic control characteristics**



5. Contributing Factors Influence Crashes

- *Human* – (age, judgment, skill, attention, fatigue, experience, sobriety)
- *Vehicle* – (design, manufacture, maintenance)
- *Roadway/Environment* – (geometry, cross-section, traffic control devices, surface friction, grade, signage, weather, visibility)

Table 3-1. Example Haddon Matrix for Identifying Contributing Factors

Period	Human Factors	Vehicle Factors	Roadway/Environment Factors
Before Crash Factors contributing to increased risk of crash	distraction, fatigue, inattention, poor judgment, age, cell phone use, deficient driving habits	worn tires, worn brakes	wet pavement, polished aggregate, steep downgrade, poorly coordinated signal system
During Crash Factors contributing to crash severity	vulnerability to injury, age, failure to wear a seat belt, driving speed, sobriety	bumper heights and energy adsorption, headrest design, airbag operations	pavement friction, grade, roadside environment
After Crash Factors contributing to crash outcome	age, gender	ease of removal of injured passengers	the time and quality of the emergency response, subsequent medical treatment

SOURCE: HSM Chapter 3.2.1 Page 3-7

5. Contributing Factors Influence Crashes

- The Systemic Safety Approach focuses on potential risk factors that may be associated with a population of crash types and/or severities in a variety contexts.
- Factors like posted speed, horizontal curves, weaving, left-side or right-side ramps, etc. could be considered
- $Risk\ Factors \neq Crashes$

https://safety.fhwa.dot.gov/systemic/pdf/FHWA_SystemicApproach_PotentialRiskFactors.pdf

Potential Risk Factors

The systemic approach focuses on risk rather than exact locations. Once states identify a risk factor that involves a number of crashes, they can be proactive and fix the problem wherever that risk feature exists. Following is a list of potential risk factors where states may want to examine their crash database to determine whether there is a problem.

Roadway and Intersection Features

- Number of lanes
- Lane width
- Shoulder surface width/type
- Median width/type
- Horizontal curvature, delineation, or advance warning
- Horizontal curve and tangent speed differential
- Roadside or edge hazard rating (potentially including sideslope design)
- Driveway density
- Presence of shoulder or centerline rumble strips
- Presence of lighting
- Presence of on-street parking
- Intersection skew angle
- Intersection traffic control device
- Number of signal heads versus number of lanes
- Presence of backplates
- Presence of advanced warning signs
- Intersection located in/near horizontal curve
- Presence of left-turn or right-turn lanes
- Left-turn phasing
- Allowance of right-turn-on-red
- Overhead versus pedestal mounted signal heads
- Pedestrian crosswalk presence, crossing distance, signal head type




Traffic Volume

- Average daily traffic volumes
- Average daily entering vehicles

Other Features

- Posted speed limit or operating speed
- Presence of nearby railroad crossing
- Presence of automated enforcement
- Adjacent land use type, such as schools, commercial, or alcohol-sales establishments
- Location and presence of bus stops

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Safe Roads for a Safer Future

http://safety.fhwa.dot.gov

6. Users are Affected by our Decisions

- Humans make mistakes
- User decisions and behavior are influenced by roadway design & traffic control
- Every user processes and reacts differently
- The driving task features decisions on a spectrum of complexity and importance
- Designers should understand human contributing factors in design and work to reduce probability and severities of user error

7. Evolving Crash Estimation Methods

The HSM Chapter 3 identifies three (3) quantitative safety analysis methods (i.e. crash estimation methods) *..

1) Identification and Use of Observed Crash Data (crash records)
2) Use of Surrogate Safety Measures / Indirect Safety Techniques
3) Deployment of Statistical Analysis Techniques or Crash Prediction Methods (SPF's and CMF's)
4) Other *….

* 'Other' is NOT includes in the HSM

PAUSE FOR QUESTIONS / DISCUSSION

1) Observed Crash Data

- Observed Crash Data = Frequency, Severity, Types, Rates, Trends, Factors
- Advantages:
  - *Understandability*—observed crashes are intuitive
  - *Acceptance*—it is intuitive for members of the public to assume that observed trends will continue to occur;
  - *Limited alternatives*—in the absence of another preferable methodology, observed crash data maybe the only option
- Disadvantages / Limitations:
  - Natural variability in crash frequency
  - Regression-to-the-mean and regression-to-the-mean bias
  - Variations in roadway characteristics
  - Conflict between Crash Frequency Variability and Changing Site Conditions

2) Surrogate Safety / Indirect Measures

- Indirect measures = events or conditions which presume a causal link with a crash, or are proximate to and usually precede a crash.
- Examples: near misses, conflicts, conflict points, lane changes, measurements of time-to-collision, post encroachment time, traditionally-non safety-related performance measures…
- Advantages:
  - Can be collected, measured or calculated without having to wait for sufficient crash history
- Disadvantages:
  - The relationship between many indirect measures and crashes is not known, or well-established.

3) Crash Prediction Methods

- Crash Prediction Methods = Combination of HSM and local SPF's, SDF's, AF's / Part C/D CMF's, and Calibration
- The 'primary player' and what most users think of when implementing the HSM in policy or application to a project
- Advantages:
  - Can overcome limitations / challenges with observed data
  - Established correlations between roadway conditions and safety
- Disadvantages:
  - Many methods do not explicitly account for changes in speed
  - Many facility types and conditions are not currently supported.

3) Crash Prediction Methods

- "…There are knowledge gaps in areas where tools and best practices may not yet exist for conducting a substantive or quantitative safety analysis, particularly in the area of safety for nonvehicular users. Such gaps should not discourage the practitioner from applying the methods presented in this report, nor should they prevent the use of engineering judgment and professional experience to help bridge the gaps…."

SOURCE ITE Integration of Safety in the Project Development Process and Beyond: A Context Sensitive Approach – Page 2

https://www.ite.org/pub/?id=e4edb88b-bafd-b6c9-6a19-22e98fedc8a9

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4) Other Quantitative Methods

- Other Quantitative Methods*
  - Realtime analytics, Machine Learning, Newer technologies?
- Advantages:
  - ?
  - ?
- Disadvantages / Limitations:
  - ?
  - ?

* The AASHTO HSM and other FHWA publications do not at present provide detailed information on 'other' crash estimation or quantitative safety analysis methods

Safety Analysis Options

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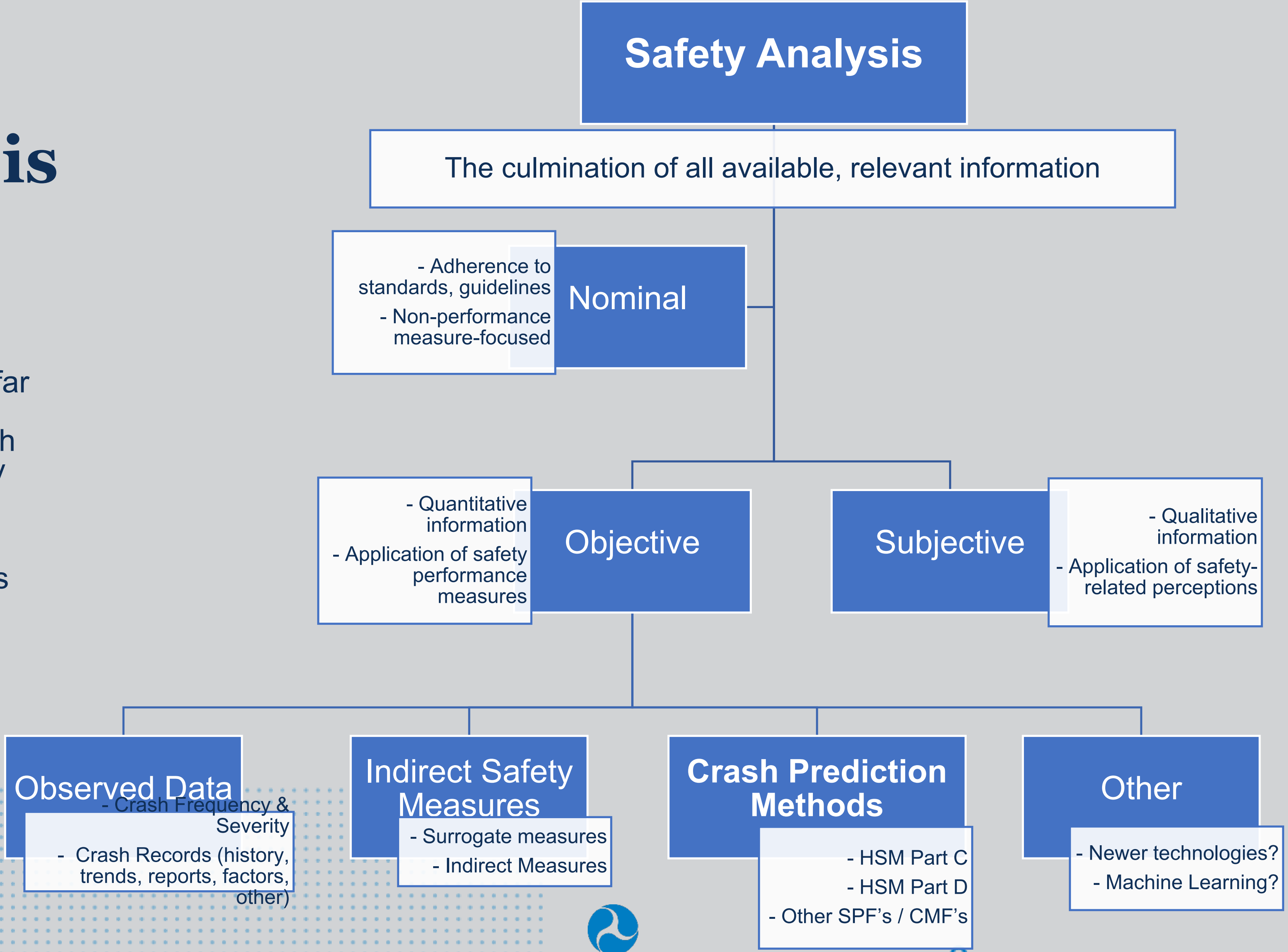


CRASH PREDICTION WORKFLOW CONSIDERATIONS

HSM Crash Prediction Methods

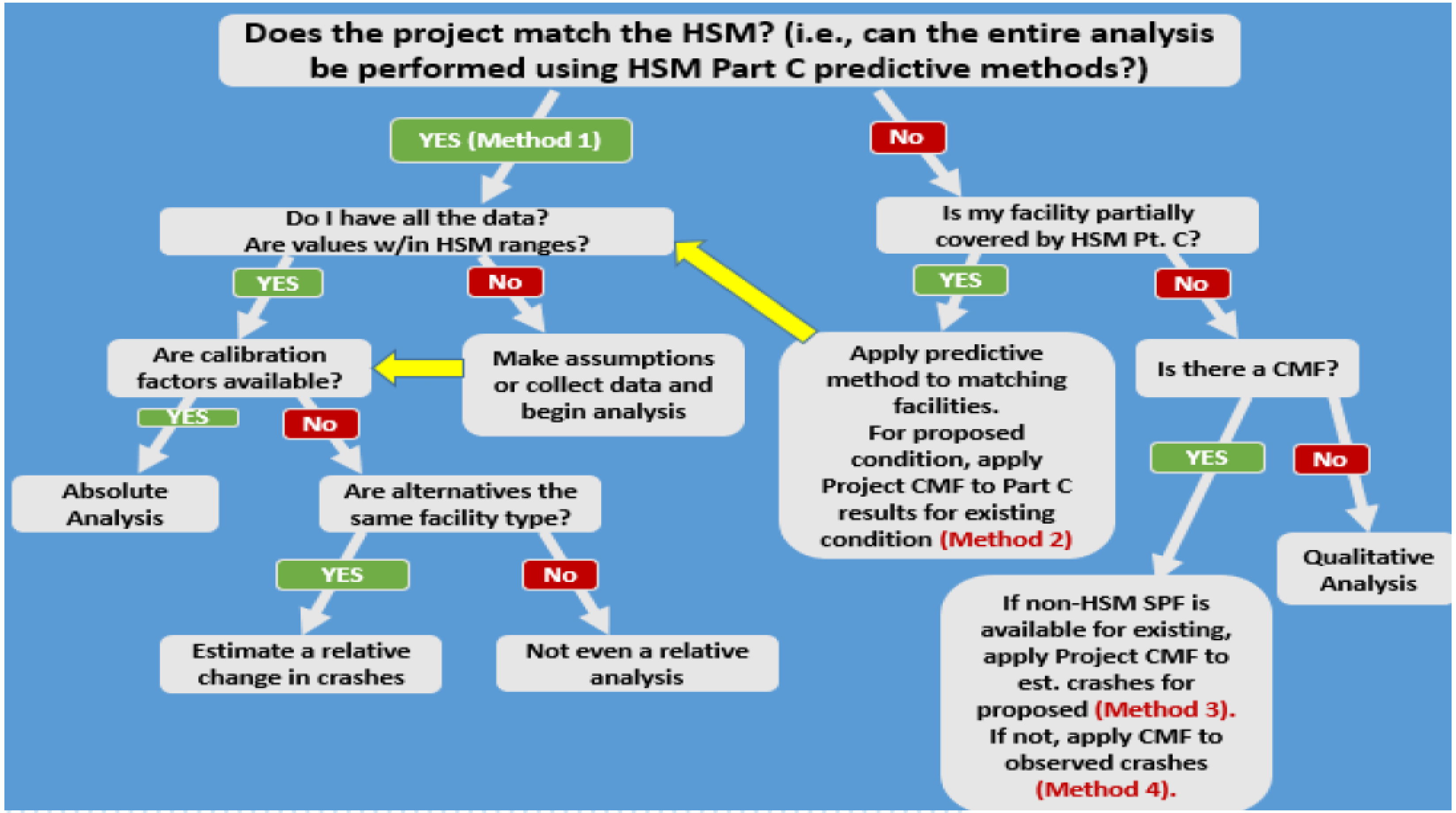
Preference

- The HSM Part C states that users should user four methods for estimating the change in expected crashes in order of reliability (from high to low, starting with Method 1).
  - Method 1 – Part C methods for existing and proposed
  - Method 2 – Part C for existing, Part D for proposed
  - Method 3 – Other SPF's for existing, Part D for proposed
  - Method 4 – Observed crashes for existing, Part D for proposed
- For all four methods, difference in expected crashes by site (base versus alternative) is used to derive effectiveness

SOURCE: AASHTO HSM Part C.7

What if no SPF's or CMF's are available?
What is no calibration or local data is available?

TRB 2020 Annual Meeting Flow Chart



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https://annualmeeting.mytrb.org/OnlineProgramArchive/Details/13367

HSM Crash Prediction Method 1

- Method 1 is the highest in predictive reliability
- Application of the AASHTO HSM Part C methods for <u>both</u> scenarios being compared
- Base case is typically the existing or no build scenario
- Comparison case is typically then future or build scenario
- BOTH cases / scenarios modeled with HSM Part C methods

HSM Crash Prediction Method 2

- Method 2 is the second highest in predictive reliability
- AASHTO HSM Part C methods for base case
- AASHTO HSM Part D / CMF for comparison case
- Base case is typically the existing or no build scenario
- Comparison case is typically then future or build scenario
- Appropriate CMF(s) used that change character of site
- If that change is captured by Part C, Method 1 should be used

HSM Crash Prediction Method 3

- Method 3 is the third highest in predictive reliability
- When AASHTO HSM Part C methods are not available, but known and applicable SPF (outside of Part C) is appropriate
- Known SPF (not HSM Part C) for base case
- AASHTO HSM Part D for comparison case
- If known SPF's outside of Part C are available for both cases, no guidance is given in the HSM
- If locally-derived CMF's outside of Part D are available, then use Method 3

HSM Crash Prediction Method 4

- Method 4 is the fourth highest in predictive reliability
- Observed crashes for existing base case
- AASHTO HSM Part D for future comparison case
- Only appropriate for comparisons under existing conditions (with or without character changing aspect of the CMF used)
- If locally-derived CMF's outside of Part D are available, no guidance is given in the HSM.

Safety Analysis Options

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Crash Prediction Methods

- AASHTO HSM Part C
- AASHTO HSM Part D
- Calibrated HSM Part C
- Locally-Developed SPF's (for use in Part C)
- Other Known / Applicable SPF's (outside of Part C)
- Locally-Developed CMFs (outside of Part D)

Method 1

- HSM Part C SPF's for both comparisons

Method 2

- HSM Part C for base case
- HSM Part D adjustment for comparison case

Method 3

- Non HSM Part C SPF for base case
- CMF (HSM Part D, or other applicable) adjustment for comparison case

Method 4

- Appropriate only for comparisons to existing conditions
- Observed crashes for existing base case only

HSM Part D adjustment for comparison case (existing conditions only)

- Expected Crashes for Minor Changes (EB)
- Predicted Crashes for Major Changes

Safety Analysis Options

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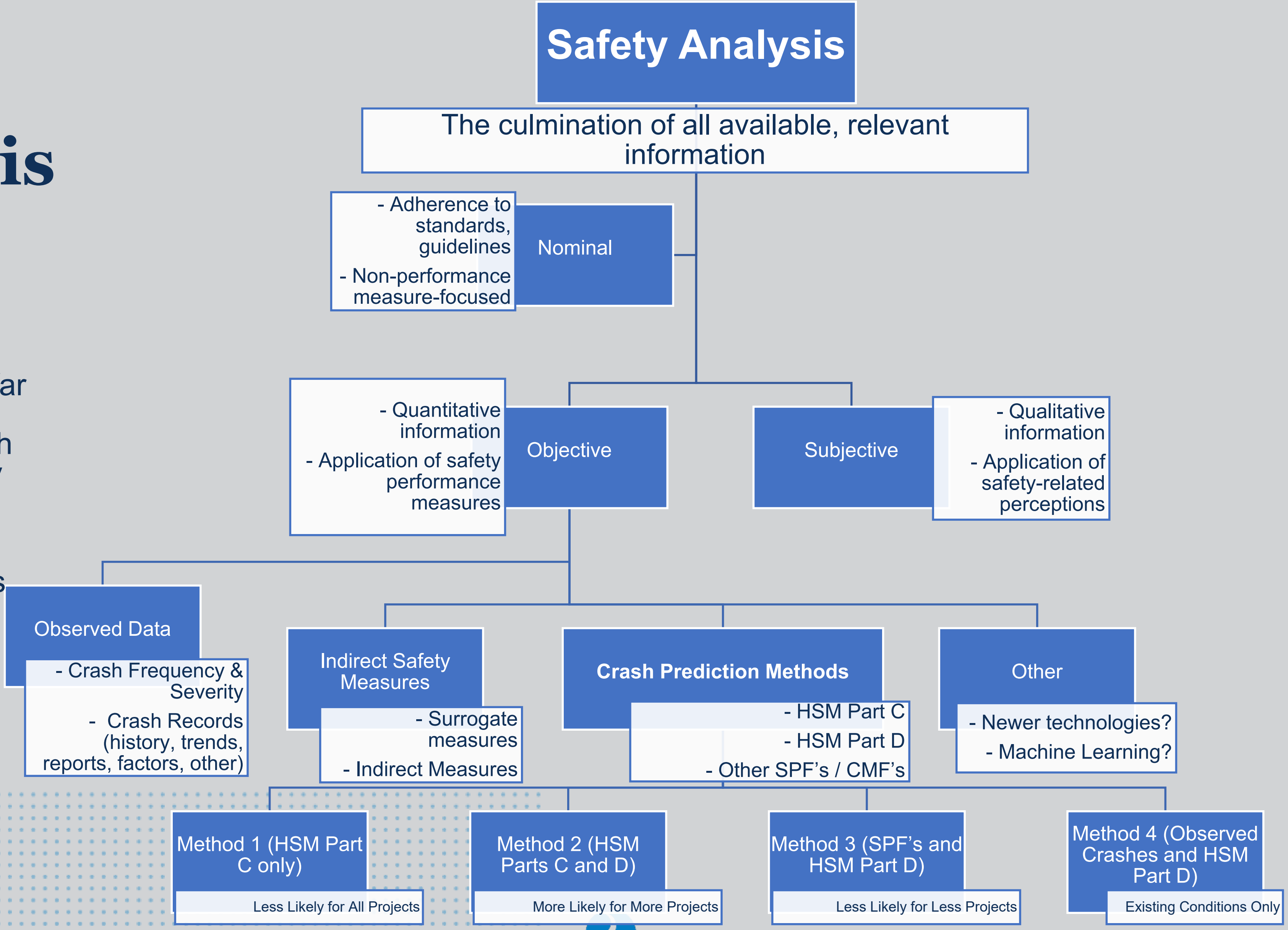


Typical Challenges

- Different levels of exposure, w/ no-build and build comparisons
- Limited/no review of underlying CMF research, despite material posted to the clearinghouse
- Modeling situations not covered by Part C / Part D
- Inconsistencies among agency teams, between program areas
- Aggregating network-wide results, less facility-specific review
- EB is occasionally used for existing and future no build cases, but future alternatives render expected crash comparisons difficult

Typical Challenges (continued)

- Disconnect between overall analysis & proposed projects
- Several cases where detailed crash data is used, but EB is not
- Existing conditions are seldom modeled
- Future no build conditions are typically the benchmark or base case for comparative analysis work
- Some inputs are ignored or defaulted (i.e. freeway PHV)
- Absolute crash values and BCA used less often than more comparative (i.e. percent change) analysis efforts

Some feedback over the years….

- When encountering HSM Part C / D limitations, supplemental analysis techniques are of interest
- Similar to the HCM, limitations in the HSM should be upfront, and a process when encountering a limitation should be given
- More tools are implementing the HSM. Who verifies?
- Version control for Clearinghouse / HSM is of interest
- Part C Calibration should also include collision distributions

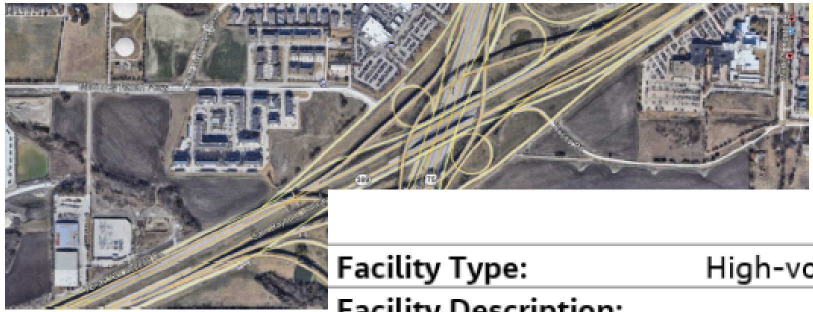
PAUSE FOR QUESTIONS / DISCUSSION

EXAMPLES

Anonymous HSM Part C / D Examples

Project	Size	Chapter/Tool	Notes
1. +$1.4 Billion New Interstate Alignment & Interchange, Widening & Reconstruction {Mid West}	- Large network of surface streets, intersections, ramps, interchanges, freeways, (+100 facilities, +1,500 homogeneous segments)	Part C – 10,11,12,18,19 Part D IHSDM	**Largest known IHSDM model** in the nation, spanning rural and urban areas, LandXML
2. Land Development Project (+500 homes) & Zoning Case {East Coast}	- Small Suburban Study Area, 3 intersections	Part C - 12 Spreadsheets	Judge denied developer request for zoning relief, cited safety (HSM)
3. ~$500 Million Interchange Access Request & Alternatives Analysis {West}	- Large urban network, spanning local and state systems, large interchange and freeway system - 10 intersections, 50 segments	Part C – 12,18,19 Part D IHSDM	Preferred alternative with **more roadway crashes and less intersection crashes**, several Part D CMF's
4. Two-Lane Highway Design Exception {South}	Rural Area, 5-mile section	Part C – 10,11 Spreadsheets	Design exception, 1-yr study period, slightly higher crashes
5. ~$50M Interchange Closure Project	Rural freeway and surface streets (100+ homogeneous segments, 8 intersections)	Part C – 10,11,18,19 ISATe IHSDM	Initial focus on just freeway crashes led to different conclusions.

TRB 2020 Freeway C Example



Freeway Example C:

Location Information

Facility Type:	High-volume urban freeway interchange area in the southwest
Facility Description:	

A freeway interchange between two high-volume freeways in a dense, restricted urban environment. The facility includes multiple exit and entrance points along both the right and left sides of the mainline, an HOV lane in the westbound direction to serve inbound commuters, and weaving movements of types A, B, and C. The HOV lane is primarily needed during peak hour and events.

Project Information

Project Type:	Alternative Design Analysis
HSM Method:	Part C freeway and ramp crash prediction
Project Description:	

Due to poor operational performance, increasing traffic demands, and high frequencies of congestion-related crashes (e.g., rear-end), the DOT has decided to explore redesign options. Though the primary reason for the project is operational needs, the DOT would like to include traffic safety in the decision-making process.

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TRB 2020 Freeway C Example

HIGHWAYSAFETYMANUAL

Freeway Example C:

TRB Workshop: HSM Freeway Example C (continued)

Project Challenges:

- HSM models only directly account for Type B weaves (i.e., not Type A or C)
- HSM models have major limitations in evaluating HOV /managed lanes
- Alignments differ by direction and while HSM models evaluate both directions, modeling one direction only may be needed
- Only annual crashes are predicted that do not account for seasonal differences and average daily traffic does not account for peak hour or events
- EB analysis is not achievable, due to lack of quality crash data, or since existing condition differs significantly from alternative designs

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TRB 2020 Freeway C Example Notes

- Using the flowchart, attendees discussed process for addressing project challenges to determine a reasonable crash prediction.
- HOV Modeling: University of Florida (UF) and Florida International University (FIU) –2015
  - Developed predictive methods to determine crash frequency on freeways with HOV and HOT lanes. https://rosap.ntl.bts.gov/view/dot/29139
  - Crash modification factors (CMFs) to control for roadway geometry features and the types of separation between the general purpose and the HOV/HOT lanes.
  - The models will be implemented in a simple spreadsheet tool to allow analysts to use the equations for predictive assessments.
- Investigate available CMFs.
- NCHRP 17-89A is underway for HOV and HOT lanes with anticipated completion summer 2020.

Use of Safety Performance in Day-to-Day Transportation Decision Making

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TRB 2020 Freeway C Example Notes

- Alignments differ by direction
  - Model each direction separately
- Weave Type C
  - HSM Models only directly account for Type B (i.e., not Type A or C).
  - Model as type B and document results and disclaimer
- AADT Models
  - Do not account for seasonal differences and AADT doesn't account for peak hour or events. Research is underway to address this issue
- EB analysis is not achievable since existing condition differs significantly from alternative designs.

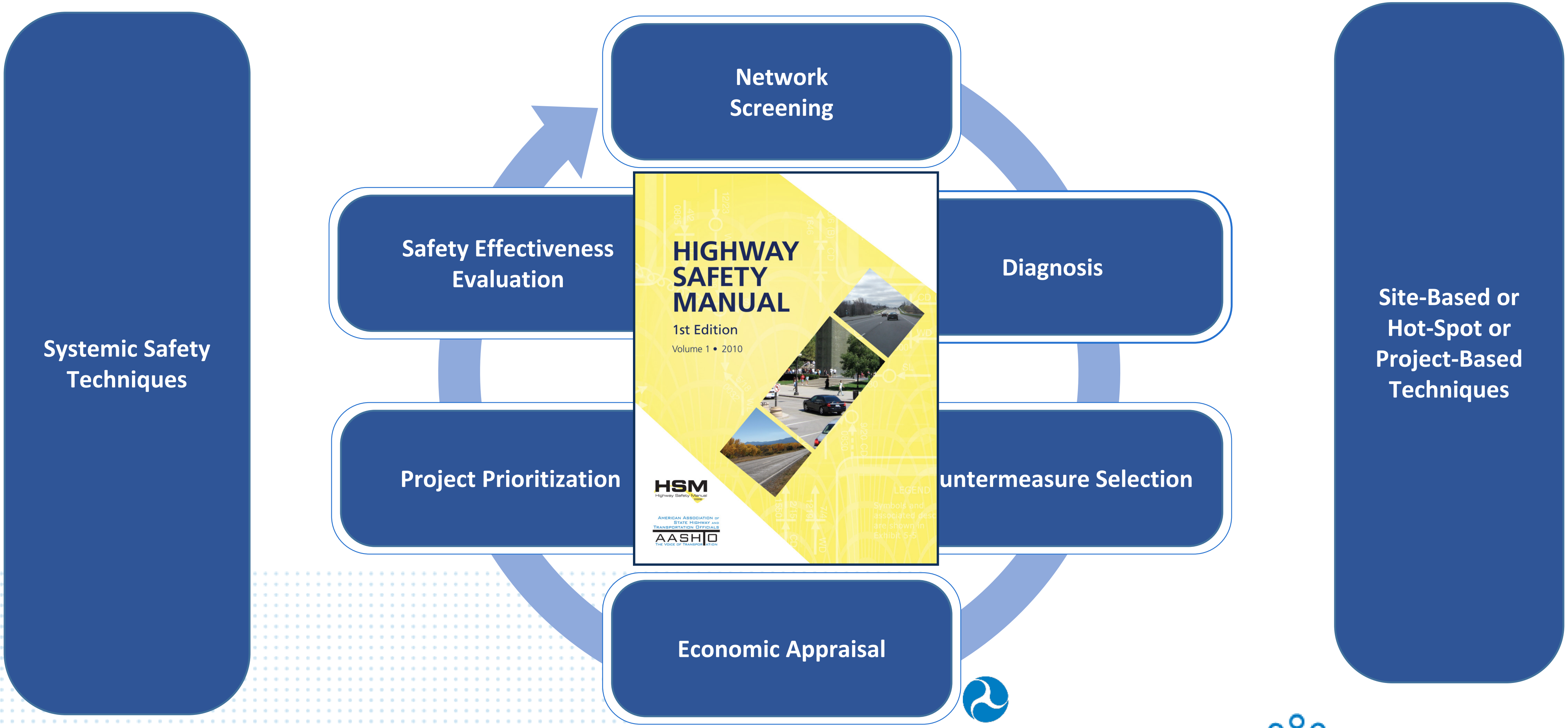
CONCLUSIONS

Growth Mindset

Group Discussion

- Is the Highway Safety Manual (HSM) a helpful tool?
- Is the HSM an ‘easy’ tool?
- What happens if I use the HSM?
- What happens if I do not use the HSM?

The HSM in the Road Safety Management Process



The HSM in the Project Development Process

Conclusions

- Extensive documentation and resources are available
- Training and customer service opportunities through FHWA
- The HSM can quantify safety relative to other performance measures
- The HSM can help to streamline and better inform project identification and deployment efforts
- The HSM can help to refine project alternatives
- The HSM can help to document design decisions

Parting Wisdoms

- Don’t forget the reason(s) for the safety analysis
  - Do the Right Thing
- Document and Communicate
  - … and then Communicate and Document ☺
- Quality Control
  - No funny business
- Our tools aren’t perfect
  - Don’t be so certain you’re right
  - Don’t think of absolutes without considering error

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Thank you!

David A. Petrucci, Jr., P.E., PTOE, RSP2I
Senior Safety Engineer
USDOT-FHWA Resource Center SDTST
202-823-2260 (cell)
david.petrucci@dot.gov

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Take Home Material

Quantitative Safety Analysis: A Discussion on Practical Applications and Options in Project-Decision Making

MATURITY MATRIX

Maturity Matrix

- Relative to the material previously covered, how would you rate or evaluate your organization's acceptance and use of said material throughout your planning and project development processes? Use the following Maturity Matrix and supporting information

Maturity Matrix

- Let's examine the idea of a maturity matrix
- Assess your organization's position within the matrix
- Try to identify elements that could move your agency toward greater implementation

Not Implementing	The agency does not have a formal, established practice for application of crash diagnosis.
Development	The agency is collecting guidance and best practices, building support with partners and stakeholders, and developing an implementation process.
Demonstration	The agency is testing and/or piloting the practice.
Assessment	The agency is assessing the performance of and process for carrying out the practice.
Institutionalized	The agency has a standard process or practice and uses it regularly.

Maturity Matrix

- Initiation – **The *Organization*** *has acknowledged the need for this item (scoring range: 1-2)*
  - Does agency management acknowledge the need for a particular item?
  - Has exploratory research taken place to assess the benefits of this item?
  - Does management support further development of this item's requirements?

Maturity Matrix

- Development – ***The Organization has developed a plan or approach to address this item (scoring range: 3-4)***
  - Has the agency developed a plan or approach to address the item's requirements? Has the agency started to investigate the feasibility of implementation?
  - Does the agency have standards and guidance to enable the item's implementation?
  - Does the agency have the approvals necessary for implementation?
  - Are resources in place to support the adoption of this item?

Maturity Matrix

- Demonstration – ***The Organization is executing or has executed a plan or approach to address this item (scoring range: 5-6)***
  - Is the agency implementing/carrying out the requirements of this item?
  - Has the agency allocated financial or staff resources necessary for the item's execution?
  - Have appropriate personnel been trained to execute the item's requirements?
  - Has a process owner been established?

Maturity Matrix

- Assessment – ***The Organization has assessed this item's performance and its success in achieving agency goals and objectives (scoring range: 7-8)***
  - Has the agency assessed how well this item performs in optimizing costs and maximizing effectiveness of solutions?
  - Has the agency assessed the process for carrying out this item?
  - Has the agency implemented appropriate changes to the requirements of this item based on performance assessments?

Maturity Matrix

- Adoption / Institutionalization – ***The Organization has institutionalized this item into its project execution process and culture (scoring range: 9-10)***
  - Has the agency integrated the requirements of this item into quality improvement processes?
  - Are the requirements of this item integrated into agency culture?
  - Are the requirements of this item included as part of the employee performance rating system?

Maturity Matrix

- Assign a score for each cell in the Part B, Part C, Part D, and Software columns in the table below based on your ratings, and total the scores in the left-most 'Total Score' column. Assume that Part B and Part C are not applicable in construction-related stages.

Stage in Project Life Cycle	Total SCORE	HSM Part A	HSM Part B	HSM Part C	HSM Part D
Concept Development					
Planning / Alternatives					
Preliminary Engineering					
Final Design					
Operations / Maintenance					
Construction		NA	NA	NA	

RESOURCES

Available Software

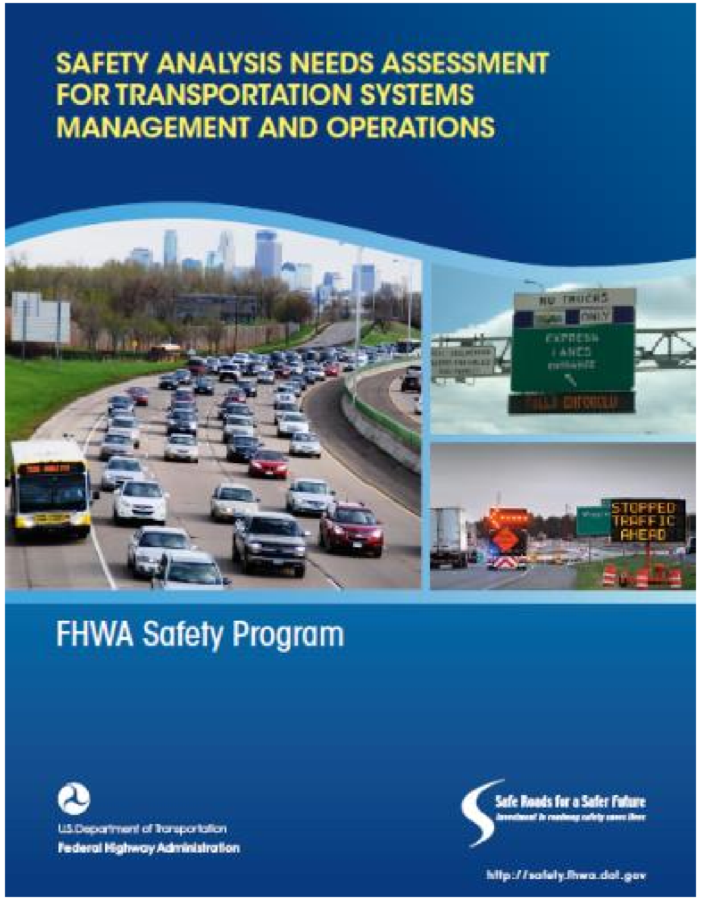
- HSM Conventional Spreadsheets
- HSM Maco-Enabled Spreadsheets
- Interchange Safety Analysis Tool Enhanced (ISATE)
- Interactive Highway Safety Design Model (IHSDM)
- Safety Performance for Intersection Control Evaluation (SPICE)
- Intersection Safety Analysis Tool (INSAT)
- Systemic Safety Tool Crash Tree Maker
- Surrogate Safety Analysis Model (SSAM)
- Life Cycle Cost Estimation Tool (LCCET)

Available Software

- HSM Conventional Spreadsheets
- http://www.highwaysafetymanual.org/Pages/default.aspx
- HSM Maco-Enabled Spreadsheets
- http://www.highwaysafetymanual.org/Pages/default.aspx
- Interchange Safety Analysis Tool Enhanced (ISATE)
- http://www.highwaysafetymanual.org/Pages/default.aspx
- Interactive Highway Safety Design Model (IHSDM)
- http://www.ihsdm.org/wiki/Welcome
- Safety Performance for Intersection Control Evaluation (SPICE)
- http://www.cmfclearinghouse.org/resources_selection.cfm
- Intersection Safety Analysis Tool (INSAT)
- http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w204InSATTool.xls
- Systemic Safety Tool Crash Tree Maker
- http://www.cmfclearinghouse.org/resources_selection.cfm
- Surrogate Safety Analysis Model (SSAM)
- http://www.fhwa.dot.gov/research/tfhrc/projects/projectsite/safety/ssam/index.cfm
- Life Cycle Cost Estimation Tool (LCCET)
- http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w220LCCET.xlsm

Safety Analysis Needs for TSMO

- How will implementing a TSMO strategy (or combination of strategies) impact safety performance? (prediction)
  - Or how has it impacted safety performance? (evaluation)
- 3 general sets of effectiveness approaches considered:
  - Analysis of crash data
  - Alternative (surrogate) measures of safety
  - Simulating crash occurrence and severity



https://safety.fhwa.dot.gov/rsdp/downloads/fhwssa19041.pdf

Synthesis of Safety Performance Information

- Managed Lanes
  - HOV/HOT Lanes
  - Truck Lanes and Truck Restrictions
  - Bus Lanes
- Part-Time Shoulder Use
- Reversible Lanes
- Dynamic Lane Use Control
- Dynamic Junction Control
- Ramp Metering
- Variable Speed Limits
- Traffic Signal Coordination
- Adaptive Signal Control Technology
- Transit Signal Priority
- Truck Signal Priority
- Queue Jump Lanes
- Safety Warning Applications
  - Intersection Warning
  - Curve Warning
  - Queue Warning
  - Animal Warning
- Work Zone Management
- Traffic Incident Clearance

Guidance Documents

- Safety Performance Function Decision Guide: SPF Calibration vs. SPF Development: http://safety.fhwa.dot.gov/rsdp/downloads/spf_decision_guide_final.pdf
- User's Guide to Develop HSM Safety Performance Function Calibration Factors: http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-07(332)_FinalGuide.pdf
- Additional Resource: (http://www.cmfclearinghouse.org/collateral/Appendix%20B%20Excel%20Tables%20for%20use%20with%20HR%2020-7(332)%20Guide%20for%20SPF%20Calibration%20Factors.xlsm)
- Safety Performance Function Development Guide: Developing Jurisdiction-Specific SPFs: http://safety.fhwa.dot.gov/rsdp/downloads/spf_development_guide_final.pdf
- State Policies and Procedures on Use of the Highway Safety Manual, 2016: https://safety.fhwa.dot.gov/hsm/spp/fhwasa16119.pdf
- Scale and Scope of Safety Assessment Methods in the Project Development Process, 2016: https://safety.fhwa.dot.gov/hsm/fhwasa16106/

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Implications

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