2015 Design Training Expo

Highway Safety Manual

Overview and Florida Update

Joe Santos, State Safety Engineer, FDOT

Design Expo Sessions Including HSM

- HSM Design Exceptions
- Engineering Statistics 101 for Safety
- MUTS Update
- Safety Considerations for Project Development
- Guidance from 2014 FDOT Traffic Analysis Handbook

"Road safety management is in transition. The transition is from action based on experience, intuition, judgment, and tradition, to action based on empirical evidence, science, and technology…"

Ezra Hauer (2005)

Learning Outcomes

HSM:

- **Overview**
  - **Purpose**
  - **Audience**
  - **Structure**
  - **Benefits**
  - **Integration**
- **Florida Activities**
  - **Research**
  - **Calibration Efforts**

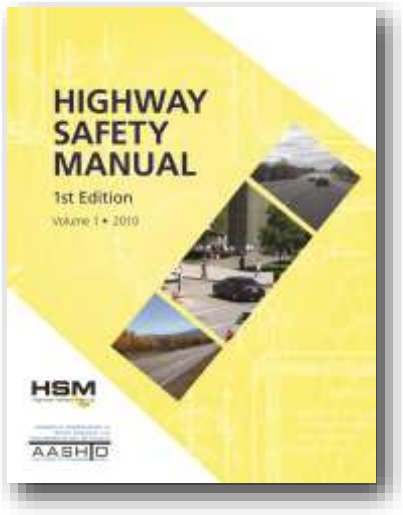
How Important is Safety?

- **Programming and prioritization**
- **System planning**
- **Program administration**
- **Policy development**
- **Project development**
- **Operations and maintenance**
- **Public affairs**
- **Interagency coordination**

Safety Trade-Offs?

Balance the array of issues

HSM
Content and Structure



Vol. 1 - Part A
Introduction
Human Factors
Fundamentals

Vol. 3 - Part D
Crash Modification
Factors (CMFs)

HSM
Highway Safety Manual

Vol. 1 - Part B
Roadway Safety
Management
Process

Vol. 2 - Part C
Predictive Method

Part A

Part B

Part C

Part D

- **Introduction and Overview (Ch. 1)**
- **Human Factors (Ch. 2)**
- **Fundamentals (Ch. 3)**

Part A

Part B

Part C

Part D

Road Safety Management Process

Network Screening (Ch. 4)

⇩

Diagnosis and Countermeasure Selection (Ch. 5 & 6)

⇩

Economic Appraisal and Prioritization (Ch. 7 & 8)

⇩

Safety Effectiveness Evaluation (Ch. 9)

Part A

Part B

Part C

Part D

Predictive Method

- **Methodology**
  - **Safety Performance Functions**
  - **Crash Modification Factors**
  - **Calibration**
- **Applications**
- **Example problems**
- **References**

Part A

Part B

Part C

Part D

Part C Facilities

- **Rural Two-lane Roads (Ch. 10)**

- **Rural Multi-lane Roads (Ch. 11)**

- **Urban Suburban Arterials (Ch. 12)**

Part A

Part B

Part C

Part D

Predictive Method

Common Procedures Appendix:

- **Calibrating predictive methods**
- **Empirical Bayes -combining predicted with observed crashes**

Part A

Part B

Part C

Part D

Crash Modification Factors

- **Roadway segments (Ch. 13)**
- **Intersections (Ch. 14)**
- **Interchanges (Ch. 15)**
- **Special facilities and geometric situations (Ch. 16)**
- **Road Networks (Ch. 17)**

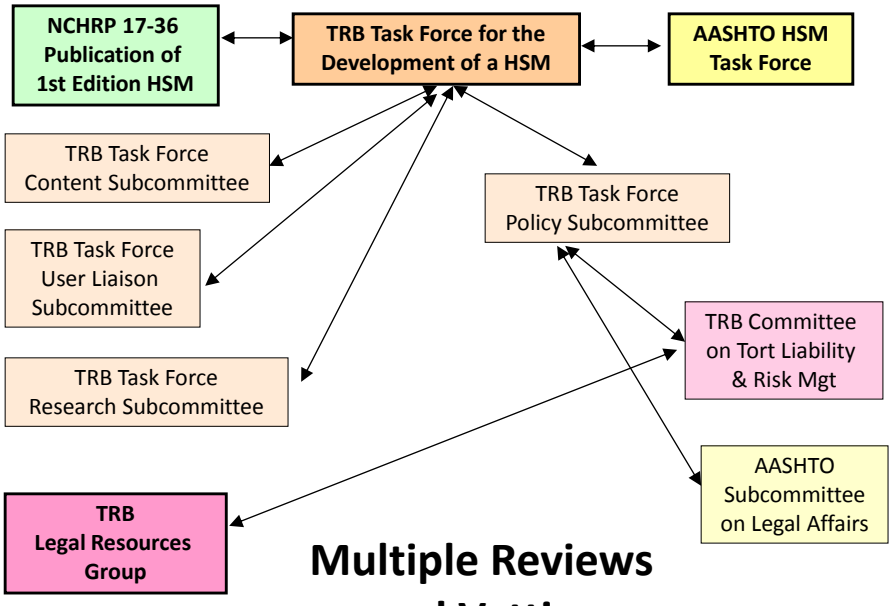
CMFs

Companion Software

HSM Part	Supporting Tool
Part B: **Roadway Safety Management Process**	**SafetyAnalyst** **www.safetyanalyst.org**
Part C: **Predictive Methods**	**IHSDM** **www.ihsdm.org** **HiSafe** **www.HiSafe.org** **ALDOT and VDOT Predictive Method Spreadsheet** http://safetyperformance.org/?q=node/44
Part D: **Crash Modification Factors**	**FHWA CRF/CMF Clearinghouse** **www.cmfclearinghouse.com**

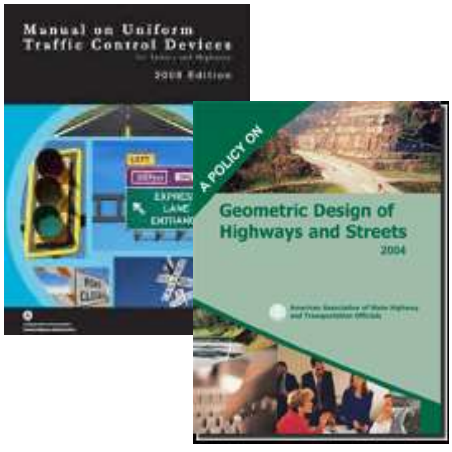
Institutional History

- **Joint Subcommittee**
- **Task Force**
- **Thousands of volunteer hours**
- **NCHRP, AASHTO, FHWA resources**
- **FDOT was on the Task Force Jim Mills and Mark Wilson**
- **TRB Task Force**



Multiple Reviews and Vetting

The HSM and Other Documents



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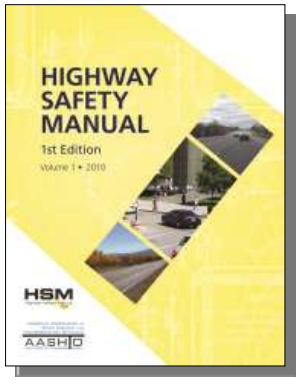


The HSM provides better methods to improve the bottom line

- Better safety analysis tools to support decision making
- More safety cost-effective investments
- More lives saved and injuries avoided per dollar invested

What is Safety?

- **The HSM uses crashes as a *measure of safety***

Forces Influencing Application of Quantitative Safety Information

Driving Forces	*Restraining Forces*
• Legislative mandates • Public pressures • Peer pressure (other agencies) • Sense of professional responsibility • Lack of resources	• Lack of resources • Lack of data • Lack of knowledge • Fear of tort liability • Cultural/institutional inertia

What is the HSM?

- **Quantify Effect of Safety Decisions**
- **Accountability/ Performance Measurement**

HSM Vision Akin to HCM

1. **Definitive; represents quantitative 'state-of-the-art' information**
2. **Widely accepted within professional practice of transportation engineering**
3. **Science-based; updated regularly to reflect research**

Why do we need it?

- **Limited Resources, Science, and Technology**
- **Legislatively Mandated Priorities**

Where can the HSM be used?

Jurisdiction

- **State**
- **County**
- **Region**
- **Local**

Facility Type

- **Two-Lane Rural Highways**
- **Rural Multi-Lane Highways**
- **Urban-Suburban Arterials**
- **Freeways**

Who is the target user?

- **Transportation Planners**
- **Traffic Engineers**
- **Safety Engineers**
- **Designers**
- **Capital Programmers**

When can the HSM be used?

1. System Management

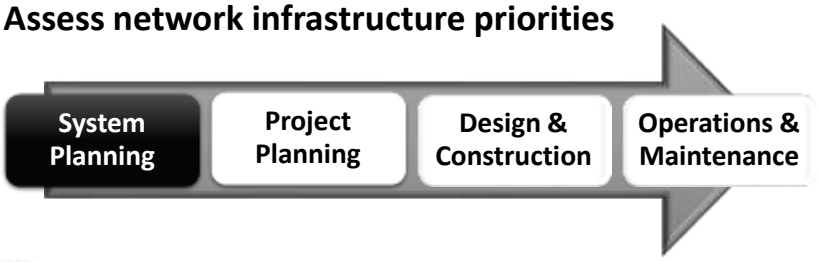
2. Project Development Process

When can the HSM be used?

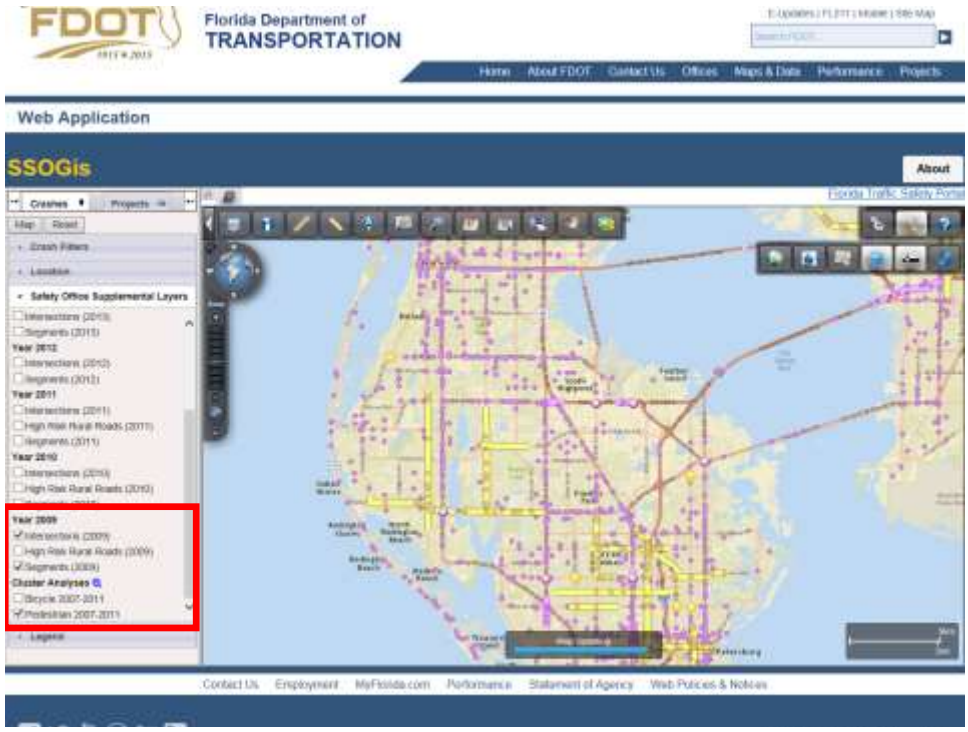
- Identifying sites with potential for crash reduction
- Identifying crash patterns and treatments
- Conducting economic appraisals
- Evaluating the crash reduction benefits of implemented treatments
- Estimating the crash reduction effects of design decisions

System Planning and Programming

- **Assess system needs**
- **Identify projects/studies**
- **Assess network infrastructure priorities**



Systemwide Safety Improvement Programs



Project Development - Planning

- **Define scope / problem(s) / constraints**
- **Identify solutions**
- **Evaluate expected quantitative safety effects**
- **Select preferred alternative**

Planning

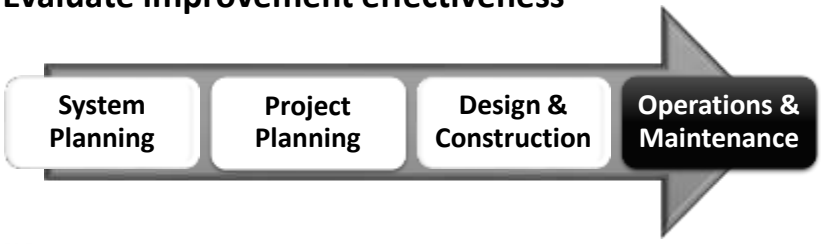
Project Development – Design and Construction

- **Evaluate safety of alternative designs**
- **Review / document design exceptions, variances, and waivers**
- **Inform construction decisions**

Design

Operations and Maintenance

- **Monitor operations balance - safety, mobility, and access**
- **Evaluate improvement effectiveness**



Highway Safety has Two Dimensions

Nominal Safety

Standards Compliance

Substantive Safety

HSM
Highway Safety Manual

Expected or Actual Crash Frequency and Severity

Nominal Safety vs. Substantive Safety

"Nominally" Safe Streets and Highways

+

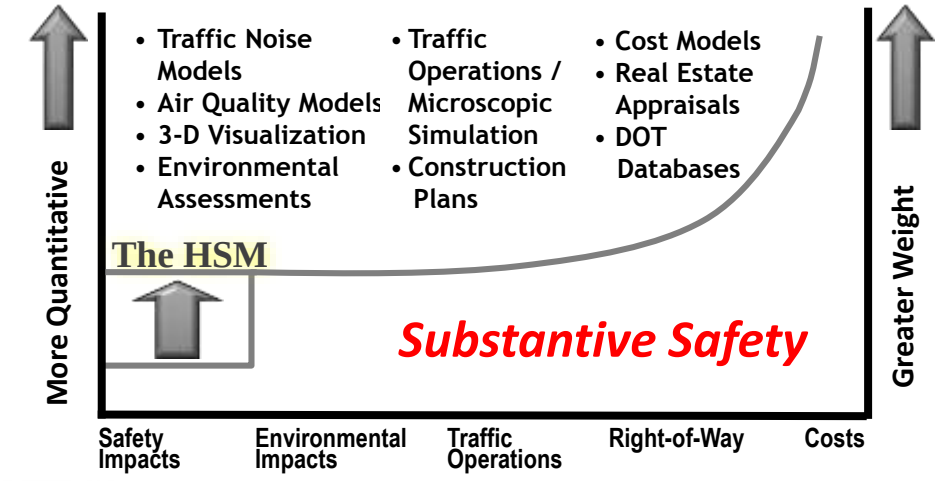
Application of Highway Safety Research and Results

+

Performance Monitoring

"Substantively" Safe Streets and Highways

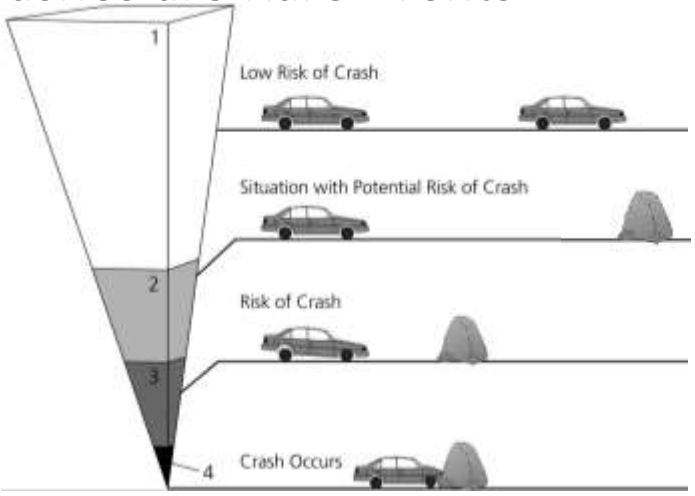
Common Impacts for Project Level Decisions?



Other Considerations

- Crashes are rare and random events
- **93%** of all crashes involve human error
- Contributing factors influence crashes and can be mitigated using various strategies
- Changing the roadway/environment can reduce crashes

Crashes are Rare Events

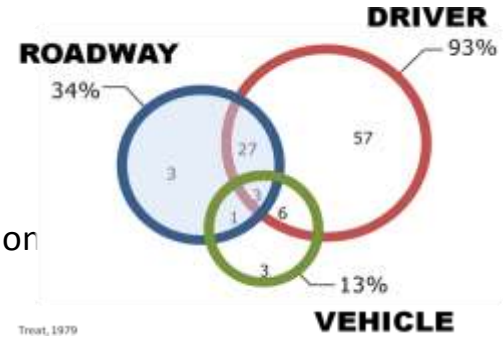


Relative Proportion of Crash Events

Crashes are Random Events

Contributing Crash Factors

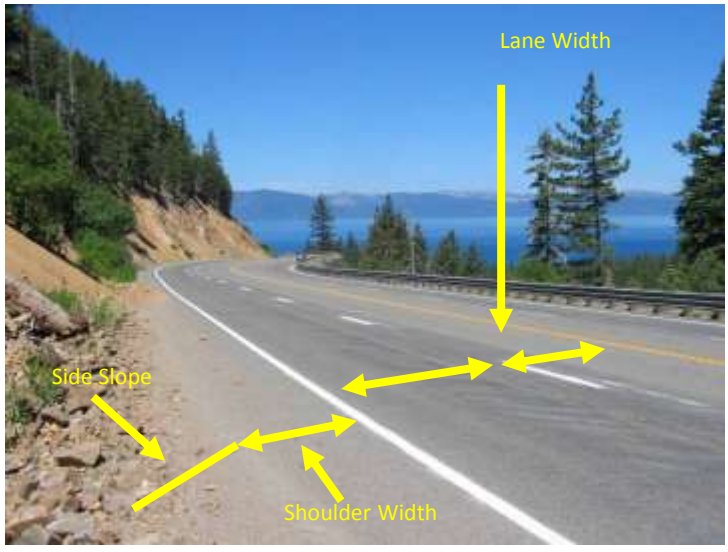
- Judgment errors
- Distractions
- Information overload
- Driver expectation violations
- Rules of the road violation



Data Needs for Crash Estimation

- Crash Data
- Facility Physical Data
- Facility Traffic Data

Data Needs – Physical Facility Features



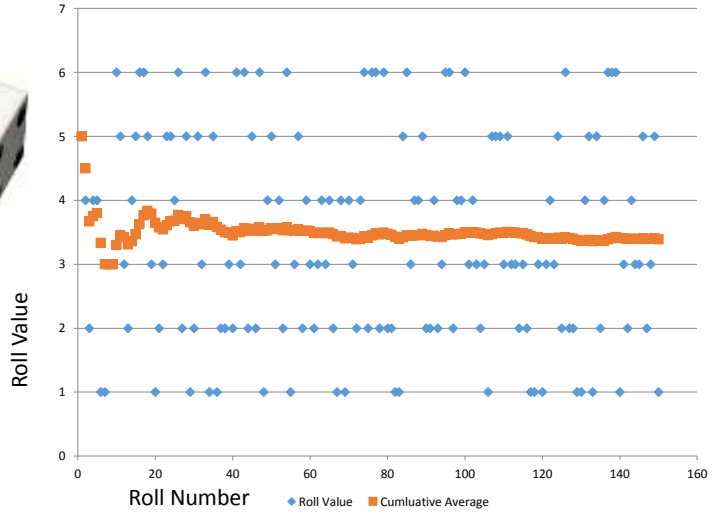
Limitations of Crash Data

- Not all crashes are reported
- Differences in crash reporting thresholds
- Judgment of observer preparing crash report
- Differing standards for crash databases
- Subsequent injury or fatality
- Data entry can introduce typographical errors, imprecise location data, incorrect entries, lack of training, subjectivity

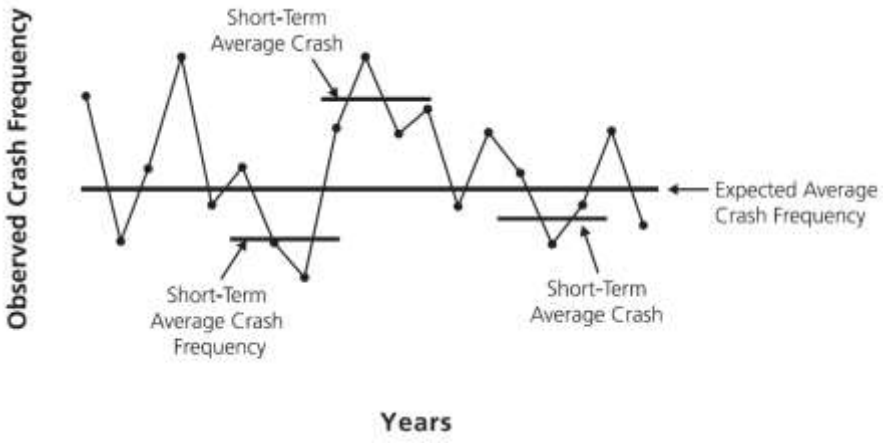
Data Randomness and Change

- Natural variability in crash frequency
- Regression-to-the-mean
- Variations in roadway characteristics
- Conflict between crash frequency variability and changing site conditions

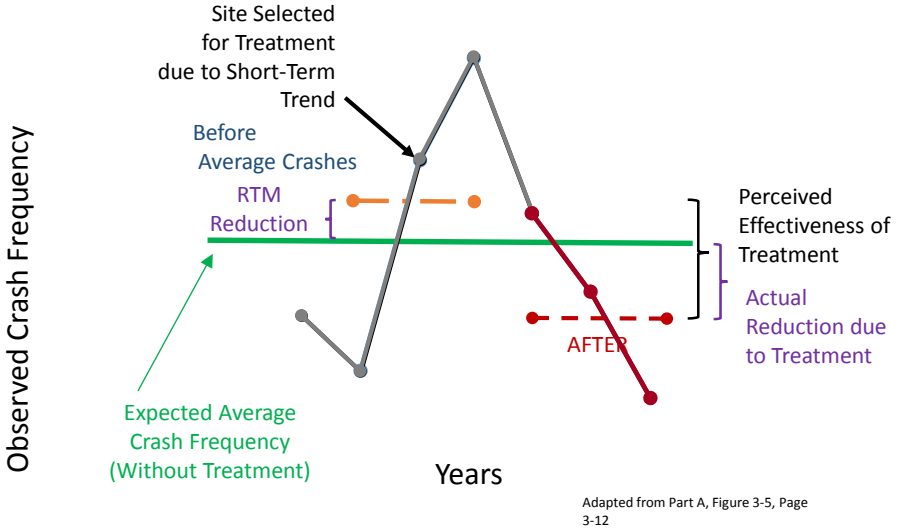
Regression to the Mean (RTM)



Crashes Regress to the Mean as Well



RTM and RTM BIAS



Adapted from Part A, Figure 3-5, Page 3-12

Crash Estimation – Predictive Models

- Safety Performance Functions
- Crash Modification Factors
- Calibration Factors
- Rural Two-Lane Two-Way Roads
- Rural Multilane Highways
- Urban and Suburban Arterials
- Freeways and Ramps (NCHRP 17-45)
  - http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2512

Safety Performance Functions

$$N_{SPFrs} = (AADT) \times (L) \times 365 \times 10^{-6} \times e^{(-0.4865)}$$

(Example)

- N_{SPFrs} = Predicted crash frequency for base conditions for a rural 2-lane, 2-way roadway segment
- *AADT* = Average Annual Daily Traffic
- *L* = Length of Roadway Segment (Miles)

SPFs in the 1st Edition HSM

Rural two-lane
- 1 segment SPF
- 3 intersection SPFs

Rural multilane
- 2 segment SPFs
- 3 intersection SPFs

Urban and suburban arterials
- 5 segment SPFs
- 4 intersection SPFs

18 SPFs in First Edition HSM

Intersection Safety Performance Functions

	Intersections			
	Stop Control on Minor Leg(s)		Signalized	
	3-Leg	4-Leg	3-Leg	4-Leg
Rural 2-Lane Roads	✓	✓	—	✓
Rural Multi-Lane Highways	✓	✓	—	✓
Urban and Suburban Arterial Highways	✓	✓	✓	✓

Crash Modification Factors

Crash Modification Factors represent the relative change in crash frequency due to a change in one specific condition, when all other conditions and characteristics remain constant

CMFs Modify the Base Condition

$$N_{predicted} = N_{SPF\,x} \times (CMF_{1x} \times CMF_{2x} \times \ldots \times CMF_{yx}) \times C_x$$

Where –

N_{SPFx} = Base condition crash frequency from SPF for site type x

CMF_{yx} = Crash Modification Factors

C_x = Calibration factor for site type x

Crash Modification Factors (CMF)

CMFs are the ratio of the crash frequencies at a site under two different conditions

$$\text{CMF} = \frac{\textbf{Crash Frequency with Site Condition 'A'}}{\textbf{Crash Frequency with Site Condition 'B'}}$$

Therefore –

Crashes for Condition 'A' = CMF × Crashes for Condition 'B'

Where –

Condition 'A' is a change from "base" or existing condition
Condition 'B' is the base or existing condition

CMFs may serve as an estimate of the effect of a particular geometric design or traffic control feature or the effectiveness of a particular treatment or condition.

Crash Modification Factors

- If a CMF = 0.90, then the expected change is 100% × (1.0-0.90) = 10% (Reduction)
- If a CMF = 1.20, then the expected change is 100% × (1.0-1.20) = -20% (Increase)
- Crash Reduction Factors
  - If a CRF = 10%, then the corresponding CMF is 100%-10% ÷ 100 = 0.90
  - If a CRF = -20%, then the corresponding CMF is
  - 100% + 20% ÷ 100 = 1.20

Calibration Factors

- Account For Differences In Geographical Areas
  - Driver Characteristics
  - Terrain
  - Climate
  - Animal Population
  - Crash Reporting Threshold
  - Crash Reporting Practices

SPFs and CMFs in the updated HSM

Table 18-13. Freeway Crash Modification Factors and their Corresponding SPFs

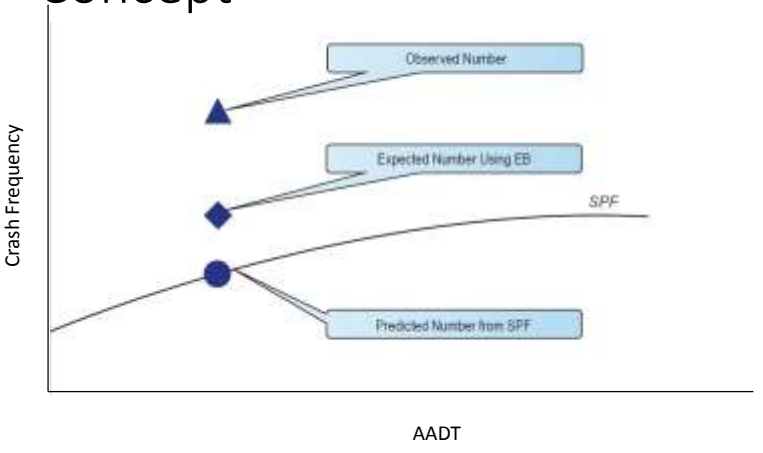
Applicable SPF(s)	CMF Variable	CMF Description	CMF Equations
Freeway segments or speed-change lanes	$CMF_{1,w,x,y,z}$	Horizontal curve	Equation 18-24, Equation 18-40
	$CMF_{2,w,x,y,z}$	Lane width	Equation 18-25, Equation 18-41
	$CMF_{3,w,x,y,z}$	Inside shoulder width	Equation 18-26, Equation 18-42
	$CMF_{4,w,x,y,z}$	Median width	Equation 18-27, Equation 18-43
	$CMF_{5,w,x,y,z}$	Median barrier	Equation 18-28, Equation 18-44
	$CMF_{6,w,x,y,z}$	High volume	Equation 18-29, Equation 18-45
Multiple-vehicle crashes on freeway segments	$CMF_{7,fi,ac,ms,z}$	Lane change	Equation 18-30
Single-vehicle crashes on freeway segments	$CMF_{8,fi,ac,os,z}$	Outside shoulder width	Equation 18-35
	$CMF_{9,fi,ac,os,fi}$	Shoulder rumble strip	Equation 18-36
	$CMF_{10,fi,ac,os,fi}$	Outside clearance	Equation 18-38
	$CMF_{11,fi,ac,os,z}$	Outside barrier	Equation 18-39
Ramp entrances	$CMF_{12,ac,ADT,ac,z}$	Ramp entrance	Equation 18-46
Ramp exits	$CMF_{13,ac,ADT,ac,z}$	Ramp exit	Equation 18-47

SPFs and CMFs in the updated HSM

Table 19-1. Ramp and Collector-Distributor Road SPFs

Site Type (*st*)	Cross Section (*x*)	Crash Type (*y*)	Crash Severity (*z*)	SPF
Ramp segments (*rps*)	One-lane entrance ramp (*1EN*)	Multiple vehicle (*mv*)	Fatal and injury (*fi*)	$N_{spf\ rps,\ 1EN,\ mv,\ fi}$
			Property damage only (*pdo*)	$N_{spf\ rps,\ 1EN,\ mv,\ pdo}$
		Single vehicle (*sv*)	Fatal and injury (*fi*)	$N_{spf\ rps,\ 1EN,\ sv,\ fi}$
			Property damage only (*pdo*)	$N_{spf\ rps,\ 1EN,\ sv,\ pdo}$
	Two-lane entrance ramp (*2EN*) (urban areas only)	Multiple vehicle (*mv*)	Fatal and injury (*fi*)	$N_{spf\ rps,\ 2EN,\ mv,\ fi}$
			Property damage only (*pdo*)	$N_{spf\ rps,\ 2EN,\ mv,\ pdo}$
		Single vehicle (*sv*)	Fatal and injury (*fi*)	$N_{spf\ rps,\ 2EN,\ sv,\ fi}$
			Property damage only (*pdo*)	$N_{spf\ rps,\ 2EN,\ sv,\ pdo}$
	One-lane exit ramp (*1EX*)	Multiple vehicle (*mv*)	Fatal and injury (*fi*)	$N_{spf\ rps,\ 1EX,\ mv,\ fi}$
			Property damage only (*pdo*)	$N_{spf\ rps,\ 1EX,\ mv,\ pdo}$
		Single vehicle (*sv*)	Fatal and injury (*fi*)	$N_{spf\ rps,\ 1EX,\ sv,\ fi}$
			Property damage only (*pdo*)	$N_{spf\ rps,\ 1EX,\ sv,\ pdo}$
	Two-lane exit ramp (*2EX*) (urban areas only)	Multiple vehicle (*mv*)	Fatal and injury (*fi*)	$N_{spf\ rps,\ 2EX,\ mv,\ fi}$
			Property damage only (*pdo*)	$N_{spf\ rps,\ 2EX,\ mv,\ pdo}$
		Single vehicle (*sv*)	Fatal and injury (*fi*)	$N_{spf\ rps,\ 2EX,\ sv,\ fi}$
			Property damage only (*pdo*)	$N_{spf\ rps,\ 2EX,\ sv,\ pdo}$

Empirical Bayes (EB) Method Concept



EB Method Equations

$$N_{expected} = w \times N_{predicted} + (1 - w) \times N_{observed}$$

Weighted Adjustment

$$w = \frac{1}{1 + k \times (\sum_{\substack{\text{all} \\ \text{study} \\ \text{years}}} N_{predicted})}$$

Overdispersion Parameter
(given with SPF)

Evolution of Crash Estimation Methods

- Crash Rates - Probability per million vehicle miles

$$Crash\ Rate = \frac{Average\ Crash\ Frequency\ in\ a\ Period}{Exposure\ in\ Same\ Period}$$

- Historical Crash Method – 3 to 5 years of data
- Highway Safety Manual – Statistical analysis using EB Method

FDOT HSM Progress

- Calibration of Segments and Intersections
- District Pilot Projects
- Manual Updates
  - Systems Planning
    - Engineering Studies
  - PD&E
    - PD&E Manual
  - Traffic Operations
- Advanced Training in all Districts
- Completed Research
  - CMF Development
  - Safety Analyst

FDOT HSM Initiatives

- Recalibration of Segments
- Recalibration of Intersections
- Vetting of CMFs (Part D)
- Standards for CMFs
- Design Exception and Design Variation Training
- Freeway and Ramps Training
- Managed Lanes Research

Florida Activities

- Completed Research
  - CMF Development
  - Safety Analyst
- Systems Planning
  - Engineering Studies
- PD&E
  - PD&E Manual

HSM Websites

- AASHTO HSM, http://www.highwaysafetymanual.org/
  - About, Getting Started, Tools, Training, Resources
- FHWA HSM, http://safety.fhwa.dot.gov/hsm/
  - Outreach materials, Guidance, Case Studies
- FDOT HSM, http://www.dot.state.fl.us/safety/11A-SafetyEngineering/TransSafEng/HighwaySafetyManual.shtm
  - Crash Distribution, Calibration Factors, Organizational Chart, Implementation Summary, Implementation Plan Timeline, Presentations
- TRB, NCHRP 17-45, Freeways and Interchanges
  http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2512

HSM Websites – AASHTO HSM

HSM Websites – FHWA HSM

HSM Websites – FDOT HSM

State Safety Office

State Safety Office / Safety Engineering / Highway Safety Manual

Highway Safety Manual

Welcome to the Florida Department of Transportation Highway Safety Manual (HSM) webpage on HSM statewide implementation efforts. This page will be focused on providing information on what implementation efforts have been done and are planned to do. Key information will include implementation plan timeline, management presentations, district projects, and training schedules. Also included on the site will be links to national implementation efforts of the HSM. We welcome you to visit the site often as this page will be frequently updated as the department moves forward with HSM implementation efforts.

Please feel free to contact Joe Santos, FDOT, Safety Engineer, joseph.santos@dot.state.fl.us, 850.414.4097 should you have any questions.

FDOT HSM User Guide 2015

FDOT Crash Distribution 2008-2012

FDOT Calibration Factors 2012

FDOT HSM Organizational Chart

FDOT HSM Implementation Summary

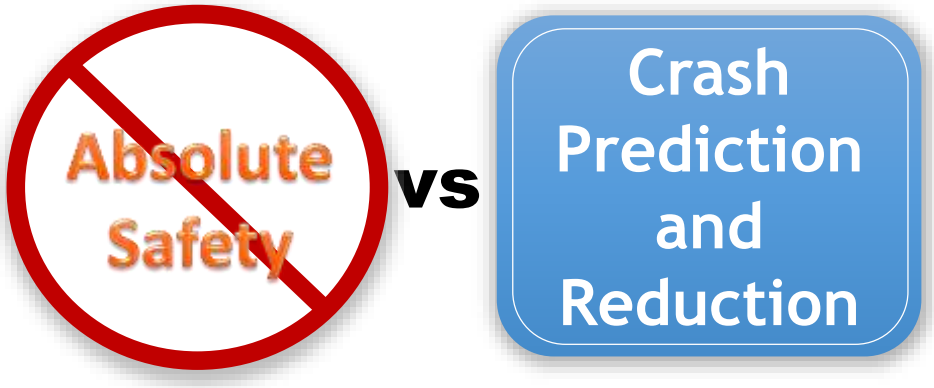
FDOT HSM Implementation Plan Timeline

National Training Activities

- Training (highwaysafetymanual.org)
  - Training is an important first step before using the HSM. Following is a brief description of the various training programs currently available to help state DOTs maximize the effectiveness of the HSM.
- **HSM Online Overview Course** – (FHWA-NHI 380106) is now available free of charge through the National Highway Institute (NHI) web site.
- **HSM Training Guide** – This guide focuses on identifying HSM training currently available to state and local agencies who are considering implementation of the HSM.
- **NHI HSM Training Courses** – FHWA has developed training courses on specific parts of the HSM that are offered through the National Highway Institute (NHI).
- **Webinar Series** – The FHWA HSM webinar series, which began in June 2010, was recorded.
- **Training Webinars** – These webinars are available from the FHWA Resource Center.
- **US Roadway Safety.org** – This web site has a searchable database for safety training courses.

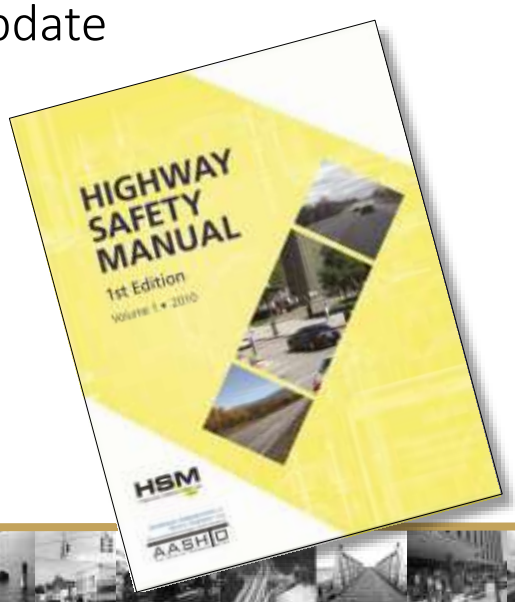
HSM Training

- National Highway Institute (NHI), https://www.nhi.fhwa.dot.gov/default.aspx
  - FHWA-NHI-380106, Highway Safety Manual Online Overview
    - Free Web Based Training (WBT) course includes an introduction of terminology, examples of the Roadway Safety Management Process (Part B) and Predictive Methods (Part C), explains the relationship of Crash Modification Factors (CMFs) to decision making and quantitative safety analysis, and human factors
    - Length: 12 Hours



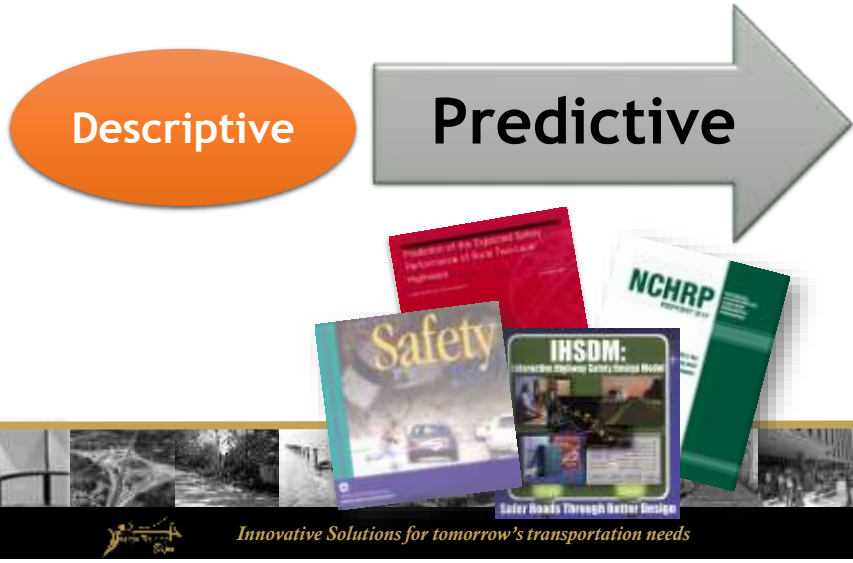
Design Training Expo 2015 – HSM Overview and Update

Questions?



Innovative Solutions for tomorrow's transportation needs

Advance Safety Knowledge



Innovative Solutions for tomorrow's transportation needs