# HSM Workshop Agenda

## DAY 1

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Duration</th>
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</thead>
<tbody>
<tr>
<td>8:00</td>
<td>Registration</td>
<td>30 minutes</td>
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<tr>
<td>8:30</td>
<td>Module 1 Introduction to the HSM</td>
<td>45 minutes</td>
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<tr>
<td>9:15</td>
<td>Module 2 Fundamentals</td>
<td>45 minutes</td>
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<tr>
<td>10:00</td>
<td>Break</td>
<td>15 minutes</td>
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<tr>
<td>10:15</td>
<td>Module 2 Fundamentals (Continued)</td>
<td>45 minutes</td>
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<tr>
<td>11:00</td>
<td>Module 3 Overview – Crash Modification Factors</td>
<td>60 minutes</td>
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<tr>
<td>12:00</td>
<td>Lunch</td>
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<tr>
<td>1:00</td>
<td>Module 4 HSM Predictive Method Process</td>
<td>80 minutes</td>
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<tr>
<td>2:20</td>
<td>Break</td>
<td>15 minutes</td>
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<tr>
<td>2:35</td>
<td>Module 4 HSM Predictive Method Process (continued) -- Overview of Spreadsheet Tool and Example Application</td>
<td>75 minutes</td>
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<tr>
<td>3:50</td>
<td>Break</td>
<td>10 minutes</td>
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<tr>
<td>4:00</td>
<td>Module 5 HSM Calibration Procedure</td>
<td>60 minutes</td>
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<td>5:00</td>
<td>Adjourn Day 1</td>
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## HSM Workshop Agenda

### DAY 2

<table>
<thead>
<tr>
<th>Time</th>
<th>Module</th>
<th>Title</th>
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<tbody>
<tr>
<td>8:00</td>
<td>Module 6</td>
<td>Overview of HSM Part B</td>
<td>35 minutes</td>
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<tr>
<td>8:35</td>
<td>Module 7</td>
<td>Network Screening</td>
<td>40 minutes</td>
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<tr>
<td>9:15</td>
<td>Module 8</td>
<td>Human Factors</td>
<td>35 minutes</td>
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<td>Break</td>
<td>15 minutes</td>
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<tr>
<td>10:05</td>
<td>Module 9</td>
<td>Diagnosis and Countermeasure Selection</td>
<td>40 minutes</td>
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<tr>
<td>10:45</td>
<td>Module 10</td>
<td>Economic Appraisal and Project Prioritization</td>
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<tr>
<td>11:30</td>
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<td>Lunch</td>
<td>60 minutes</td>
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<tr>
<td>12:30</td>
<td>Module 11</td>
<td>Safety Effectiveness Evaluation</td>
<td>60 minutes</td>
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<td>Break</td>
<td>15 minutes</td>
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<tr>
<td>1:45</td>
<td>Module 11</td>
<td>Safety Effectiveness Evaluation (Continued)</td>
<td>60 minutes</td>
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<tr>
<td>2:45</td>
<td>Module 12</td>
<td>Overall HSM Summary</td>
<td>45 minutes</td>
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<td>3:30</td>
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<td>Adjourn</td>
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HSM Workshop Acronyms

4D - 4-Lane Divided
4SG - 4-leg Signalized
AASHTO - American Association of State Highway and Transportation Officials
AADT - Annual Average Daily Traffic
ADT - Average Daily Traffic
AM - Annual Monetary Value
BCR - Benefit-Cost Ratio
C - Calibration Factor
CI - Confidence Interval
CMF - Crash Modification Factor (or Function) - Expected safety performance associated with application of treatment to base.
CR - Crash rate
CRF - Crash Reduction Factor
DD - Driveway Density
EB - Empirical Bayes - A statistically reliable way of adjusting the outcome of a crash prediction model.
EPDO - Equivalent Property Damage Only
EMT - Emergency Medical Treatment
FARS - Fatality Analysis Reporting System
FHWA - Federal Highway Administration
FI - Fatal and Injury crashes
GIS - Geographic Information Systems
HCM – Highway Capacity Manual
HSIS –Highway Safety Information System
HSM - Highway Safety Manual
i – Discount Rate
IHSNM -Interactive Highway Safety Design Model
K – Overdispersion Parameter
KABCO – Scale used to identify five levels of crash severity: K = Fatal, A = Incapacitating Injury, B = Non-incapacitating Injury, C = Possible Injury, O = Property Damage Only
L - Segment Length (miles)
LW - Lane Width
N - Number of crashes
NEPA - National Environmental Policy Act
NPV - Net Present Value
NCHRP - National Cooperative Highway Research Program
NSC - National Safety Council
MV - Multiple Vehicle
MIRE – Model Inventory of Roadway Elements
MMUCC – Model Minimum Uniform Crash Criteria
MSE - Multiple of Standard Error
MUTCD - Manual on Uniform Traffic Control Devices
OR - odds ratio
PC - Point of Curvature
Pr - Proportion of Affected Crashes
PDO – Property Damage Only crash
PRT - Perception Reaction Time
PVC - Present Value Cost
RHR - Roadside Hazard Rating
RTM - Regression to the Mean
R/W - Right-of-Way
PVI - Point of Vertical Intersection
SE - Standard Error
SPF - Safety Performance Function
SV - Single Vehicle
SW - Shoulder Width
TEV - Total Entering Vehicles
TRB - Transportation Research Board
VMT - Vehicle Miles Traveled
w - weighted adjustment to be placed on the predictive model estimate
HSM Workshop

This document follows the NCHRP 17-38 course presentation which is different than the order of material in the HSM

Module 1 – Introduction

At the conclusion of this module participants will be able to:

- Define the purpose of the HSM;
- Recognize the target audience; safety specialists, design and traffic engineers, and transportation planners;
- Diagram the HSM structure and chapter content;
- Relate the advantages of implementing the HSM for each target audience;
- Describe the relevance of advanced road safety knowledge to HSM implementation;
- Relate activities and projects relative to the HSM; and
- Identify how to integrate the HSM into project development.

Key Points

What is the Highway Safety Manual?

The Highway Safety Manual (HSM) introduces a science-based technical approach that takes the Guess work out of safety analysis. The HSM provides tools to conduct quantitative safety analyses, allowing for safety to be quantitatively evaluated alongside other transportation performance measures such as traffic operations, environmental impacts, and construction costs.

For example, the HSM provides a method to quantify changes in crash frequency as a function of cross-sectional features. With this method, the expected change in crash frequency of different design alternatives can be compared with the operational benefits or environmental impacts of these same alternatives. As another example, the costs of constructing a left-turn lane on a two-lane rural road can be compared to the safety benefits in terms of reducing a certain number of crashes.

- “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…” – Dr. Ezra Hauer
- Safety functions are imbedded in many functions in a transportation organization.
- Agencies should integrate safety into their decision process to quantify the effect infrastructure decisions will have on safety performance.
- Virtually all decisions and judgments, whether at the program, resource allocation, or project level, involve trade-offs. Safety is one of those.
- Nominal safety vs. Substantive safety. The term “nominal” safety was coined to describe the adherence to design standards and practices as a measure of safety. Substantive safety or quantitative safety is its actual or expected performance in terms of crash frequency and severity.
- The HSM does not establish a legal standard of care, create a public duty, and contain warrants or standards. You are not required to use the HSM. The HSM does not establish design, other practices, or standards.
- The HSM methods can be applied to all transportation projects—not just those specifically focused on responding to safety needs.
The HSM is divided in four parts in three volumes: Vol. 1 Part A (Introduction, Human Factors, and Fundamentals); Vol. 1 Part B (Roadway Safety Management Process); Vol. 2 Part C (Predictive Method); and Vol. 3 Part D (Crash Modification Factors CMFs).

Part A describes the purpose and scope of the HSM, explaining the relationship of the HSM to planning, design, operations, and maintenance activities. Part A also includes fundamentals of the processes and tools described in the HSM. Chapter 3 (Fundamentals) provides background information needed to apply the predictive method, crash modification factors, and evaluation methods provided in Parts B, C, and D of the HSM.

The chapters in Part A are:

- Chapter 1 – Introduction and Overview
- Chapter 2 – Human Factors
- Chapter 3 – Fundamentals

Part B presents suggested steps to monitor and reduce crash frequency and severity on existing roadway networks. It includes methods useful for identifying improvement sites, diagnosis, countermeasure selection, economic appraisal, project prioritization, and effectiveness evaluation.

As shown in Figure 1, the chapters in Part B are:

- Chapter 4 – Network Screening
- Chapter 5 – Diagnosis
- Chapter 6 – Select Countermeasures
- Chapter 7 – Economic Appraisal
- Chapter 8 – Prioritize Projects
- Chapter 9 – Safety Effectiveness Evaluation

There are three chapters’ in Part C, covering predictive methodologies for three different types of highway facilities:

- Chapter 10 – 2-lane Rural Highways
- Chapter 11 – Multi-lane rural highways
- Chapter 12 – Urban and Suburban arterials
Part D of the HSM contains information on Crash Modification Factors (CMF). The information is organized by facility type in four chapters:

- Chapter 13 – Roadway Segments
- Chapter 14 – Intersections
- Chapter 15 – Interchanges
- Chapter 16 – Special Facilities and Geometric Situations
- Chapter 17 – Road Networks

The HSM provides the following tools:

- Methods for developing an effective roadway safety management program and evaluating its effects. A roadway safety management program is the overall process for identifying sites with potential for safety improvement, diagnosing conditions at the site, evaluating conditions and identifying potential treatments at the sites, prioritizing and programming treatments, and subsequently evaluating the effectiveness at reducing crashes of the programmed treatments.

  Many of the methods included in the HSM account for regression-to-the-mean (RTM) and can result in more effectively identifying improvements to achieve a quantifiable reduction in crash frequency or severity. Safety funds can then be used as efficiently as possible based on the identified locations.

- A predictive method to estimate crash frequency and severity. This method can be used to make informed decisions throughout the project development process, including: planning, design, operations, maintenance, and the roadway safety management process. Specific examples include screening potential locations for improvement and choosing alternative roadway designs.

- A catalog of crash modification factors (CMFs) for a variety of geometric and operational treatment types, backed by robust scientific evidence. The CMFs in the HSM have been developed using high-quality before/after studies that account for regression to the mean. The HSM emphasizes the use of analytical methods to quantify the safety effects of decisions in planning, design, operations, and maintenance. The first edition does not address issues such as driver education, law enforcement, and vehicle safety, although these are important considerations within the broad topic of improving highway safety. The HSM is written for practitioners at the state, county, metropolitan planning organization (MPO), or local level.

What is the Value of Using the HSM?

The HSM provides methods to integrate quantitative estimates of crash frequency and severity into planning, project alternatives analysis, and program development and evaluation, allowing safety to become a meaningful project performance measure. As the old adage says, “what gets measured gets done.” By applying the HSM tools, improvements in safety will “get done.”

Further, from a legislative perspective, the HSM will support states’ progress toward federal, state, and local safety goals to reduce fatalities and serious injuries. As public agencies work toward their safety goals, the quantitative methods in the HSM can be used to evaluate which programs and project improvements are achieving desired results; as a result, agencies can reallocate funds toward those that are having the greatest benefit.

How is the HSM Applied?

The HSM provides an opportunity to consider safety quantitatively along with other typical transportation performance measures. The HSM outlines and provides examples of the following applications:
identifying sites with the most potential for crash frequency or severity reduction;
identifying factors contributing to crashes and associated potential countermeasures to address these issues;
conducting economic appraisals of potential improvements and prioritizing projects;
evaluating the crash reduction benefits of implemented treatments; and
estimating potential effects on crash frequency and severity of planning, design, operations, and policy decisions.

the hsm can be used for projects that are focused specifically on responding to safety-related questions. in addition, the hsm can be used to conduct quantitative safety analyses on projects that have not traditionally included this type of analysis, such as corridor studies to identify capacity improvements and intersection studies to identify alternative forms of traffic control. the hsm can also be used to add quantitative safety analyses to multidisciplinary transportation projects.

module 2 – hsm fundamentals and terms

this module is designed for you to become familiar with fundamentals and terms used in the hsm and what we mean by safety as it relates to the hsm.

at the conclusion of this module participants will have fundamental background that will enable you to:

- recognize hsm safety measurement by crashes;
- describe data needs for the hsm;
- describe the evolution of crash estimation methods;
- recognize predictive methods in part c of the hsm; and
- identify benefits and limitations in the evaluation of safety effectiveness.

key points

- what is safety? – the hsm uses the number crashes as a measure of safety since it is objective and quantifiable.
- measuring safety – subjective (varies among observers) vs. objective (quantifiable and independent of the observer). subjective – what people feel is safe or dangerous. objective – the number of crash events observed or predicted.
- a crash is a set of events that result in injury or property damage involving at least one motorized vehicle. a crash may involve a collision with another motorized vehicle such as a motorcycle or another road user, such as a pedestrian or bicyclist.
- crashes – are random events that are rare in occurrence. they are influenced by many factors including some that can be controlled and some that cannot be controlled.

[diagram of contributing factors]
We can group the contributing factors to crashes in three broad categories: the human, the vehicle, and the roadway environment. In analysis of crashes, the primary goal is to determine the cause of a crash. If we know the contributing factors of a crash, we can review alternatives to reduce the risk of that crash occurring again. However, in reality most crashes cannot be attributed to a single contributing factor. Instead, a crash is the result of a convergence of a series of events influenced by a number of different contributing factors. These contributing factors may be time of day, driver attentiveness, speed, vehicle condition, road design, the weather, glare, etc.

Each of these factors can influence events before, during, and after a crash.

- **Before-crash events** -- we can learn about factors that may have contributed to the risk of the crash occurring, such as whether the brakes of one of the vehicles were worn.

- **Crash events** -- we learn about factors that could influence crash severity and thus how engineering or technological advances could change crash severity, such as whether the clear zone was adequate for the vehicle to recover or the vehicle occupants were wearing safety belts.

- **After-crash events** -- we learn how improvements in, for example, emergency response and medical treatment could have changed the outcome of the crash. These may include response time and quality of service.

- **Crash severity** -- KABCO -- most severe injury controls level of crash severity
  - **K** – One or more people died within 30 days of crash
  - **A** – Incapacitating injury
  - **B** – Non-incapacitating injury
  - **C** – Possible Injury
  - **O** – No injury, property damage only

- **Crash frequency** -- number of crashes/ number of years. It is a short term measure.

- **Crash estimation** -- is the forecast or prediction of an expected average crash frequency. In the HSM, we use crash estimation to forecast/predict the crash frequency of:
  - An existing roadway for existing conditions during a past or future period;
  - An existing roadway for alternative conditions during a past or future period; or
  - A new roadway for given conditions for a future period.

Estimated “expected average crash frequency” – given a specific geometric design, traffic volumes, and a given time period. When we estimate safety, we are using a statistical method and the answer is not an exact number but rather a statistical estimate. To state it another way, it means if we review 100 similar sites with the same characteristics, on average, we can expect to measure that frequency. Crashes are random events; hence crash frequency at a site will always fluctuate from year to year. For this reason, we need to talk about “expected average” crash frequency rather than just crash frequency when predicting crashes.

Crash frequency refers to the short term only. Over the long-term, we can expect several changes to occur at the site. For example, traffic volumes, the pavement markings, vehicle designs, networks, vehicle mix on the facility, etc. may change. For that reason, we **estimate the future expected average crash frequency** using methods that account for these changes (for the most part).

- **Data needs for expected average crash frequency**:
In general, there are three categories of data needed to apply the HSM: crash data, traffic volume data, and roadway characteristics data. The crash data needs are limited to crash data by date(year), location, type, severity level, relationship to intersection (at-intersection, intersection related, not intersection related), and distance from the intersection. The traffic volume data requirement for roadway segments is the annual average daily traffic (AADT). For intersections, the traffic volume requirement is the major and minor street entering AADT.

The roadway characteristics data requirements change as a function of the facility type (e.g., two-lane, two-way rural road, multilane rural highway, urban/suburban arterial) and whether an intersection or segment is under consideration.

Data needs for applying the HSM methods change by the type of facility. The HSM Data Needs Guide, NCHRP Research Results Digest 329, provides additional information about the specific data elements used in the different parts of the HSM. [http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rrd_329.pdf](http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rrd_329.pdf)

- Observed crash data limitations: include quality and accuracy; different reporting thresholds, different severity definitions. All these factors can differ among reporting jurisdictions.
- Data are limited because of randomness and change.
- Examples of data limitations related to randomness and change include:
  - Crash frequency varies naturally from year to year;
  - Regression-to-the-mean and regression-to-the-mean bias occurs;
  - Roadway characteristics vary over time; and
  - Conflict may occur between crash frequency variability and changing site conditions.

- Crashes are random and frequency varies over time; hence, short term crash frequency is not a good indicator of long term crash frequency. Earlier we talked about crashes being random and crash frequencies varying from year to year. Crashes vary naturally over time at a particular site. Because of this phenomenon, short term crash frequency is not a good indicator of long term crash frequency at a particular site. Even if we use a three-year period for our analysis, we simply do not know whether this three-year period presents a typically high, medium, or low crash frequency. This phenomenon is particularly challenging at sites where we observed very low crash frequencies.
Regression-to-the-Mean (RTM) is the natural variation in crash data. RTM can cause the overstatement of a safety intervention’s effectiveness based on normal changes in the short term average crash frequency. If regression to the mean is not accounted for, a site might be selected for study when the crashes are at a randomly high fluctuation, or overlooked from study when the site is at a randomly low fluctuation.

Consider Site Changes Over Time:

- Traffic volume
- Weather
- Traffic control
- Geometric design

Site characteristics are subject to change over time due to changes in traffic volume, weather, traffic control, land use, and geometric design. When we measure the effectiveness of a treatment, it is not always clear whether the measured change in observed crashes is because of the treatment or because of other changes in the roadway and environment. For example, if a state evaluates all their centerline rumble strip installation, the data may indicate the number of motorcycle crashes increased. This increase was not because the facilities became more unsafe but because the amount of motorcycle miles traveled has increased. Conclusions regarding the impact of a treatment should not be drawn without considering other factors that may change at the site (even those we do not measure).

The implications of the crash frequency variability and changing site conditions are in conflict.

On the one hand we observe fluctuations in the crash frequency and realize that considering counts over a longer period of time would be beneficial but on the other hand, we realize that the longer the review period, the more likely that site conditions will change. This conflict requires considerable judgment, particularly when we use crash estimation procedures based on observed crash frequency. One way to accommodate for this conflict is to use the predictive methods in Part C to estimate the expected average crash frequency for the specific conditions for each year of study period.

Crash estimation has evolved as a result of improvements in statistical sophistication and changes in thinking.
In this section, we will discuss the benefits and limitations of the different methods, and focus on three crash estimation methods:

- Observed crash frequency and crash rates over a short-term period, and a long-term period (e.g., more than 10 years);
- Indirect safety measures for identifying high crash locations. (We also refer to indirect safety measures as surrogate measures); and
- Statistical analysis techniques and statistical methodologies to incorporate observed crash data to improve the reliability of crash estimation models.

**Method 1 - Observed Crash Frequency and Crash Rate Methods**

Crash rate: \( \text{average crash} = \frac{\text{frequency in period}}{\text{exposure in the same period}} \)

The first method is observed crash frequency and crash rate methods. This method uses observed crash frequency and crash rate methods. Observed crash frequency refers to the historical crash data for a site (the number of recorded crashes per year). Crash rate refers to the number of crashes that occurred at a site during a time period to a particular measure of exposure. Statistically, we can interpret crash rates as the probability, based on past events, of being involved in a crash per instance of the exposure measure. Observed crash frequency and crash rates are often used as a tool to identify and prioritize sites in need of modifications and for evaluation of the effectiveness of treatments. Sites with the highest crash rate or rates higher than a particular crash rate are further analyzed for potential modifications to reduce crashes. Appendix A.3 for Chapter 3 of the HSM provides examples of this method.

Observed crash frequency and crash rate methods

**Advantages:**
- Intuitive
- Acceptance
- Limited alternatives

**Limitations:**
- Assumes a linear relationship between crash frequency and exposure
- Inability to account for changes in geometric design volumes and design alternatives
Why are crash rates not always good performance measures? Though crash rates are a common and intuitive way to evaluate crashes relative to traffic exposure, there are circumstances where the crash rate is not informative and may even provide incorrect information. In this example, a 2-lane rural corridor experiences a considerable growth in traffic and crashes, but the physical road geometry did not change during this time period. The average crash rate decreased (2.28 crash rate prior to 1992 compared to a 1.24 rate later), but this change is due primarily to the dramatic increase in traffic volume.

Why did the traffic volume increase so dramatically? In 1992 a casino was constructed in a remote location along this road and the increase in traffic was primarily due to that new development. Before gambling the crash rate was 2.28. The road alignment and cross-section did not change. After the introduction of gambling the crash rate was 1.24 but impaired driving crashes increased by 500%. As expected, the construction of a casino introduces more at-risk personalities, many of who tend to drink and drive. If crash rate is used as an indicator, one possible conclusion would be that drinking and driving when combined with gambling is good for safety. We know this is probably not true, but if only crash rates are used to evaluate safety then this would be the conclusion derived from this evaluation.

### Crash Rate Conclusion?

**Before Gambling**

- Average Rate = 2.28
- Highway Alignment and Typical Cross-Section not Changed

**After Gambling**

- Average Rate = 1.24
- but the Percent of Alcohol Related Crashes increased 500%

Possible Conclusion: Is Drinking and Driving in Concert with Gambling Good for Safety?

- Probably Not but Crash Rates Say Otherwise

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Method 2 - Indirect Measures – based on events preceding crashes such as a conflict study

This method provides a surrogate methodology when crash frequencies are not available because the roadway or facility is not yet in service; has only been in service for a short time; crash frequencies are low or have not been collected; or when a roadway or facility has significant unique features. The advantage of surrogate safety measures is they may save having sufficient crashes to materialize before a safety issue is recognized and a remedy applied.
Note: The HSM does not include indirect measures because the HSM is focused on quantitative crash information.

The strength of surrogate safety measures lies in the fact that data for analysis are more readily available and there is no need to wait for crashes to occur before analysis can take place. The major concern regarding surrogate safety measures is the often unproven relationship between the surrogate measure and crash estimation.

Advantages:
- Acceptance data for analysis is readily available
- No need to wait for crashes to occur before analysis can take place.

Limitations:
- Unproven relationship between the surrogate measure and crash estimation

Method 3 - Statistical Methods

Statistical methods using regression analysis offer solutions to some of the limitations of the methods we discussed earlier (e.g., RTM bias). Crash Estimation using Statistical Methods increases the ability to reliably estimate the expected average crash frequency for existing and new roadway designs prior to construction and use.

The reliability of a model is only as good as:
- How well the model fits the original data
- How well the model has been calibrated to local data

Numerous statistical methods are available to estimate expected average crash frequency. The HSM focuses on the Empirical Bayes Method (EB). Other methods are the hierarchical Bayes method and the full Bayes method. In the next section we will briefly review the predictive method in Part C of the HSM.

The topics in Part C include:
- Overview
- SPFs
- CMFs and CRFs
- Calibration
- Weighting with EB
- Limitations

The predictive method in Part C consists of two basic elements: a predictive model is used to estimate the average crash frequency for a specific site type; and the EB method is applied.

The predictive model is developed using data from a number of similar sites. The model is then adjusted for specific site and local conditions.

The EB method allows us to combine estimation from the statistical model with the observed crash frequency at the specific site. We apply a weighting factor to the two estimates to reflect the statistical reliability of the model.

The predictive methods in Part C offer a number of advantages.
The predictive methods:

- Account for regression-to-the-mean bias
- Reliance on the availability of limited crash data for any one site is reduced by incorporating predictive relationships based on data from many similar sites
- The methods account for the nonlinear relationship between crash frequency and traffic volume
- The SPFs in Part C use the negative binomial distribution. This statistical distribution is better suited for modeling crash data since a typical crash data set is randomly distributed with a variance larger than its mean indicating that the data is overdispersed.
- Reliable estimate for expected average crash frequency for existing projects and design projects
- Model reliability function of: original data fit and local data model calibration
- Empirical Bayes

Limitations
- Complex method

Safety Performance Functions - SPFs – mathematical expression used to estimate the expected average crash frequency for base conditions. The SPFs are developed by using statistical methods applied to actual crash databases. To develop consistent assessments for similar conditions, crashes based on similar conditions should be used for developing the SPFs. As a result, these similar conditions are referred to as “Base Conditions” and should be documented with the SPF information. An example of a base condition is a 2-lane rural highways for roadway segments, 12’ lanes and 6’ shoulders at locations, level terrain, and clear, traversable roadside conditions.

We use the SPF to estimate the average crash frequency for a facility type with specified base conditions. In the SPF you see factors such as AADT, segment length. Other SPFs may have variables such as shoulder width and so on, as well. SPFs for the following facility types in Part C include:

- Two-lane rural highways
- Rural multilane highways
- Urban and suburban arterials.

The SPFs in the HSM are used to estimate the average crash frequency for all crashes (KABCO). The HSM also provides default distributions for crash severity levels and collision types. If the agency prefers, they can use more advanced statistical approaches to estimate changes in severity levels.
Though some of the estimated SPFs may follow a linear format, it is also just as likely that a SPF may be non-linear.

Since the SPF represents the general distribution of crashes it is important that the SPF reflect actual patterns as they relate to traffic volume and crash frequency. The crash-volume relationship is not always linear and so the uses of crash rates (which assume this linear relationship) are not suitable for all road types. As a result, the use of crash rates to estimate the number of predicted crashes is unlikely to accurately reflect safety conditions for all traffic volume thresholds.

If a SPF was developed for another region or jurisdiction, it is necessary to perform calibration.

Calibrations must be performed because regions differ in climate, animal population, driver populations, crash reporting threshold, crash reporting practices, etc. A calibration factor is really just an adjustment factor to adjust crashes upward or downward so that the estimate better represent what is happening locally. Every SPF has an over-dispersion parameter, which is an artifact of the negative binomial regression process. With the EB process we apply a weight factor that adjusts for the over-dispersion parameter (how well the model fits) and regression-to-the-mean. The weighting process is presented in HSM Chapters 9 through 11. To use the EB procedure, however, historic crash data must be available for the study location. The EB procedure will enhance predictive accuracy for a specific site, but if the historic crash data is not available the predicted number of crashes (using the SPF and local calibration) provides an average crash prediction of similar facilities.

**Crash modification factors (CMF)** estimate the expected influence of a specific countermeasure or condition. CMFs (sometimes referred to as crash modification functions) are values we multiply times the predicted number of crashes in an effort to estimate the expected influence of a specific countermeasure or condition. If the countermeasure has no direct influence on expected safety performance then the CMF = 1.0. If the countermeasure is expected to increase the number of crashes then the CMF > 1.0. If the countermeasure is expected to reduce the number of crashes, the CMF < 1.0

- CMFs – crash modification factor

\[
CMF = \frac{\text{Expected average crash frequency with condition on}}{\text{Expected average crash frequency with condition off}}
\]

The CMF or crash modification factor is a proportion we apply to determine how a particular treatment will change crash frequency for a base condition.

\[
N_{\text{predicted}} = N_{\text{SPF}} \times (CMF_{1x} \times CMF_{2x} \times \ldots \times CMF_{yx}) \times C_x
\]

- \(N_{\text{predicted}}\) = Expected crash frequency from SPF for base condition
- \(N_{\text{SPF}}\) = Expected crash frequency
- \(CMF_{ix}\) = Crash modification factors
- \(C_x\) = Calibration factor

The CMF and Vol. 2 (Part C)

2-54
A CMF is the ratio of the effectiveness of one condition in comparison to another condition. We multiply the CMF by the SPF to account for differences between the base conditions and site conditions.

When applying the CMFs in the HSM or any CMF developed locally, keep in mind:

- Only apply a CMF to a known base condition (need to know when the CMF is equal to 1);
- Know the setting and road type for which the CMF was developed;
- Know the AADT range of the data used to develop the CMF; and
- Some CMFs represent total crashes while others are specific to crash type or crash severity.

Some agencies use a Crash Reduction Factor or CRF. This value can be directly converted to a CMF. The CRF is used by many agencies to directly calculate the number of reduced crashes that can be expected as a result of deploying a safety countermeasure. The CRF is presented as the portion of crashes that should be reduced. For example, the CRF value can be multiplied by the “before” number of crashes to indicate the number of expected crashes reduced. For a CRF value of 0.2 (you can also think of this as 20%), if “before” you have 100 crashes and the countermeasure is deployed you can expect to reduce the number of crashes by 20. In other words, the number of crashes for the “after” condition would be 100 (before) – 20 (reduced) = 80 (after).

HSM Statistical Methods Application

- It is not possible to predict a specific value for the observed crash frequency because crashes are random. The HSM allows us to calculate the expected average crash frequency – a value that is representative of the average for a large group of similar sites under consistent long-term periods.
- It is necessary to calibrate SPFs to local conditions
- Engineering judgment should always be used when applying methods and values from the HSM
- Crash data have errors and limitations that inherently influence the quality of SPFs, CMFs and our estimates.
- To develop SPFs and CMFs, it is necessary to have a good understanding of statistical regression modeling and crash analysis techniques (this is not covered in the HSM).

Evaluating Safety Effectiveness

We will briefly introduce the effectiveness evaluation process is described in the HSM. The purpose of the effectiveness evaluation process is to evaluate the change in crashes brought about by the project. In other words it is a quantitative estimate of the effect of a treatment, project, or a group of projects. It is necessary to perform these evaluations because they support future decision-making and policy development.

We can use the evaluation process to determine the percentage change in crash frequency, the shift in proportions of crashes by type or severity, the CMF for a treatment, or to compare benefits achieved as a function of the cost of a project or treatment.

Observational studies refer to evaluations of changes implemented in the normal course of efforts to improve the transportation system. In other words, we are not implementing treatments for the purpose of the evaluation.

In contrast, in experimental studies we select sites for improvement and similar sites for control sites (no improvement) through a random selection process. With the experimental study, we’re therefore able to directly attribute differences between the control and treatment sites to the treatment. Observational studies are much more common among agencies, because agencies function with limited budgets and typically need
to prioritize projects based on the benefits returned. In this sense the random selection process will not
optimize investment selection.

The HSM covers three different effectiveness evaluation types:

- Observational before-after studies;
- Observational cross-sectional studies; and
- Experimental before/after studies.

Observational before-after studies are used to evaluate a treatment when the only change to the site is the
particular treatment.

We collect data for both the before and after periods and then estimate crashes for the ‘before’ period. The
estimated expected average crash frequency based on the ‘before’ period is then adjusted for changes in
conditions in the ‘after’ period to allow us to predict what the expected crash frequency would have been had
we not installed the particular treatment. The difference between these two values is then determined to reflect
the actual safety of the treatment.

The observational cross-sectional study is used to evaluate a treatment where a set of sites are treated and
other sites are not.

**Module 3 – Crash Modification Factors**

HSM Part D is a resource for Crash Modification Factors. Module 3 presents information on Crash Modification
Factors (CMF), safety trends, and unknown effects of various treatments.

At the conclusion of this module participants will:

- Be familiar with crash modification factors; and
- Recognize Volume 3, Part D as a resource for CMFs relative to:
  - Roadway segments;
  - Intersections;
  - Interchanges; and
  - Special facilities, geometric situation, and road networks.

**Key Points**

PART D Crash Modification Factors

For each facility type, prediction models for set base conditions are found. CMFs quantify the change in
expected average crash frequency as a result of geometric or operational modifications to a site that differs
from set base conditions. As shown in Table 2, Part D provides a catalog of treatments organized by site type:

- Chapter 13 – Roadway Segments
- Chapter 14 – Intersections
- Chapter 15 – Interchanges
- Chapter 16 – Special Facilities
- Chapter 17 – Road Networks
The CMFs will be readily applicable to any design or evaluation process where optional treatments are being considered. The CMFs will also be a valuable addition to the documentation of design exceptions.

**A Crash Modification Factor (CMF)** is a factor estimating the potential changes in crash frequency or crash severity due to installing a particular treatment or countermeasure. The CMFs in the HSM have been developed based on a rigorous and reliable scientific process.

- **CMFs – crash modification factor**
  \[ CMF = \frac{\text{Expected average crash frequency with condition } \beta}{\text{Expected average crash frequency with condition } \alpha} \]

- To use a CMF effectively you must know base conditions.

- CMFs and Crash reduction Factors (CRFs) are related CMF = (1 - CRF).

- A CMF may apply to all crashes, or some sub-segment of crashes defined by crash type or circumstances. The same treatment applied to different road types may have different effects; hence one needs to understand the applicability of any CMF to the condition. Multiple treatments may be applied at any one location. The process of estimating aggregate effects of multiple treatments is to multiply the CMFs.

- Same treatment in different contexts or highway types may have different effects and CMF values. In some instances the same treatment can have opposite effects for various severity levels. As an example, the installation of a changeable “Queue Ahead” warning sign, located upstream of a construction zone, can result in a reduction in injury rear-end crashes while the same treatment can contribute to an increase in non-injury rear-end crashes.

- Multiple CMFs may be applied to same location (multiply). The HSM permits the multiplication of several CMFs for a single location; however, each CMF has some level of uncertainty associated with it so it is advisable to use judgment when selecting the optimal number of CMFs to multiply. CMF values may not be explained by a simple value. When a CMF would be defined by a curve or line, it is considered to be a Crash Modification Function.

- A CMF is a one value, but experience suggests a variance. As each location is different, one cannot expect the actual performance of a treatment to be uniformly the same. A range in the variance for each CMF should be understood. This may be explained by the treatment itself, and/or the quantity and quality of the underlying research.

- **Vol. 3 (Part D) CMF Applications**
  - Infrastructure treatments
    - Widening lanes or shoulders
    - Flattening curves
    - Improving roadside (barrier, slope treatments, etc.)
    - Install rumble strips
    - Traffic control
    - Signing, pavement markings
    - Signalization
• Operational strategies
  ▪ On-street parking prohibition, regulation
  ▪ Changeable message advance warning signing on freeways
  ▪ Access management (driveway closure, median closures)
  ▪ Left turn signalization, clearance intervals

• Maintenance strategies
  ▪ Winter maintenance, anti-icing applications
  ▪ Work zone duration

• The standard error (SE) is the estimated standard deviation of the difference between estimated values and observed values.

**CMF Confidence Intervals**

\[
CI(X\%) = \text{CMF} \pm (\text{SE} \times \text{MSE})
\]

<table>
<thead>
<tr>
<th>Desired Level of Confidence</th>
<th>Confidence Interval</th>
<th>Multiple of Standard Error (MSE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>65% - 70%</td>
<td>1</td>
</tr>
<tr>
<td>Medium</td>
<td>95%</td>
<td>2</td>
</tr>
<tr>
<td>High</td>
<td>99.9%</td>
<td>3</td>
</tr>
</tbody>
</table>

• Much effort was placed in development of the HSM to understand and report on the variance in CMFs from the literature. Such variance is considered as important as the CMF value itself, as an analyst or engineer needs to understand the full implications of using any CMF.

FHWA has assembled and committed to maintaining the currency of the knowledge base on CMFs through their CMF clearinghouse.
**Module 4 – Predictive Methods**

Reliable quantitative assessment procedures that are scientifically based will help confirm that resources are distributed in a manner that effectively enhances safety. The HSM includes predictive methods that provide this type of information and, as a result, will help agencies appropriately delegate funds that will benefit safety. These predictive methods are presented in this module.

At the conclusion of this module participants will be able to:

- Explain the predictive method and the analysis process;
- Identify required data for basic and supplemental analysis;
- Define the predictive method, application, and limitations;
- Compare the differences among predictive methods based on characteristics of roadway types; and
- Demonstrate the predictive method.

**Key Points**

Historically safety assessments have primarily occurred based on subjective evaluations. For example, intuitively the addition of a left-turn lane is considered a safety enhancement because this type of facility removes stopped vehicles from an active, through travel lane. By using a series of simplified procedures we could further say, with some confidence that based on enhanced traffic operations the safety at this location has been improved as a result of this countermeasure (maybe by using simple before-after evaluations or comparison sites). What we were not able to confidently answer, however, was did the improvement result in one less crash? Did it result in an expected crash reduction of 10 crashes? Maybe results in a reduction of 100 crashes?

Reliable quantitative assessment procedures that are scientifically based will help confirm that resources are distributed in a manner that effectively enhances safety. The HSM includes predictive methods that provide this type of information and, as a result, will help agencies appropriately delegate funds that will benefit safety. These predictive methods are presented in this module.

Part C provides a predictive method for estimating and comparing expected average crash frequency of existing facilities, alternative design modifications, new facility designs, and estimated countermeasure effectiveness.

As shown in Table 1, the SPFs in the chapters in Part C provide the means for predictive method for segments and intersections for the following facility types:

<table>
<thead>
<tr>
<th>Chapter 10 – Rural Two-Lane, Two-Way Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapter 11 – Rural Multilane Highways</td>
</tr>
<tr>
<td>Chapter 12 – Urban and Suburban Arterials</td>
</tr>
</tbody>
</table>
Predicting expected average crash frequency as a function of traffic volume and roadway characteristics is a new approach that can be readily applied in a variety of ways, including design projects, corridor planning studies, and smaller intersections studies. The approach is applicable for both safety specific studies and as an element of a more traditional transportation study or environmental analysis.

Uses of the Predictive Method

The predictive method can be used for evaluating and comparing the expected crash frequency of:

- Existing facilities under current or future (forecast) traffic volumes
- Alternative designs for an existing facility under past or future traffic volumes
- Alternative designs for a new facility under future (forecast) traffic volumes
- The estimated effectiveness of countermeasures to an existing facility prior to implementation

Predictive Method Model Formats and Application

- Intersection
- Roadway segments

A roadway segment is a section of a continuous travel way that provides two-way operation of traffic, is not interrupted by an intersection, and consists of homogenous geometric and traffic control features.

A roadway segment begins and ends at either the center of an intersection or where the geometric design or traffic control features of a roadway segment change.

<table>
<thead>
<tr>
<th>Rural Two-Lane Two-Way Homogeneous Segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A new roadway segment begins at:</td>
</tr>
<tr>
<td>• Center of each intersection</td>
</tr>
<tr>
<td>• Horizontal curves (PC)</td>
</tr>
<tr>
<td>• End of grade (PVI)</td>
</tr>
<tr>
<td>• Limits of passing lanes or short 4-lane sections</td>
</tr>
<tr>
<td>• Limits of two-way left-turn lane</td>
</tr>
</tbody>
</table>

- Segments may begin at various points on the roadway. Roadway segments may also change when a change to the roadway occurs.
Intersections are defined as the junction of two or more roadway segments. The intersection models estimate the predicted average frequency of crashes that occur within the “curb line” limits of an intersection as well as intersection-related crashes that occur on the intersection approaches.

Using these definitions, the roadway segment predictive models estimate the frequency of crashes that would occur on the roadway if intersections were not present. The intersection predictive models estimate the frequency of additional crashes that occur due to the presence of the intersection.

- A facility consists of a contiguous set of individual intersections and roadway segments, referred to as sites, while a network consists of a number of contiguous facilities. The sum of crash frequencies for all sites is used as the estimate of the expected crash frequency for an entire facility or network.

- The HSM predictive method provides an 18 step procedure (condensed into the 5 step process below) to estimate the average crash frequency of a roadway network, facility, or site. Roadways are subdivided into individual sites which are either homogenous roadway segments or intersections.
The process is the same for calculating the expected crashes for any roadway type for either intersections or roadway segments.

The HSM provides a predictive equation, known as a Safety Performance Function (SPF) for a roadway segment or an intersection. The SPF was based on specific, fixed geometric conditions that serve as the “base case” (i.e. 12’ lanes, 6’ shoulder for roadway segment). The HSM SPFs were developed from crash information at several United States locations.

Adjustments to the SPF base case geometric conditions are made by multiplying the SPF by the appropriate Crash Modification Factors (CMFs). This converts the base conditions to site specific conditions (e.g., converts 12’ lanes to 11’ lanes and 6’ shoulders to 4’ shoulders for roadway segment).

To adjust the generalized SPF estimates to local conditions, multiply by a local calibration factor (C).

Calculate intersection crashes by summing the crashes from the applicable roadway segment SPF values and the applicable intersection SPF values.

Predicted Crash Frequency = SPF x (CMF1 x CMF2 ..... x C).
Safety performance functions differ for segments and intersections and by basic facility type. The slide shows two examples.

In the predictive method, a facility is divided into individual sites which consist of intersections and roadway segments. Separate predictive models are provided for the roadway segments and specific intersection configurations for the various road types.

In the predictive method, a facility is divided into individual sites which consist of intersections and roadway segments. Separate predictive models are provided for the roadway segments and specific intersection configurations for the various road types.

Predictive methods are available for the following:

- Chapter 10 – Rural Two-Lane Two-Way Roads
- Chapter 11 – Rural Multilane Highways
- Chapter 12 – Urban and Suburban Arterials

SPFs may be depicted graphically as shown here for one example SPF. Note the key predictive variables are AADT of both major and minor traffic movements and the non-linear form of the function.

Refer to Chapters 10, 11, and 12 for other similar graphical depictions of the SPFs.
The exhibit provides information on the availability of SPFs in the HSM based on roadway type for roadway segments, geometrics, and traffic control for intersections.

- Rural two-lane two-way roadway segments include:
  - All rural highways with two-lanes and two-way traffic operations
  - Two-lane two-way highways with center left-turn lanes
  - Two-lane highways with added passing or climbing lanes
  - Short segments of four-lane cross-sections where the added lanes are provided specifically for passing

- Rural two-lane two-way intersections include:
  - Three-leg and four-leg intersections with minor-road stop control
  - Four-leg signalized intersections on all roadway cross-sections

- Rural multi-lane segments include:
  - Rural multilane highways without full access control
  - Rural non-freeways with four through travel lanes, except two-lane highways with side-by-side passing lanes (two-miles or less in length)

- Rural multi-lane intersections include:
  - Three-leg and four-leg intersections with minor-road stop control
  - Four-leg signalized multilane highway intersections

- Urban and Suburban Arterial Segments Include:
  - Non-freeway arterials without full access control and with two, four, or six through lanes in urban and suburban areas

- Urban and Suburban Intersections Include:
  - Three-leg and four-leg intersections with minor-road stop control
  - Three-leg and four-leg intersections with traffic signal control
  - Roundabouts on all urban and suburban arterial highway cross-sections
Details on the 5 steps for performing the predictive method.

Applying Predictive Method Process – Basic Analysis Steps

1. Determine data needs
   - Study limits
   - Facility type
   - Study period
   - Site conditions (geometry, traffic control, etc.)
   - Traffic volume (vehicles/day)

2. Divide locations into homogeneous segments or intersections
   - Type of intersections
   - Number of lanes
   - Cross section dimensions (LW, SW)
   - Alignment change (Horiz, Vertical)
   - Change in roadside conditions
   - Change in traffic volume

3. Identify and apply the appropriate SPF
   - Chapter 10 2-Lane Rural Highway SPFs
   - Chapter 12 Urban Arterial SPFs
   - Chapter 12 Multilane Rural Highway SPFs

4. Apply CMFs to calculated SPF values
   - Review applicable SPF “base case” or typical features
   - Determine how study site differs from “base case”
   - Select CMFs for road type and atypical features from Volume 2 (Part C)
   - Multiply SPF value by applicable CMFs

5. Apply local calibration factors
   - “C” adjusts HSM SPF-derived crash estimates to reflect local conditions
   - Reporting levels
   - Weather and other similar factors
   - Each SPF requires its unique “C”
   - See HSM Vol. 2 (Part C) Appendix

Step 1 – Determine Data Needs

The following input data is required for the predictive method. The data include:

- Limits of the roadway and facility type in the study
- Period of interest
- Geometric design features, traffic control, and site characteristics
- Availability of traffic volume for the study period
- For intersections, AADT volumes are needed for both the major and minor streets
- If the EB Method is used, AADT traffic volumes are needed for each year for which observed crash data are available
Step 2 – Divide Locations into Homogeneous Segments or Intersections

Define a ‘homogeneous’ segment. Divide the study area into individual homogenous (or similar) roadway segments or intersections. For roadway segments, the recommended site length is equal to or greater than 0.10 miles. Smaller segments would result in excessive and needless calculations. An example for identifying boundaries of homogeneous features is: Field measurements suggest at one location the lane width is 11.8 ft wide and downstream the lane width is 12.1 ft. For these two locations, it is reasonable to assume both segments have lanes widths of approximately 12 ft and are similar (part of the same homogeneous segment for lane width criteria). If, on the other hand, the downstream lane width measured 10.3 ft, then the lane widths are no longer similar, and these two locations should not be included in the same study segment. The HSM provides guidance on how to determine homogeneous thresholds.

The HSM includes recommendations for rounding variables that then helps clarify the boundaries of homogeneous segments. This information is located on pages 10-12 to 10-13 (for rural two-lane segments), pages 11-12 to 11-13 (for rural multilane highway segments), and page 12-15.

After selecting the first site and beginning with the initial period of interest, calculate the expected crashes using the appropriate SPF based on geometric design (road type) and traffic control features.

A roadway segment is a section of a continuous travel way that provides two-way operation of traffic, is not interrupted by an intersection, and consists of homogenous geometric and traffic control features. A roadway segment begins and ends at either the center of an intersection or where the geometric design or traffic control features of a roadway segment change.

Intersections are defined as the junction of two or more roadway segments. The intersection models estimate the predicted average frequency of crashes that occur within the “curb line” limits of an intersection as well as intersection-related crashes that occur on the intersection approaches.

Using these definitions, the roadway segment predictive models estimate the frequency of crashes that would occur on the roadway if intersections were not present. The intersection predictive models estimate the frequency of additional crashes that occur due to the presence of the intersection.

Step 3 – Identify and Apply the Appropriate SPF

The appropriate SPF is based on facility type, location, and whether one is looking at an intersection or segment. Appropriate SPFs for both intersections and segments are contained in each of the three chapters of Vol. 2 (Part C) covering 2-lane rural highways, multilane rural highways, and urban arterials.
The most prominent facility types that are not currently included in Vol. 2 (Part C) are freeways and interchanges. Research to develop SPFs is under way for these for future editions of the HSM.

Step 4 – Apply CMFs to Calculated SPF values

Each SPF was developed assuming a “base case” of geometric design and traffic control features. These are specified in each Vol. 2 (Part C) chapter. To convert specific geometric design and traffic control features from the base condition to those at the study site, the SPF value is multiplied by a CMF developed exclusively for the same road type.

CMFs are a ratio of the estimated average crash frequency for a site under two different conditions, so a CMF represents the relative change in crash frequency due to a change in one specific condition (or countermeasure) when all other conditions remain constant.

Separate CMFs are required for each SPF based on roadway type (e.g. rural two-lane two-way roadway, rural multilane highway, and urban and suburban arterials). As a result, CMFs which were developed from blended data of various roadway types cannot be used with the predictive methods.

Chapter 10 includes CMFs for each of the variables listed. The tables summarize the base conditions. Changes in these base conditions require the use of the appropriate CMF to adjust the prediction using the Chapter 10 SPFs. Wherever any element changes, a new segment are defined and application of CMFs for that segment is necessary.
Two-Lane Rural Highway CMFs. The crash modification factors shown in the exhibit are used to adjust the base conditions for the site specific rural two-lane two-way locations. Only the CMFs noted in this Table should be used with SPFs in Chapter 10 of the HSM.

This slide demonstrates how to determine the lane width CMF proportional adjustment (since only run-off-road, rear-end, and sideswipe crashes will be influenced by a change in lane width).

For the applicable lane-width crash conditions, the proportions for the total number of crashes (all severity levels) are as follows:

- Ran off road: 52.1% so 0.521 (proportion)
- Head-on collision: 1.6% so 0.016
- Sideswipe collision: 3.7% so 0.037
- 52.1+1.6+3.7 = 57.4%
- Total proportion is then 0.521 + 0.016 + 0.037 = 0.574

\[
CMF_{lw} = (CMF_{lw} - 1.0) \times p_{lw} + 1.0
\]

\[
p_{lw} = \frac{52.1 + 1.6 + 3.7}{100} = 0.574
\]

\[
CMF_{lw} = (1.05 - 1.0) \times 0.574 + 1.0 = 1.0287
\]
Using the CMF for related crashes and the proportion of total crashes represented by the related crashes, a CMF for the effect of lane width on total crashes can then be determined.

The equation is: \( CMF_{1r} = (CMF_{ra} - 1.0) \times p_{ra} + 1.0 \)

Where:

- \( CMF_{1r} \) = CMF #1 for the effect of lane widths on total roadway segment crashes.
- \( CMF_{ra} \) = CMF for the effect of lane width on related crashes (for the lane width CMF this is single-vehicle run-off-the-road, multiple-vehicle head-on, and multiple-vehicle sideswipe crashes).
- \( p_{ra} \) = proportion of total crashes constituted by related crashes (in other words a ratio of the affected percent of crashes divided by the total percent of crashes).

Chapter 11 includes CMFs for each of the variables listed. The tables summarize the base conditions. Changes in these base conditions require the use of the appropriate CMF to adjust the prediction using the Chapter 11 SPFs.

### Base Conditions Multilane Rural Arterials (Ch 11)

**Intersections**
- 90° angle (0° skew)
- No left turn lanes
- No right turn lanes
- No lighting

**Road segments**
- 12-ft lane widths
- 8-ft shoulder widths
- 30-ft median (4D)
- No lighting
- No automated speed enforcement

Chapter 12 includes CMFs for each of the variables listed; the tables summarize the base conditions. Changes in these base conditions require the use of the appropriate CMF to adjust the prediction using the Chapter 12 SPFs.

### Base Conditions Urban and Suburban Arterial SPFs (Ch 12)

**Intersections**
- No left-turn lanes
- Permissive left-turn signal phasing
- No right-turn lanes
- Right-turn on red permitted
- No lighting
- No automated enforcement
- No bus stops, schools or alcohol sales establishments near intersection

**Road segments**
- No on-street parking
- No roadside fixed objects
- 15-ft median (4D)
- No lighting
- No automated speed enforcement
Step 5 – Apply Local Calibration Factor (C)

The SPFs used in the predictive method have each been developed from multiple jurisdictions and must be calibrated to the specific study site or area.

A calibration factor (C) should be applied to each SPF in the predictive method to convert the expected number of crashes to an adjusted value appropriate for the study site. The C value helps account for regional differences in driving behavior, roadway design standards, and weather (as examples).

Separate calibration factors are required for each SPF roadway type (e.g. rural two-lane two-way roadway, rural multilane highway, and urban and suburban arterials). If a jurisdiction has not developed regional calibration factors, the transportation professionals can still use the SPFs for approximate estimates suitable for comparisons to other SPF-generated values. The level of precision, however, would be less than estimates achieved using calibration factors.

Predictive Method Process Supplemental Steps

The HSM procedure can be used to further evaluate different time periods or different sites, to enhance prediction quality. In addition to the basic steps previously reviewed, the HSM procedure can be used to further evaluate different time periods or different sites, to enhance prediction quality using historic crash information, and to perform comparisons as shown in the following seven supplemental steps:

- Repeat basic steps for next time period
- Apply site-specific EB Method
- Repeat basic steps for next study site
- Apply project-level EB Method
- Calculate total expected crashes for project
- Evaluate alternate design
- Evaluate and compare results

After calculating the expected crashes using the SPF for the initial site and time period, and multiplying it by the appropriate CMFs and calibration factor, repeat the process for the next time period of interest for that site (when applicable).

Apply Site-Specific Empirical Bayes (EB) Method

- Reduces effects of regression-to-the-mean
- Improves the crash frequency estimate
- Both SPF and crash data must be available
- See HSM Vol. 2 (Part C) Appendix

- If the site-specific EB Method is applicable, it is applied to the estimated expected average crash frequency for the site previously calculated.
Using historic crashes for the site, the EB Method combines the predictive model estimate of average crash frequency with the observed crash frequency of the selected site. (See HSM Vol. 2 (Part C) Appendix for Additional Information).

The Empirical Bayes Method (EB) is used to reduce the effects of regression-to-the-mean and improve the estimate of crash frequency.

The EB Method is only applicable when both the SPF and observed crash data are available for the specific study site. Information about the EB Method is presented in the HSM Vol. 2 (Part C) Appendix.

**EB Method Application and Formula**

**Expected Crash Frequency:**

\[
N_{\text{expected}} = w \times N_{\text{predicted}} + (1.00 - w) \times N_{\text{observed}}
\]

Formula for applying the EB Method -- The estimated crash frequency formula is for the site-specific EB application and illustrates mathematically how observed crash data is combined with predicted crash data to improve the estimate of the predictive crash frequency. This is important for a site-specific analysis since the predictive crash frequency represents an average for all similar configurations and does not account for potential local affects unique to the region or location.

As the value of the over-dispersion parameter (k) increases, the value of the weighted adjustment factor decreases, and more emphasis is placed on the observed rather than the SPF predicted crash frequency.

The weighted adjustment is:

\[
N_{\text{expected}} = w \times N_{\text{predicted}} + (1.00 - w) \times N_{\text{observed}}
\]

Where:

- \(N_{\text{expected}}\) = estimate of expected average crash frequency for the study period;
- \(N_{\text{predicted}}\) = predictive model estimate of predicted average crash frequency for the study period;
- \(N_{\text{observed}}\) = observed crash frequency at site over the study period;
- \(w\) = weighted adjustment to be placed on the SPF prediction;
- \(k\) = over-dispersion parameter from the associated SPF (larger k value indicates greater variability in the SPF estimates)

Apply the project level EB Method if observed crash data is available and the crash data is not able to be accurately assigned to specific sites.
w Calculation - Weight Adjustment for Observed Crashes

\[ w = \frac{1}{1 + k \times (\sum N_{predicted})} \]

where \( k \) is the over-dispersion parameter (unique to each SPF) and \( \sum N_{predicted} \) is the predictive model estimate for all study years.

Note: If a SPF does not include an over-dispersion parameter, assume \( k = 0 \).

The weighting factor applied to both predicted and observed is computed as shown on the slide. The \( k \) value – overdispersion parameter – is published in the HSM with each SPF. It varies based on the quality of prediction for the individual SPFs.

Project Level EB Method

- Apply method
- Repeat for next site
- Sum crash estimates

\[ N_{(total)} = \sum N_{(all\ rs)} + \sum N_{(all\ int)} \]

- Evaluate alternate designs
- Compare results

Apply the project level EB Method if observed crash data are available and the crash data are not able to be accurately assigned to specific sites. This method will still enhance your predicted crash estimate.

Repeat the basic steps plus the site-specific EB analysis (when applicable) for the next study site. Continue evaluating additional sites and time periods until all sites and time periods have been completed.

The total estimated number of crashes for the facility network during the study period is calculated using the equation:

\[ N_{(total)} = \sum N_{(all\ rs)} + \sum N_{(all\ int)} \]

Where:

- \( N_{(total)} = \) total expected number of crashes within the roadway limits of the study for all years in the period of interest. Or, the sum of the expected average crash frequency for each year for each site within the defined roadway limits within the study period;
- \( N_{(rs)} = \) expected average crash frequency for a roadway segment using the predictive method for one year;
- \( N_{(int)} = \) expected average crash frequency for an intersection using the predictive method for one year.

Repeat the process if an alternate design is to be evaluated. This generally involves modifying CMFs for the various design configurations. Since the predictive method is used to estimate the expected average crash
Some methods for estimating effectiveness are more reliable than others.

The following four methods are presented in order of predictive reliability (highest to lowest):

- Apply the Vol. 2 (Part C) predictive method to estimate the expected average crash frequency of both the existing and proposed conditions.

- Apply the Vol. 2 (Part C) predictive method to estimate the expected average crash frequency of the existing condition and apply an appropriate project CMF from Vol. 3 (Part D) to estimate the safety performance of the proposed condition.

- Use a SPF to estimate the expected crash frequency of the existing condition. Apply an appropriate CMF from Vol. 3 (Part D) to estimate the expected average crash frequency of the proposed condition.

- Use observed crash frequency to estimate the expected average crash frequency of the existing condition and apply an appropriate project CMF from Vol. 3 (Part D) to the estimated expected average crash frequency of the existing condition to obtain the estimated expected average crash frequency for the proposed condition.

**Predictive methods may have certain limitations.**

- The predictive method uses models to incorporate the effects of many, but not all, geometric designs and traffic control features.
- Non-geometric factors can only be considered in a general sense.
- The predictive method treats the effects of individual geometric design and traffic control features as independent of one another and ignores potential interactions between them.

Part C Reference Guide – provides information on the application of the Part C methodologies.

Facilities for which predictive modeling can be performed.

**Segments:**

Undivided rural two-lane, two-way roadway segments (2U)
**Intersections:**

Three-leg intersection with STOP control (3ST)
Four-leg intersection with STOP control (4ST)
Four-leg signalized intersection (4SG)

**Segments Multilane:**

Roadway Segments Rural four-lane undivided segments (4U)
Rural four-lane divided segments (4D)

**Intersections Multilane:**

Unsignalized three-leg (Stop control on minor-road approaches) (3ST)
Unsignalized four-leg (Stop control on minor-road approaches) (4ST)
Signalized four-leg (4SG)

**Segments Urban Suburban:**

Roadway Segments Two-lane undivided arterials (2U)
Three-lane arterials including a center two-way left-turn lane (TWLTL) (3T)
Four-lane undivided arterials (4U)
Four-lane divided arterials (i.e., including a raised or depressed median) (4D)
Five-lane arterials including a center TWLTL (5T)

**Intersections Urban Suburban:**

Intersections Unsignalized three-leg intersection (stop control on minor-road approaches) (3ST)
Signalized three-leg intersections (3SG)
Unsignalized four-leg intersection (stop control on minor-road approaches) (4ST)
Signalized four-leg intersection (4SG)

The tables on the following pages present key information for Chapters 10, 11, and 12 and references HSM equations and page numbers.

Tables extracted from HSM Part C Quick reference Guide

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A Product of the TRB Highway Safety Performance Committee (ANB25)
http://www.safetyperformance.org
<table>
<thead>
<tr>
<th>Basic Conditions</th>
<th>Crash Modification Factors</th>
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<tr>
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</table>

**Notes**

- Crash Modification Factors
- Basic Conditions

**Chapter 10 - Two-Way Two-Lane Rural Highway Segments**
<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>11:32</td>
<td>CMP-4</td>
<td>Aluminum speed enforcement</td>
</tr>
<tr>
<td>11:39</td>
<td>CMP-4</td>
<td>Lighting (p=1.11-76)</td>
</tr>
</tbody>
</table>
| 11:55 | CMP-4 | Shoulder Width (p=1.11-10)
| 11:57 | CMP-4 | Shoulder Width (p=1.11-10) |
| 11:58 | CMP-4 | Shoulder Width (p=1.11-10) |
| 11:59 | CMP-4 | Shoulder Width (p=1.11-10) |

**CHAPTER 11 - Rural Multilane Highway Segments**

**Highway Segment**

- **Table 11.5-2** (p=1.11-16)
- **Table 11.5-2** (p=1.11-16)
- **Table 11.5-2** (p=1.11-16)
- **Table 11.5-2** (p=1.11-16)
- **Table 11.5-2** (p=1.11-16)
- **Table 11.5-2** (p=1.11-16)
- **Table 11.5-2** (p=1.11-16)
- **Table 11.5-2** (p=1.11-16)

**Traffic Flow**

- **Table 11.5-2** (p=1.11-16)
- **Table 11.5-2** (p=1.11-16)
- **Table 11.5-2** (p=1.11-16)
- **Table 11.5-2** (p=1.11-16)
- **Table 11.5-2** (p=1.11-16)
- **Table 11.5-2** (p=1.11-16)
- **Table 11.5-2** (p=1.11-16)
- **Table 11.5-2** (p=1.11-16)
## Crash Notes

<table>
<thead>
<tr>
<th>Special Notes</th>
<th>Crash Modulation Notes</th>
<th>STEPS</th>
<th>Crash Collision</th>
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</table>

### CHAPTER 12 - Urban and Suburban Arterial Segments

- Vehicle PTV:
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  - [Page 12-28]
  - [Page 12-29]
  - [Page 12-30]

- Pedestrian PTV:
  - [Page 12-31]
  - [Page 12-32]

### General Notes

- [Page 12-33]
- [Page 12-34]
- [Page 12-35]

### Table

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Action</th>
<th>Next Step</th>
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<tr>
<td>1</td>
<td>Collect data</td>
<td>Review</td>
<td>2</td>
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<tr>
<td>2</td>
<td>Analyze data</td>
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</table>

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- [Page 12-37]
- [Page 12-38]

### Diagram

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- [Page 12-42]
- [Page 12-43]
- [Page 12-44]
Module 5 – Calibration and Predictive Methods Specialized Procedures

Module five addresses specialized procedures associated with Vol. 2 (Part C) Predictive Methods.

At the conclusion of this module, participants will be able to:

- Describe how to calibrate predictive methods;
- Describe the guidance of the HSM on the creation of jurisdiction-specific SPFs;
- Recognize how to replace default crash statistics with local values; and
- Identify suitable EB Method applications.

Key Points

- Calibration of Predictive Models are covered in Vol. 2 (part C)
- To provide accurate results you must adjust predictive models to local conditions such as:
  - Climate
  - Driver populations
  - Animal populations
  - Crash reporting thresholds
  - Crash reporting system procedures

The purpose of the calibration factors is to adjust for differences in crash frequency for the initial regions of model development to those for local conditions.

- Calibration factor \( C = \frac{\text{Total Observed Crashes}}{\text{Total Predicted Crashes}} \)

To allow us to take full advantage of the methods in Vol. 2 (Part C), we need to develop calibration factors for each of the SPFs in Vol. 2 (Part C).

The calibration factor, \( C \), represents the ratio of the total observed crash frequencies for a selected set of sites to the total expected average crash frequency for the sites (using the Vol. 2 (Part C) SPFs) over the same time period.

If \( C=1 \), the observed and predicted crash frequencies are equal;
If \( C > 1 \), there are more observed crashes than predicted crashes; and
If \( C < 1 \), there are fewer observed crashes than predicted crashes.

Calibration factors should be replaced every 2 to 3 years; although some jurisdictions may calibrate the SPFs annually. Unless the sites change, agencies can use the same dataset but with newer crash data for calibration.

- Calibration procedure – see Appendix A Part C
- Local derived values will improve the reliability of Vol. 2 (Part C) predictive models
  - SPFs
  - Crash distributions
Replace Default Crash Distributions with Local Values

• All facilities:
  – Crash severity and collision type
  – Ratio of nighttime to total crashes
  – Ratio of driveway-related crashes to total crashes (segments)
• Urban and suburban facilities:
  – Pedestrian adjustment factor
  – Bicycle adjustment factor

- Default crash distributions are provided in the HSM, and these can be replaced by locally-derived values.
- Note: It is optional to replace the default crash distributions with local values.
- The SPF coefficients in Chapters 10 through 12 should not be changed unless a jurisdiction develops SPFs based on local data.

Predictive Methods Specialized Procedures

Does EB Method Apply?

• “Do nothing” sites
• Basic number through lanes intact but with minor cross section changes
• Minor changes in horizontal alignment
• Rural 2-lane highway with passing lanes or short 4-lane sections added
• Any combination of the above

- We can use the EB method for sites and projects that remain essentially the same for the future analysis period. This way, the crash history of the site is applicable to the observed condition (i.e. the observed is applicable to future conditions).
- The use of the EB method is not appropriate at locations where substantial changes took place during the study period. For example, major changes in alignment or modification of intersection legs or traffic control would be considered as substantial changes. For these reconstructed conditions, the historic crash information is no longer applicable to the facility type and the analysis cannot benefit from the EB Method.
Apply Site-Specific EB Method

\[ N_{\text{expected}} = w \times N_{\text{predicted}} + (1 - w) \times N_{\text{observed}} \]

Weighted Adjustment:

\[ w = \frac{1}{1 + k \times \sum_{\text{all study years}} N_{\text{predicted}}} \]

For site-specific EB Method applications, apply the following equations shown where:

- \( N_{\text{expected}} \) = estimate of expected average crash frequency for the study period
- \( N_{\text{predicted}} \) = predictive model estimate of average crash frequency predicted for the study period under given conditions (from the Vol. 2 (Part C) predictive methods)
- \( N_{\text{observed}} \) = observed crash frequency at the site over the study period (from actual site crash data)
- \( w \) = weighted adjustment to be placed on the predictive model estimate
- \( k \) = over-dispersion parameter of the associated SPF used to estimate \( N_{\text{predicted}} \) (from the Vol. 2 (Part C) predictive methods or the jurisdiction-specific SPF)

Adjust Estimated Crash Frequency to Future Time Period

\[ N_f = N_p \left( \frac{CMF_{1f}}{CMF_{1p}} \right) \left( \frac{CMF_{2f}}{CMF_{2p}} \right) \ldots \left( \frac{CMF_{nf}}{CMF_{np}} \right) \]

\( f = \) future time period
\( p = \) present time period

Adjust one estimated crash frequency to future time period. This is Equation A-15, page A-23 of Vol. 2.

In the last step of the EB method, we estimate the EB combined expected average crash frequency for a future period (after period) by correcting the value for:

- Differences in the duration of the before and after periods;
- Growth or decline in AADTs between before and after periods; and
- Changes in geometric design or traffic control features from the before to the after period.

For the equation shown, the variables are as follows:

- \( N_f \) = expected average crash frequency during the future time period (after period);
- \( N_p \) = expected average crash frequency for the past time period for which observed crash data were available (before period);
- \( CMF_{nf} \) = value of the nth CMF for the geometric conditions planned for the future design; and
- \( CMF_{np} \) = value of the nth CMF for the geometric conditions for the past (existing) design.
Module 6 – Roadway Safety Management Process Overview

Module six provides a VERY BRIEF overview of the structure of the Vol. 1 (Part B) content for the HSM.

At the conclusion of this module, participants will be able to:
- Recognize the purpose of Vol. 1 (Part B);
- Describe the Vol. 1 (Part B) structure;
- Cite an overview of the six step Roadway Safety Management Process;
- Describe how to use Vol. 1 (Part B); and

Key points

Volume 1 Part B Purpose
- Procedures and information useful in monitoring and reducing crash frequency
- Roadway Safety Management Process

Six steps occur during the Roadway Safety Management Process. The HSM chapters where the steps occur are noted on the slide.

- Chapter 4 – Step 1: Network Screening
- Chapter 5 – Step 2: Diagnosis
- Chapter 6 – Step 3: Countermeasure Selection
- Chapter 7 – Step 4: Economic Appraisal
- Chapter 8 – Step 5: Project Prioritization
- Chapter 9 – Step 6: Safety Effectiveness Evaluation

Network Screening is the process used to identify and rank sites based on the potential for reducing average crash frequency.

The basic steps in network screening include:
- Review the transportation network
- Identify the problem locations, road segments, corridors, etc.
- Rank the sites based on the potential for reducing crash frequency
**Diagnosis** involves analyzing and evaluating data to identify crash patterns.

The data used in diagnosis include:

- Crash data;
- Historic site data;
- Field conditions; and
- Other information.

**Countermeasure Selection** involves identifying contributing crash factors and identifying and selecting countermeasures with the potential for reducing the average crash frequency.

**Economic Appraisal** involves evaluating the benefits and costs of possible countermeasures and identifying cost-effective or economically justified projects.

**Prioritizing Projects** involves evaluating economically justified improvements at specific sites and across multiple sites to identify a set of improvement projects that meet your objectives, such as safety, cost, mobility, or environmental impacts.

**Safety Effectiveness** evaluation requires that we evaluate countermeasure implementation to determine the level of effectiveness in reducing serious crashes.

The HSM methods can be applied in each step of the project development process. *Vol. 1 (Part B)* chapters can be used sequentially as a process, or they can be selected and applied individually to respond to the specific problem or project under investigation.

Using a systematic and quantitative process has many benefits. The benefits of implementing a roadway safety management process include:

- A systematic and repeatable process for identifying opportunities to reduce crashes and identifying potential countermeasures resulting in a prioritized list of cost-effective safety countermeasures;
- A quantitative and systematic process that addresses a broad range of roadway safety conditions and tradeoffs;
- Provides the opportunity to leverage funding; coordinates improvements with other planned infrastructure improvement programs;
- Uses comprehensive methods that consider traffic volume, collision data, traffic operations, roadway geometry, and user expectations; and
- Makes use of the opportunity to use a proactive process to increase the effectiveness of countermeasures intended to reduce crash frequency.

Absolute safety does not exist. Risk is an element in all highway transportation. A universal objective is to reduce the number and severity of crashes within the limits of available resources, science, technology, and legislatively-mandated priorities.

The material in *Vol. 1 (Part B)* is one resource for information and methodologies used in efforts to reduce crashes on existing roadway networks. Applying these methods does not guarantee crashes will decrease across all sites. The methods are a set of tools available for use in conjunction with sound engineering judgment.
Module 7 – Network Screening

This module is an outline of the network screening process and various reference populations, performance measures (strengths and limitations), and screening methods that can be used. Network screening is the process of evaluating a network of facilities for sites likely to respond to safety improvements.

At the conclusion of this module, participants will be able to:

- Recognize network screening process;
- Establish reference populations;
- Select performance measures;
- Select screening method; and
- Screen and evaluate results.

Highlights of this part of the manual are advances in network screening methods and safety evaluation methods. In Chapter 4 (Network Screening), several new network screening performance measures are introduced to shift the safety analysis focus away from traditional crash rates. The major limitation associated with crash rate analysis is the incorrect assumption that a linear relationship exists between traffic volume and the frequency of crashes. As an alternative analysis tool, a focus on expected crash frequency can account for regression to the mean when developing performance measures for network screening. This analysis will provide a more stable list of locations that might respond to safety improvements than lists prepared with traditional methods. This, in turn, will result in a more effective spending of improvement funds.

Network screening is a process for reviewing a transportation network to identify and rank sites from most likely to least likely to realize a reduction in crash frequency with implementation of a safety-based program, countermeasure, or treatment. Those sites identified as most likely to realize a reduction in crash frequency are studied in more detail to identify crash patterns, contributing factors, and select site-appropriate countermeasures. Each of the five steps in the process is described in detail in the HSM.

1 - Establish Focus

Network screening can be conducted and focused on one or both of the following:

- Overall crash reduction – An agency wishes to identify and rank sites where improvements have potential to reduce the number of crashes; and/or
- Policy implementation – An agency is implementing a particular safety-based strategy or policy. To do so, they evaluate the network to identify sites with a particular crash type or severity level (e.g., identify sites with a high number of run-off-the-road crashes to prioritize the replacement of non-standard guardrail statewide).
2 - Identify Reference Population

The second step in the network screening process identifies the roadway network elements to be screened and organizes these elements into reference populations for analysis purposes. A reference population is a grouping of sites with similar characteristics (e.g., 4-leg signalized intersections, two-lane rural highways, etc.)

3 - Select Performance Measures

The third step in network screening is to select one or several performance measures to be used in evaluating the potential to reduce the number of crashes or crash severity. Just as intersection traffic operations can be measured using performance measures such as vehicle delay, queue length, volume-to-capacity ratio, intersection safety can be quantitatively measured in terms of expected crash frequency, expected crash severity, critical crash rate, etc.

The HSM includes 13 performance measures, which are summarized in Figure 4-4, p. 4-7, Vol. 1 of the HSM.

<table>
<thead>
<tr>
<th>Selecting Performance Measures</th>
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<tbody>
<tr>
<td>Key Criteria</td>
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<tr>
<td>• Data availability (see Table 4-1)</td>
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<tr>
<td>- Crashes</td>
</tr>
<tr>
<td>- Traffic volumes</td>
</tr>
<tr>
<td>- Safety performance functions</td>
</tr>
<tr>
<td>- Severity weighting factors</td>
</tr>
<tr>
<td>• Regression-to-the-mean bias</td>
</tr>
<tr>
<td>• Performance threshold</td>
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</tbody>
</table>

The key considerations in selecting performance measures are: data availability, regression-to-the-mean, and how the performance threshold is established. Table 4-1 on page 4-8 of Vol. 1 summarizes data needs for performance measures.

Regression-to-the-mean was discussed in Module 2. RTM bias occurs when sites are selected for treatment based on short-term trends in observed crash frequency. Given the relative rarity of crashes, and in particular crashes with high severity, one and even two year periods will not be long enough to know with certainty that a trend or anomaly has emerged. For example, a site is selected for treatment based on a high observed crash frequency during a very short period of time (2 years). However, the site’s long-term crash frequency may be substantially lower and as a result the proposed treatment may have been more cost effective at an alternate site.

Performance threshold values provide a reference point for comparison of performance measure values from specific sites. Sites can be grouped based on whether the estimated performance measure score for each site was higher or lower than the threshold value. Those sites with a performance value higher than the threshold site can be studied in greater detail to determine if a reduction in crash frequency or severity is possible.

4 - Select Screening Method

The fourth step in the network screening process is to select a network screening method. The HSM includes three types of screening methods:

- Sliding Window
- Peak Searching
- Simple Ranking
In the sliding window method, a window of specified length is moved in increments of a specified length along a roadway segment from beginning to end. The performance measure used to screen the segment is applied to each incremental position of the window, and the results are recorded. Based on the results of all the window positions, the window position with the highest value according to the performance measure is used to represent the performance measure for the entire roadway segment.

The peak searching method subdivides each roadway segment into windows of similar length, potentially enlarging the length incrementally until the length of the window equals the length of the entire roadway segment. For each window, the chosen performance measure is calculated. Based upon the statistical precision of the performance measure, the window with the maximum value of the performance measure within a roadway segment is used to rank that site relative to the other sites being screened.

With simple ranking, the performance measures are calculated for all of the sites under consideration, and the results are ordered from high to low.

5 - Screen/ Evaluate results

The performance measure(s) and the screening method(s) are applied to the segments, nodes, and/or facilities according to the methods outlined in Steps 3 and 4. Conceptually, for each segment or node, the selected performance measure is calculated and recorded with the sites being rank ordered in a list. Those sites higher on the list are most likely to benefit from the countermeasure.

As we perform our calculations and work with the various performance measures, it is important to keep in mind that Appendix A to Chapter 4 is a valuable resource as it relates to crash cost.

Module 8 – Human Factors

Network screening helps us understand where crashes occur or are likely to occur. Understanding human factors helps us identify why those crashes are occurring, i.e. what human factors are contributing to the crashes.

The HSM includes a chapter (Ch. 2) that specifically introduces the role of human factors in road safety, discusses the driving task model, introduces driver characteristics and limitations, highlights the role of positive guidance, and reviews impacts of road design on the driver. Module eight begins the process of diagnosis, e.g., identifying contributing crash factors and focuses on human factors.

At the conclusion of this module, participants will be able to:

- Describe human factors and its role in road safety;
- Recognize the impact of road design on the driver; and
- Describe how human factors are integrated within the HSM.

Key Points

Human factors help identify how the user interacts with the road environment. Many comprehensive publications exist on this topic; however, the HSM includes a chapter (Ch. 2) that specifically introduces the role of human factors in road safety, discusses the driving task model, introduces driver characteristics and limitations, highlights the role of positive guidance, and reviews impacts of road design on the driver.
We are all human and the drivers that we design and plan for are also human. Humans have capabilities and limitations. In other words, how does road design impact drivers and how we can adjust the way we do business to allow for the limitations and capabilities of human beings. We will also discuss how human factors are integrated within the HSM.

When we consider human factors, we reduce the “probability and consequences of human errors within the highway system …as a consequence, we reduce the conflicts that may result in crashes, leading to injuries and deaths. These conflicts do not always result in crashes because the circumstances are often forgiving of these errors.

Contributing factors due to human error may occur because road users make errors in judgment; they may be distracted from the driving task; they may be suffering from too much information; and because their expectations are violated. In some cases, the “errors” are purposeful, i.e. drivers run red lights, follow too closely, speed, drive impaired, and commit other traffic violations.

- Drivers can make judgment errors when judging closing speed, gaps, negotiating a curve, and when they select speeds to approach intersections.
- Distractions in the vehicle and from the road environment, inattentiveness, and driver weariness can lead to errors. Inattention can lead to inadvertent movements out of a lane, failure to detect a stop sign, a traffic signal, or a vehicle or pedestrian on a conflicting path in an intersection.
- The information necessary to carry out a combination of tasks can also overload a driver and lead to errors.
- Drivers rely on prior knowledge in an attempt to reduce their information load. They are therefore more likely to make mistakes when their expectations are not met.
- In the video clip we saw at the beginning of the presentation, our expectation was violated; we simply did not expect a girl with an umbrella to walk past the basketball players.
- Besides unintentional errors, drivers also deliberately violate traffic control devices and laws.
Safe driving consists of three tasks: **control, guidance, and navigation.**

- The first step is to keep the vehicle in control, e.g. proper speed, lane position, etc.
- The second step involves appropriate guidance, e.g., interacting safely with other vehicles when following passing, merging, etc.
- Finally, safe drivers safely navigate the path from the origin to destination by using guide signs and landmarks.

Roadway design and transportation planning require evaluation of the consequences of driver failure for each of these tasks. Control is most important because failure has the greatest consequence, but as we move to the less important tasks, the complexity also increases, which makes it necessary to evaluate how we provide information.

The ability of the road user to pay attention and process information is limited. The driver is required to switch attention between the different elements in the driving task. Even though we may think that the drivers can distribute their attention well, we know that we can only attend well to one source at a time.

One potential solution to driver overload is to reduce the driver workload.

We provide:
- Consistent information and provide it consistently.
- Information sequentially, one message at a time (for each of the driving tasks).
- Clues to help drivers prioritize information correctly so they can shed extraneous information.
It is important to manage driver expectancy in both the short and long term. If roadways are designed with consistent features, the driver has less information to manage.

Examples of types of short term expectancy management include:

- **Curves** -- If curves are gentle the upcoming curves should also be gentle.
- **Speed** -- If the posted speed has been high for a while, the upcoming roadway will be designed for the same speed.
- **Timing** -- If a number of signals are coordinated, the rest on the corridor should be too. Coordination refers to the “green-green-green” drivers will receive when travelling at the posted speed through a well-timed corridor.

Some long term expectancies that can be effectively managed include the design of ramp exits, stop controls, and left turn lanes.

Examples of types of long term expectancy management include:

- **Ramp** – Ramps should be consistently constructed on the RIGHT.
- **Stop control** – At major-minor intersections, the minor intersection should be STOP controlled.
- **Left turn lane** – Left turn, stop controlled lanes protect drivers from angle crashes in intersections.
- **Through lanes** -- Continuous through lanes on freeways/arterials should not end at an intersection/intersection junction.
Several vision elements affect traveler safety.

The elements are:

**Visual acuity** refers to how well we see. Poor vision can sometimes be corrected by glasses or contacts but not always. We consider 20/20 vision as normal. A person with 20/40 vision would need letters twice as high to read the letters at the same distance as the individual with normal vision. When looking at font sizes, this means that a person with 20/20 vision can just see a one inch letter at 57 ft.

**Contrast sensitivity** refers to the ability to distinguish between low contrast features which is sometimes of greater importance than visual acuity. It allows you to distinguish a curb, debris on the road, or a pedestrian at dusk. Research shows that even alert drivers can come as close as 30-ft before detecting a pedestrian in dark clothing.

**Peripheral vision** - Even though our visual field is large, we can only see accurately within a small area: a cone of about two to four degrees from the focal point. Everything outside of this accurate vision area, we call the peripheral vision. We can still detect objects within this area – our eyes will then shift to the object so we can see the object clearly. The closer objects are to the focal point, the greater the possibility of us detecting them. This is why the MUTCD requires traffic signals be placed at specific locations at intersections, i.e., to increase the likelihood of detection.

**Depth perception** - Another aspect that affects how a user views and navigates through the roadway environment is movement in depth. Even though we often pride ourselves on our ability to judge speed, we are in fact quite poor at it. How do we perceive movement? We process the relative change in size of an object (measured by the rate of change of the visual angle occupied by the object) to estimate the vehicle travel speed. This all sounds great except for the fact that viewing distance and relative change in object size is not linearly related. Over long distances, we are poor at estimating speed or, in fact, the relative distance between us and, for example, an oncoming vehicle. This is because there is very little change in the relative size of the object.

**Visual search** - Studies have shown open road drivers fixated about 90% of the time in a 4-degree region vertically and horizontally from a point directly ahead of the driver. Moreover, within this region, slightly more than 50% of the fixations were on the right side of the road where road signs are placed.
PRT refers to the time the road user uses to detect a target, process the information, decide on an appropriate response and initiate a response. Although we commonly use values between 1.5 and 2.5 seconds, this value is not fixed within a person or for different driving situations. It depends greatly on aspects we already covered in this Session: information processing, alertness, expectations, and vision.

PRT starts when the user detects an object or obstacle. The user does not know at this point whether the object is relevant to the driving task or not. Detection can take a fraction of a second or a couple of seconds, depending on the conspicuity of the object. In other words, if the object is within the line of sight and high contrast, then detection will be quick compared to an object that has low contrast with the surrounding background.

We often fail to detect objects when they:

- Are more than a few degrees from the line of sight of the user;
- Have low contrast with the background;
- Are small in size;
- Are seen in the presence of glare;
- Are stationary, or
- Are unexpected (the driver is not actively searching for it).

Positive guidance principles take human capabilities and limitations into account when designing and managing operations. Positive guidance is based on the principle that the road environment is designed and operated to increase the likelihood of correct and timely responses from the user. By designing the environment in such a way that it conforms to the long-term expectancies of a driver (such as, exits from a freeway are always to the RIGHT), reduces the chance of driver error and subsequently crashes.
Positive guidance methods are designed to ensure the greatest likelihood of appropriate response to the roadway environment.

The positive guidance process requires we consider the following:

- **Primacy.** Which information is the most important? Provide that information first. If information is not essential – consider not providing it (this reduces the chance for driver overload)
- **Spreading.** Rather than give a large amount of information on one sign, consider breaking it up into small but manageable chunks of information to reduce information load.
- **Coding.** Use uniform traffic control devices. Signs use shape and color to present specific information that is easily and quickly processed.
- **Redundancy.** The STOP sign is a classic example of redundancy. The shape and color of the sign is unique to a STOP sign. Providing the text as well creates redundancy. In another case, one would indicate a no-passing zone with pavement markings and signage.
Module 9 - Diagnosis and Countermeasure Selection

Module nine introduces methods for diagnosing the problems or contributing crash factors and selecting appropriate countermeasure or solutions.

At the conclusion of this module, participants will be able to:

- Describe the diagnosis process;
- Recognize the importance of crash and supporting data;
- Recognize how field conditions influence diagnosis;
- Identify contributing factors; and
- Select potential countermeasures.

Key Points

**Diagnosis Process**

<table>
<thead>
<tr>
<th>STEP 1: Review safety data</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEP 2: Assess supporting documentation</td>
</tr>
<tr>
<td>STEP 3: Assess field conditions</td>
</tr>
</tbody>
</table>

**Desired Outcomes**

- Understand site conditions
- Identify crash patterns
- Gain insight on countermeasure selection

Activities included in the diagnosis step provide an understanding of crash patterns, supporting documentation, and the physical characteristics of the site or sites.

Diagnosis involves three steps:

- Review crash data;
- Assess supporting documentation; and
- Assess field condition.

The expected outcome of diagnosis is an understanding of site conditions and crash pattern identification.

Site Diagnosis begins with safety data review to identify patterns in crash type, severity, roadway or environmental conditions, and other factors. The review may identify patterns related to time of day, direction of travel, weather conditions, driver behavior, etc.

Safety data review consists of:

- Descriptive statistics of crash conditions (e.g. counts of crashes by type, severity, and/or roadway and environmental conditions);
- Contributing factors sequence of events; and
- Crash locations (i.e. collision diagrams, condition diagrams, and crash mapping).

Assess Supporting Documentation involves several other types of supporting documentation that may be available.
Examples of assessing supporting documentation also include:

- Land use mapping;
- Historic patterns of adverse weather;
- Known land use plans;
- Public comment records;
- Roadway improvement plans; and
- Anecdotal information.

Conduct a field review of the site. Prepare site diagrams, take photos, and observe conditions. Read the road with regard to “cues” of safety performance such as: skid marks, scarred trees, and debris.

**Example of Verified Field Review**

- Signalized intersection
- Left turn lanes in all quadrants
  - Permissive/protected phasing
- Pedestrian crossings and signal control
- Clearance interval not adequate for prevailing speeds

**Summary**

**Safety Diagnosis Essentials**

- Data - sufficient quantity and quality
- Field observations
- Diagnostic tools
- Knowledge
  - Safety fundamentals
  - Human factors
  - Traffic and highway engineering
- Good judgment

**Countermeasures**

(Common 6)

- Identify contributing factors
- Select potential countermeasures or treatments
- Apply countermeasures
HSM Chapter 6 is about methods for identifying and selecting countermeasures.

Topics in Chapter 6 include:

- Identifying contributing factors;
- Selecting potential countermeasures; and
- Applying countermeasure.

Multiple contributing factors may be identified for each crash.

Identify a broad range of possible contributing factors to minimize the possibility a major factor will be overlooked.

Contributing factors for a crash can be classified into three categories:

- Roadway
- Human
- Vehicle

The HSM has five categories outlined for possible contributing crash factors:

- Crashes on roadway segments
- Crashes at signalized intersections
- Crashes at unsignalized intersections
- Crashes at highway-rail grade crossings
- Crashes involving bicyclists and pedestrians

Based on evaluation of the contributing factors, a checklist of contributing factors associated with a variety of crash types is outlined in the HSM that will be utilized for consideration in the selection of the countermeasures.

It is important to note that the checklist is not and can never be a comprehensive list since each site and crash history is unique and identification of crash contributing factors is most effectively completed by careful consideration of all the facts gathered during the diagnosis process.

Many specific types of highway crashes or contributing factors are discussed in detail in NCHRP Report 500: Guidance for implementation of the AASHTO Strategic Highway Safety Plan. The intent of the checklists are to verify that key contributing factors are not forgotten or overlooked.
To select potential countermeasures for a site:

- Identify potential crash contributing factors;
- Relate contributing factors to treatable actions;
- Identify and list countermeasures which may address the contributing factors;
- Conduct a cost-benefit analysis, if possible; and
- Recommend preferred treatments.

Engineering judgment and local knowledge are necessary to compare contributing factors to potential countermeasures. Before selecting a countermeasure(s), consideration must be given to why the contributing factor might be occurring, what could address the factor(s), and what is physically, financially, and politically feasible in the jurisdiction.

Once the potential countermeasure(s) are identified, it is important to review the crash modification factors (CMF) for specific treatment(s) under consideration. A CMF represents the estimated change in crash frequency and severity with implementation of a specific treatment. *Part D* of the HSM is a resource for countermeasures (treatments) with quantitative CMF information and can be used in the countermeasure selection process.

When a specific contributing factor and/or associated treatment may not be easily identifiable, even when there is a prominent crash pattern or concern, conditions upstream or downstream of the site should also be evaluated to determine if there is any influence at the site under consideration. When a countermeasure or combination of countermeasures is selected for a specific location, perform an economic appraisal that includes a cost-benefit analysis for all sites under consideration. The economic appraisal helps evaluate the effectiveness of the countermeasures.

**Module 10 – Economic Appraisal and Prioritization**

After the economic appraisal is conducted, the results are used to rank and prioritize our projects. In this module we discuss the methods for conducting an economic evaluation.

At the conclusion of the module, participants will be able to:

- Describe an overview of project benefits and costs;
- Define economic evaluation methods for individual sites;
- Recognize non-monetary considerations;
- Identify three prioritization methods; and
- Describe applications of economic appraisal and prioritization methods.
Key Points

Once the potential countermeasures have been selected, the next step is to conduct an economic appraisal to identify the best investments. The purpose of an economic appraisal is to provide highway agencies with a means for comparing benefits of crash reduction to project costs. After the economic appraisal is conducted, the results are used to rank and prioritize our projects.

Site economic appraisals are conducted once the highway network is screened, the selected sites are diagnosed, and potential countermeasures for reducing crash frequency or crash severity have been selected. Once economically justified countermeasures have been identified using an economic appraisal, the next step in the roadway safety management process is to prioritize countermeasure implementation projects.

In terms of the HSM, “prioritization” refers to a review of possible projects or project alternatives for construction and developing an ordered list of recommended projects based on the results of ranking and optimization processes. “Ranking” refers to an ordered list of projects or project alternatives based on specific factors or project benefits and costs. “Optimization” is used to describe the process by which a set of projects or project alternatives are selected by maximizing benefits according to budget and other constraints.

Economic evaluation methods for individual sites

The two main objectives of the economic evaluation of countermeasures implementation are:

- Determine whether a project is economically justified
- Determine which countermeasures or projects would provide the greatest value for the required investment

In an economic appraisal, project costs are addressed in monetary terms.

Two types of economic appraisal – benefit-cost analysis and cost-effectiveness analysis - address project benefits in different ways. Both types begin quantifying the benefits of a proposed project, expressed as the estimated change in crash frequency or severity, as a result of implementing a countermeasure.

In **benefit-cost analysis**, the expected change in average crash frequency or severity is converted to monetary values, summed, and compared to the cost of implementing the countermeasure. One way to interpret the benefit-cost analysis approach is by evaluating a ratio of benefit to cost. If the value of the ratio is greater than 1.0 then the candidate countermeasure is a good investment. If, for example, you calculated a benefit-to-cost ratio of 3.0 this would mean that you can expect a $3.00 return for every $1.00 spent.

In **cost-effectiveness analysis**, the change in crash frequency is compared directly to the cost of implementing the countermeasure. This approach develops a ratio of the countermeasure cost to the number
of reduced crashes. One critical difference about the cost-effectiveness analysis is that is does not consider crash severity in the analysis.

Crash Cost Estimates by Crash Severity

The Federal Highway Administration has completed research that establishes a basis for quantifying in monetary terms the costs to society of fatalities and injuries from highway crashes. Annual benefits of a safety improvement can be calculated by multiplying the predicted reduction in a given crash severity by the applicable societal cost. Some agencies elect to use local values they have developed for societal costs of crashes rather than the federal societal costs.

In Michigan, the Michigan Department of Transportation (MDOT) uses crash costs by severity from the National Safety Council (NSC) for internal and local systems application. Current NSC values can be downloaded as part of the Michigan Time-of-Return spreadsheet. For a copy of the spreadsheet, please contact James D’Lamater of the MDOT Design Division’s Local Agency Programs Unit at (517) 335-2224.

Counter Measure Information

To perform an economic appraisal on each of the countermeasures considered we need the costs of each countermeasure, the discount rate (to transpose future costs and benefits to the present), expected traffic growth (or decline), and the service life for each of the countermeasures.

On occasion one may find that the countermeasure service life differs among countermeasures. In that case we may choose a particular analysis period and then transform the service life to fit to the analysis period.

Calculate Benefits Present Value

Based on Annual Benefit

Countermeasures 30 Year Service Life

Convert Non-Uniform Annual Benefit to Present Value:

\[(P/F, i, y) = (1+i)^{-y}\]  

(Equation 7-2)

where \(i\) is the discount rate and \(y\) is the year in the service life of the countermeasure

The next step in the economic appraisal process is to use the discount rate, \(i\), to convert the annual benefits and costs to a present value. A dollar in the present time is worth more than at some future point in time. By converting all the costs and benefits to present values, we are comparing apples with apples rather than apples with oranges.
In benefit-cost analysis we can calculate the net present value or use the benefit-cost ratio. These measures consider the same elements (benefits associated with crash and/or severity reduction and costs associated with the countermeasure) but express the number differently. Most agencies use the BCR method.

Two common methods are used to evaluate the economic effectiveness and feasibility of roadway projects. These are the net present-value (NPV) and benefit-cost ratio (BCR).

- **Net Present Value (NPV)**
  \[ NPV = \text{Present Value of Benefits} - \text{Present Value of Project Costs} \]

- **Benefit-Cost Ratio (BCR)**
  \[ BCR = \frac{\text{Present Value of Benefits}}{\text{Present Value of Project Costs}} \]

The ratio of the present-value of benefits to the present value of implementation costs is referred to as the *benefit-cost ratio*. Projects with \( BCR > 0 \) are economically justified. Countermeasures that produce the highest BCR for a specific site are the most desirable. However, an incremental benefit-cost analysis is needed to use the BCR as a tool for comparing project alternatives.

**Additional Considerations**

**Influence Decisions**

- Non-monetary*
  - Public perceptions
  - Air Pollution
  - Energy Consumption
- Other monetary
  - Road user costs (delay, operating costs)
  - Maintenance and operations
  - Costs to achieve environmental standards
  - Costs to achieve ecological protection

*Not every benefit or cost can be translated to monetary terms
HSM Effectiveness Measures to Consider

- # total crashes reduced
- # fatal and incapacitating injury crashes reduced
- # fatal and injury crashes reduced
- Cost-effectiveness index
- Project costs

Ranking based on general effectiveness measures is the simplest method for establishing project priorities.

HSM Economic Prioritization Methods

- Total costs (present value of benefits must be equal)
- Net present value (present value of costs must be equal)
  - Benefit-cost ratio (for independent alternatives)
  - Incremental benefit-cost analysis (mutually exclusive alternatives)
- Optimization methods
- Monetary value of project benefits

Economic ranking is based on a very simple premise that you want to receive the greatest benefit (usually presented in dollars saved) for each dollar of public funds that have been invested.

In many cases safety objectives must be balanced with other facility objectives. One way of addressing this is to perform a multi-objective resource allocation where evaluation for each alternative considers the various key criteria with assigned weights (based on priority of the specific criteria) to develop a score for each alternative. If all criteria are considered equal, identical weight values can be used. The total score for an alternative is then compared to the scores for other alternatives to help with the alternative ranking and selection criteria.

To identify weights for use in the multi-objective resource allocation, the stakeholders can collectively review priorities and then develop consistent weight values for alternative assessment. This process should be documented since ultimately it will influence the decision about the expenditures of funds.

Module 11 – Safety Effectiveness Evaluation

The final step of the roadway safety management process is safety effectiveness evaluation. This step in the process occurs after selected projects have been implemented. It is critical to verify that the projects have had the intended impact on safety.
At the conclusion of this module, participants will be able to:

- Describe evaluation methods;
- Recognize the importance of safety evaluations;
- Describe evaluation study designs;
- Identify benefits and limitations of evaluation study designs;
- Identify appropriate methods to use based on available data; and
- Describe an example safety evaluation application.

**Key Points**

Safety effectiveness evaluation measures how well a treatment, project, or group of projects reduced crash severity or frequency.

Safety evaluations are important because they:

- Prove the effectiveness of our investments;
- Demonstrate the value of our program to decision-makers (be accountable);
- Add to the scientific knowledge base; and
- Improve our decisions and optimize future investments in safety.

A variety of different study designs can be used to evaluate the safety effectiveness of a treatment or project.

Three major considerations in selecting the study design for the safety effectiveness evaluation are:

- Nature of treatment;
- Type of sites at which treatment has been implemented; and
- The time periods for which data are available for those sites (or will be in the future).

The purpose of the effectiveness evaluation process is to evaluate the change in crashes that was brought about by the project. It provides a quantitative estimate of the effect of a treatment, project, or a group of projects.

It is necessary to perform evaluations because they support future decision-making and policy development. We can use the evaluation process to determine the percentage change in crash frequency, the shift in proportions of crashes by type or severity, the CMF for a treatment, or to compare benefits achieved as a function of the cost of a project or treatment.
The HSM covers three different effectiveness evaluation types:

- Observational before-after studies
- Observational cross-sectional studies
- Experimental before/after studies

**Observational** studies refer to evaluations of changes implemented to improve the transportation system. In other words, we are not implementing treatments for the purpose of the evaluation.

In contrast, in **experimental** studies we select sites for improvement and similar sites for control sites (no improvement) through a random selection process. With the experimental study, we’re therefore able to directly attribute differences between the control and treatment sites to the treatment. Observational studies are much more common among agencies, because agencies function with limited budgets and typically need to prioritize projects based on the benefits returned. In this sense the random selection process will not optimize investment selection.

There are several different types of observational before-after studies. These include:

- The naïve observational before-after study;
- The observational before-after study with SPFs (EB method); and
- The observational before-after study with comparison-groups.

The naïve observational before-after study does not use an SPF or a comparison group of sites that did not undergo the treatment. This method is prone to regression-to-the mean bias because we usually pick treatment sites because of unusually high crash frequencies. We also cannot compensate for the general time trends in crash data (because of changes in volume, weather, driver behavior, etc.).

Observational before-after studies can also incorporate SPFs using the Empirical Bayes Method. With this method, the safety performance function is used to estimate the crash frequency at the treatment sites for the “after” period if treatment did not take place.

An observational before-after study with comparison-groups method allows us to consider changes that may have occurred at the treatment sites had we not applied the treatment. We assume that the factors affecting the changes we observe at the comparison sites are equally influencing crash frequencies at the treatment sites. The selection of the comparison sites is critical. First we need to make sure the volumes, geometrics and other characteristics are exactly the same as the site without treatment. Then we need to ensure that the rate of change in crashes at the treatment sites and comparison group sites should be similar in the before period. We then use the SPF to make adjustments for the nonlinear changes in crashes because of changes in volumes between the before and after periods.
In the first step we show that the assumption with naïve before-after studies is what happened in the past will repeat itself in the future, i.e. the number of crashes that occurred before the treatment will be equal to the number of crashes that would have occurred had we not implemented the treatment.

In the second step we question whether this assumption is realistic. Keep in mind:

- RTM i.e., the number of crashes may automatically reduce the year(s) after the treatment because we may have selected the site for treatment because of upward trends
- Site conditions such as volumes may have changed.

It is therefore necessary for us to consider a methodology that allows better estimates of what would have happened without the treatment or a method that allows us to account for RTM (so we are not fooled by concluding a too high or too low benefit resulting from the measure) and also changes in traffic volumes and other site conditions.

In the EB before-after methodology we calculate the expected average crash frequency without the treatment, accounting for changes in volumes and other site related conditions, in the after period.

We use this count to compare our measured (observed) crashes in the after period to determine the effectiveness of the countermeasure(s). This allows us to measure the "real" impact rather than making
assumptions that the short term crash history in the before period will repeat itself immediately after the treatment (i.e. RTM).

We can now calculate the real benefit of the measure by measuring the difference between the estimated crash counts (calculated using the predictive method in Vol. 2 (Part C)) and the measured crash counts at our site after the treatment.

The EB method offers several advantages.

We can use existing SPFs because they represent the typical site characteristics where the treatment was applied, and we can account for regression-to-the-mean and changes to crash counts over time because of aspects such as volume, weather, driver behavior, etc.

Experimental
Before/After Study Design
• Comparable sites identified
• Treatment(s) randomly applied
• Not commonly used in highway safety
  – Agencies reluctant to randomly apply treatments

Observational
Cross-Sectional Study
• Treatment installation dates unknown
• Volumes and crash counts in before period unknown
  -OR-
• CMF function rather than single value

The last safety effectiveness evaluation method mentioned in the HSM is the observational cross-sectional study. This method is often referred to as the “with and without” study.

When we do not have installation dates or the crash and volume data before the treatment, or we want to develop a CMF function rather than a single value CMF, it is useful to apply the observational cross-sectional study. We use this when, for example, we want to know how intersections with channelized right-turn lanes compare with intersections without those lanes, and no data are available to allow evaluation of the difference in crash counts before and after installation.
The observational cross-sectional study has two substantial drawbacks:

- The method does not allow us to account for regression-to-the-mean bias because of site selection. For example, we may have selected the intersections for channelization treatment because of unusually high crash counts.

- Second, we cannot really assume cause and effect. We cannot assume the counts for the channelization are lower than those where channelization was not implemented, because of the treatment.

**Module 12 – HSM Summary and Review**

Module 12 is a review of the key learning outcomes presented in the workshop.

There is a growing body of scientific literature relevant to the safety discipline and enable their use of the *Highway Safety Manual (HSM)*. Safety is maturing as a science with more promising scientific methods and tools that can be applied to reduce the deaths and injuries occurring on our roads.

<table>
<thead>
<tr>
<th>Incorporating Safety in Project Development</th>
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<tbody>
<tr>
<td>How you do account for safety now (pre-HSM)?</td>
</tr>
<tr>
<td>• &quot;Our design standards tell us what to do.&quot;</td>
</tr>
<tr>
<td>• &quot;I don’t because I have no basis for doing so.&quot;</td>
</tr>
<tr>
<td>• &quot;I do sometimes but frankly I don’t trust the results.&quot;</td>
</tr>
<tr>
<td>• &quot;I don’t because I don’t believe you can predict safety.&quot;</td>
</tr>
<tr>
<td>• &quot;I don’t because I don’t have to and there are too many other things required of me.&quot;</td>
</tr>
<tr>
<td>• &quot;I don’t because if I do, I will get sued if something goes wrong.&quot;</td>
</tr>
<tr>
<td>• &quot;Statistics are too complicated&quot;</td>
</tr>
</tbody>
</table>

These are the types of arguments made against using quantitative safety analysis as part of project development. Predicting safety is possible; the HSM provides reliable, science-based processes; the “standards = safety” model is clearly not correct; and the methods in the HSM while statistically based can be understood and applied by practitioners with some basic training as given in this workshop. The transfer of knowledge about the HSM to the engineering profession is the subject of the National Cooperative Highway Research Program (NCHRP) Project 17-38 the basis for this workshop.

The HSM is intended to provide the best information and tools to facilitate roadway planning, design, operations, and maintenance decisions based on explicit consideration of their safety consequences. The HSM as envisioned by those who created it will forever alter project development and decision-making by directly incorporating science-based, proven measures of traffic safety in all aspects of highway and traffic engineering design and operations.

Current processes used in project development by other disciplines involve quantitative determination of important performance measures to support decision-making. Prior to the HSM safety proponents or experts had no uniformly accepted method for quantifying safety. The HSM fills this substantial gap. The HSM is science based; the result of research conducted for the highway and surface transportation community through the National Academies.
The Highway Safety Manual allows us to quantify the effect of decisions in planning, design, operations and maintenance on crashes. The document represents a significant development in our ability to analyze crash data, estimate the crash outcomes of treatments, and evaluate treatments. In short, the HSM makes your job easier and supports the goals of reducing injuries and fatalities.

There is valuable information in all four parts of the HSM for all transportation professionals.

Sources

- NCHRP Project 17-38 Training Materials
- HSM Part C Guide

Resources

  - Cost: $325 (Members), $390 (Non-members)
  - Discounts are available for those states taking HSM training
- IHSDM website: [http://www.ihsdm.org](http://www.ihsdm.org)
- SafetyAnalyst website: [http://www.safetyanalyst.org](http://www.safetyanalyst.org)
- Crash Modification Factors Clearinghouse: [http://www.cmfclearinghouse.org](http://www.cmfclearinghouse.org)
- FARS: _ Fatal Analysis Reporting System. Federal system which tries to standardize the reporting for crashes where a fatality is involved. [http://www.nhtsa.gov/FARS](http://www.nhtsa.gov/FARS)