NATIONAL CENTER FOR TRANSPORTATION SYSTEMS PRODUCTIVITY AND MANAGEMENT

DEVELOPMENT OF A WEB-BASED DECISION MAKING TOOL FOR THE HIGHWAY SAFETY MANUAL IMPLEMENTATION

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15. Supplementary Notes

The Highway Safety Manual (HSM) provides analytical tools to conduct quantitative safety analyses. Part B of the HSM discusses all six steps in the roadway safety management process (i.e., network screening, diagnosis, countermeasure selection, economic appraisal, project prioritization, and safety effectiveness evaluation). However, for each step, the manual simply discusses different available methods but provides no specific guidance on which methods an agency should use. For example, the HSM discusses 13 performance measures to conduct network screening in terms of data needs, strengths, and limitations, but no specific method is recommended. As agencies have different needs and limitations, a one-size-fits-all approach toward selecting appropriate methods is not often suitable.

This project aims toward developing a web-based decision making tool to assist agencies in tailoring the HSM to their local conditions and needs by helping them select the most suitable method(s) among those discussed in the manual. The most appropriate methods are suggested based on several factors that influence an agency's selection of the suitable methods, including available data, available statistical expertise, reliability of results, method's robustness, etc. Named the *HSM Decision Making Tool (HSM-DMT)*, the tool uses the decision making process developed as part of this project to suggest the most appropriate method that best meets the agency's needs, data, available statistical expertise, etc. The tool helps select the best available method for the following steps in the safety management process:

- Step 1: Network Screening
  - Performance Measures
  - Screening Methods
- Step 4: Economic Appraisal
- Step 6: Safety Effectiveness Evaluation

For these steps, the tool includes questions that focus on data requirements, data availability, and each method's robustness and reliability. Depending on the responses to the questions, the most suitable method(s) are recommended. The tool provides the capability to export the final recommendation(s) as a PDF file.

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LIST OF ACRONYMS/ABBREVIATIONS

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
B–A	Before–After
BCR	Benefit–Cost Ratio
CAPS	Center for Advanced Public Safety
CARE	Critical Analysis Reporting Environment
CFR	Code of Federal Regulations
CMF	Crash Modification Factor
D.C.	District of Columbia
DOT	Department of Transportation
EB	Empirical Bayes
EPDO	Equivalent Property Damage Only
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FI	Fatal and Injury
GIS	Geographic Information System
HCM	Highway Capacity Manual
HSCA	Highway Safety Corridor Analysis
HSIP	Highway Safety Improvement Program
HSIS	Highway Safety Information System
HSM	Highway Safety Manual
HSM-DMT	Highway Safety Manual Decision Making Tool
ICAPS	Investment Corridor Analysis Planning System
LOSS	Level of Service of Safety
MAP-21	Moving Ahead for Progress in the 21st Century Act
NB	Negative Binomial
NPV	Net Present Value
NPW	Net Present Worth
ODP	Overdispersion Parameter
PDO	Property Damage Only
PSI	Potential for Safety Improvement
RSA	Road Safety Audit
RSI	Relative Severity Index
RTM	Regression-to-the-mean
SAFETEA-LU	Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users
SAMS	Safety Analysis Management System
SHSP	Strategic Highway Safety Plan
SPF	Safety Performance Function
SPIS	Safety Priority Index System
USC	United States Code
usRAP	United States Road Assessment Program

CHAPTER 1
INTRODUCTION

1.1 Background

The Highway Safety Manual (HSM), published by the American Association of State Highway and Transportation Officials (AASHTO) in 2010, marks a radical shift in the approach of practitioners and administrators toward more robust measures of improving highway safety by moving toward statistically rigorous quantitative analyses. The three-volume manual is a comprehensive document that focuses on all steps in the roadway safety management process (i.e., network screening, diagnosis, countermeasure selection, economic appraisal, project prioritization, and safety effectiveness evaluation) (AASHTO, 2010a).

Unlike the Highway Capacity Manual (HCM), which contains a single procedure for determining capacity and level of service of each roadway facility, the HSM discusses the different available methods without providing specific guidance on which methods an agency should use. The two different approaches recognize that standard procedures in the HCM are needed as capacity analysis is performed by different users of different interests, while safety analysis is usually performed by or for only government agencies. As agencies have different needs and limitations, a one-size-fits-all approach toward selecting appropriate methods is not suitable. For example, the HSM discusses 13 network screening methods in terms of data needs, strengths, and limitations. However, no specific method is recommended. This does not help an agency select one method over the other when the methods have similar data needs. For example, if an agency has crash, roadway characteristics, and traffic volume data, it can select any one of the following three methods: *crash rate*, *critical crash rate*, or *excess predicted average crash frequency using method of moments*. In this case, the agency has to consider other factors such as available statistical expertise, method's robustness, etc. to select the most suitable method.

Similarly, without specific guidance, it is difficult for agencies to identify and select a suitable method to evaluate the safety effectiveness of a particular countermeasure. For example, an agency can evaluate the safety impact of installing passing lanes on rural two-lane roads using one of the three methods: *observational before–after (B–A) study*, *experimental before–after study*, or *observational cross-sectional study*. Once a method is selected, the agency has to again select a performance measure to evaluate the safety impact of passing lanes. For performance measures, the agency may select *observed crash frequency*, *target crash types as a proportion of total crashes*, or *predicted crash frequency calculated using empirical Bayes (EB) method*. Likewise, agencies have to make similar decisions at almost all the stages in the roadway safety management process.

With minimal guidance, as with the current version of the manual, local agencies with staff that have limited access to roadway safety training, safety expertise, and the latest safety analysis tools may not select appropriate methods, resulting in inefficient use of limited safety resources. The process of selecting the most suitable method can be complex and involve multiple factors, including data availability, the available staff expertise, the method's robustness and data requirements, etc. Therefore, sufficient guidance has to be provided to assist local agencies in selecting appropriate methods that are suitable to their needs.

1.2 Project Objectives

The main objective of this project is to develop a web-based decision making tool to assist agencies in tailoring the HSM to their needs by helping them select the most suitable method(s) among those discussed in the HSM. The *HSM Decision Making Tool (HSM-DMT)* uses the decision-making process developed as part of this project to suggest the most appropriate method that best meets the agency's needs, data, available statistical expertise, etc.

1.3 Report Organization

The rest of this report is organized as follows. Chapter 2 summarizes the six steps in the roadway safety management process. Chapter 3 provides a review of the states' 2014 Highway Safety Improvement Program (HSIP) reports to understand the states' current practices in safety management. Chapter 4 introduces the web-based tool. Finally, Chapter 5 summarizes this research effort.

CHAPTER 2
ROADWAY SAFETY MANAGEMENT PROCESS

The roadway safety management process, as shown in Figure 2-1, is a six-step cyclic process that considers all aspects of managing safety on a road network. This chapter summarizes these six steps.

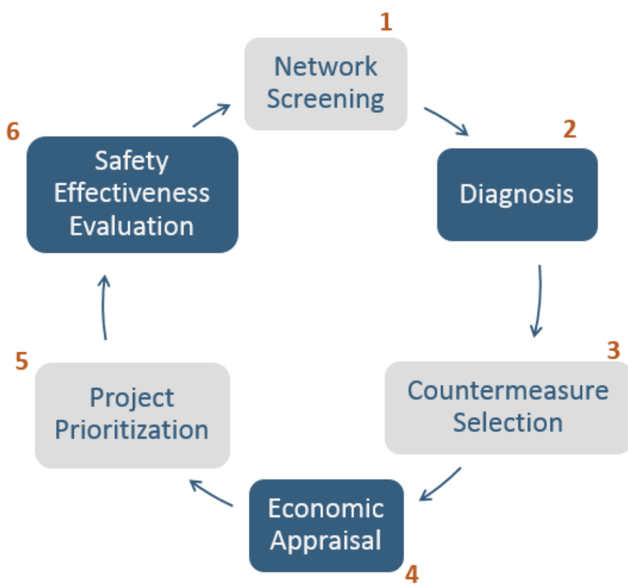

Figure 2-1: Six Steps in the Roadway Safety Management Process (Source: HSM Part B, p. 4-1)

2.1 Network Screening

Network screening is the process for reviewing a highway network to identify and rank sites likely to benefit from a safety improvement. Chapter 4 of the HSM discusses network screening in detail. Figure 2-2 lists the five major steps in network screening.

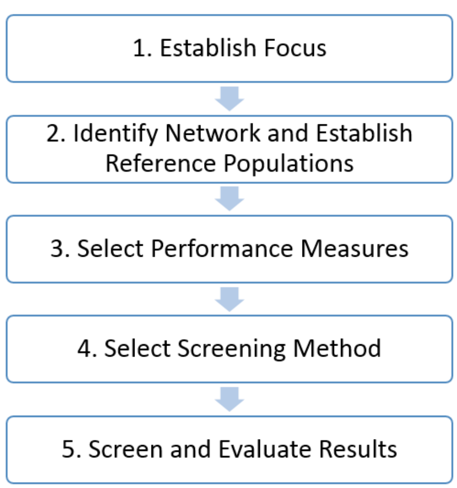

Figure 2-2: Network Screening Steps (Source: HSM Part B, p. 4-2)

In the first step, the purpose and/or intended outcome of the network screening analysis is established. For example, a focus area could be to identify sites with potential to reduce the average crash frequency or crash severity, or to target specific crash types or severity for formulation of system-wide policy. In the second step, the network is identified and the reference populations are established. For example, the type of facilities to be screened could be identified. Next, as part of the third step, the most suitable performance measures are selected from a variety of performance measures. The selection depends on several factors, including study focus, data availability, etc. Once the appropriate performance measures are identified, the fourth step is to select a screening method. The last step is to screen the network and evaluate the results.

As discussed in Chapter 4 of the HSM, the third and fourth steps in the network screening process require analysts to select a performance measure and a screening method among the ones discussed in the manual. The following subsections summarize those methods discussed in the HSM. Refer to the HSM for more details about these methods (AASHTO, 2010a).

2.1.1 Performance Measures

The HSM discusses the following 13 performance measures:

1. Average Crash Frequency
2. Crash Rate
3. Equivalent Property Damage Only (EPDO) Average Crash Frequency
4. Relative Severity Index (RSI)
5. Critical Crash Rate
6. Excess Predicted Average Crash Frequency using Method of Moments
7. Level of Service of Safety (LOSS)
8. Excess Predicted Average Crash Frequency Using Safety Performance Functions (SPFs)
9. Probability of Specific Crash Types Exceeding Threshold Proportion
10. Excess Proportion of Specific Crash Types
11. Expected Average Crash Frequency with Empirical Bayes Adjustment
12. EPDO Average Crash Frequency with EB Adjustment
13. Excess Expected Average Crash Frequency with EB Adjustment

The performance measures vary in data needs, required statistical expertise, and reliability of results. As such, the key criteria for selecting performance measures are:

- Data Availability: This criterion plays a critical role in determining the most suitable method for network screening.
- RTM Bias: The regression-to-the-mean (RTM) bias may cause locations with a high number of crashes due to random fluctuations in crash occurrences to be flagged erroneously for safety improvements, thus reducing the cost-effectiveness of safety programs, and may also result in the overestimation of crash reduction factors.
- Performance Threshold: This benchmark provides a reference point for comparison of performance measure scores within a reference population. For example, the threshold values are estimated based on the average of the observed crash frequency for the reference population, an appropriate SPF, or by EB methods.

The following paragraphs discuss the 13 performance measures in detail.

1. Average Crash Frequency
(Source: HSM Part B, pp. 4-24 to 4-25)

The site with the most total crashes or the most crashes of a particular crash severity or type, in a given time period, is given the highest rank. Table 2-1 summarizes the strengths, limitations, data needs, and output of the *Average Crash Frequency* performance measure.

Table 2-1: Average Crash Frequency

Strengths	• Simple
Limitations	• Does not account for RTM bias • Does not estimate a threshold to indicate sites experiencing more crashes than predicted for sites with similar characteristics • Does not account for traffic volume • Will not identify low-volume collision sites where simple cost-effective mitigating countermeasures could be easily applied
Data Needs	• Crash data by location • Roadway information for categorization
Output	The locations are ranked based on crash frequencies

2. Crash Rate
(Source: HSM Part B, pp. 4-26 to 4-28)

Crash rate normalizes the frequency of crashes by the exposure, usually traffic volume estimated as million entering vehicles for intersections and vehicle miles traveled for segments. Crash rate is calculated using the following equation:

$$Observed\ crash\ rate\ at\ location\ i = \frac{Total\ observed\ crashes\ at\ location\ i}{Exposure} \qquad (2\text{-}1)$$

Table 2-2 summarizes the strengths, limitations, data needs, and output of the *Crash Rate* performance measure.

Table 2-2: Crash Rate

Strengths	• Simple • Could be modified to account for severity
Limitations	• Does not account for RTM bias • Does not identify a threshold to indicate sites experiencing more crashes than predicted for sites with similar characteristics • Comparisons cannot be made across sites with significantly different traffic volumes • Will mistakenly prioritize low-volume, low-collision sites
Data Needs	• Crash data by location • Average annual daily traffic (AADT)
Output	The locations are ranked based on their crash rates

3. EPDO Average Crash Frequency
(Source: HSM Part B, pp. 4-28 to 4-31)

EPDO average crash frequency assigns weighting factors to crashes by severity to develop a combined frequency and severity score for each location. Crash costs listed in Table 2-3 are used to calculate the weighting factors. Table 2-4 summarizes the strengths, limitations, data needs, and output of the *EPDO Average Crash Frequency* performance measure.

Table 2-3: Crash Cost Estimates by Crash Severity

Crash Severity	Comprehensive Crash Cost (2001 Dollars)
Fatality (K)	$4,008,900
Disabling Injury (A)	$216,000
Evident Injury (B)	$79,000
Possible Injury (C)	$44,900
Property Damage Only (PDO) (O)	$7,400

Note: These crash costs must be adjusted to the current dollar values.

The weighting factors are calculated using the following equations:

$$\textit{Weighting factor based on crash severity} = \frac{\textit{Crash cost for specific crash severity}}{\textit{Crash cost for PDO crash severity}} \qquad (2\text{-}2)$$

$$\textit{Total EPDO Score} = f_{k(wt)} \times N_{obs,i(F)} + f_{inj(wt)} \times N_{obs,i(INJ)} + f_{PDO(wt)} \times N_{obs,i(PDO)} \qquad (2\text{-}3)$$

where,

$f_{k(wt)}$ = fatal crash weight,
$N_{obs,i(F)}$ = number of fatal crashes at location *i*,
$f_{inj(wt)}$ = injury crash weight,
$N_{obs,i(INJ)}$ = number of injury crashes at location *i*,
$f_{PDO(wt)}$ = property damage only crash weight, and
$N_{obs,i(PDO)}$ = number of PDO crashes at location *i*.

Table 2-4: EPDO Average Crash Frequency

Strengths	• Simple • Considers crash severity
Limitations	• Does not account for RTM bias • Does not identify a threshold to indicate sites experiencing more crashes than predicted for sites with similar characteristics • Does not account for traffic volume • May overemphasize locations with a low frequency of severe crashes depending on weighting factors used
Data Needs	• Crash data by location and severity • Crash severity weighting factors • Crash costs by crash severity
Output	The locations are ranked based on their EPDO scores

4. Relative Severity Index (RSI)
(Source: HSM Part B, pp. 4-31 to 4-35)

Crash costs are assigned to each crash type and the total cost of all crashes is calculated for each location. An average crash cost per site is then compared to an overall average crash cost for the location's reference population. The resulting RSI shows whether or not a site is experiencing higher crash costs than the average for other sites with similar characteristics. Table 2-5 lists the crash cost estimates by crash type. Table 2-6 summarizes the strengths, limitations, data needs, and output of the *RSI* performance measure.

Table 2-5: Crash Cost Estimates by Crash Type

Crash Type	Comprehensive Crash Cost (2001 Dollars)
Rear End – Signalized Intersection	$26,700
Rear End – Unsignalized Intersection	$13,200
Sideswipe/Overtaking	$34,000
Angle – Signalized Intersection	$47,300
Angle – Unsignalized Intersection	$61,100
Pedestrian/Bike at an Intersection	$158,900
Pedestrian/Bike at Non-Intersection	$287,900
Head-On – Signalized Intersection	$24,100
Head-On – Unsignalized Intersection	$47,500
Fixed Object	$94,700
Other/Undefined	$55,100

Note: These crash costs must be adjusted to the current dollar values.

The RSI value for a site is calculated using the following equation:

$$\overline{RSI_i} = \frac{\sum_j RSI_j}{N_{observed,i}} \tag{2-4}$$

where,

$\overline{RSI_i}$ = average RSI cost for location *i*,
RSI_j = RSI cost for each crash type *j*, and
$N_{observed,i}$ = number of observed crashes at location *i*.

The RSI value for the reference population is calculated using the following equation:

$$\overline{RSI_{av(control)}} = \frac{\sum_{i=1}^{n} RSI_i}{\sum_{i=1}^{n} N_{observed,i}} \tag{2-5}$$

where,

$\overline{RSI_{av(control)}}$ = average RSI cost for the reference population (i.e., control group),
RSI_i = RSI cost at location *i*, and
$N_{observed,i}$ = number of observed crashes at location *i*.

Table 2-6: Relative Severity Index

Strengths	• Simple • Considers collision type and crash severity
Limitations	• Does not account for RTM bias • May overemphasize locations with a small number of severe crashes depending on weighting factors used • Does not account for traffic volume • Will mistakenly prioritize low-volume, low-collision sites
Data Needs	• Crash data by type and location • Crash costs of each crash type • Reference population
Output	The locations are ranked based on their relative severity index

5. Critical Crash Rate
(Source: HSM Part B, pp. 4-35 to 4-39)

Critical crash rate depends on the average crash rate at similar sites, traffic volume, and a statistical constant that represents a desired level of significance. The observed crash rate at each site is compared to the calculated critical crash rate. Sites that exceed their respective critical crash rate are flagged for further review. Table 2-7 summarizes the strengths, limitations, data needs, and output of the *Critical Crash Rate* performance measure.

Table 2-7: Critical Crash Rate

Strengths	• Reduces exaggerated effect of sites with low volumes • Considers variance in crash data • Establishes a threshold for comparison
Limitations	• Does not account for RTM bias
Data Needs	• Crash data by location • Roadway information for categorization • Traffic data (AADT)
Output	The locations are ranked based on their critical crash rate

Critical crash rate is calculated using the following equations:

$$R_i = \frac{N_{observed,i(total)}}{Exposure} \tag{2-6}$$

where R_i is the observed crash rate at location i and $N_{observed,i(total)}$ is the total number of observed crashes at location i. In the above equation, the exposure is traffic volume estimated as million vehicles miles traveled for segments and million entering vehicles for intersections.

$$R_a = \frac{\sum_i (Exposure_i \times R_i)}{\sum_i Exposure_i} \tag{2-7}$$

where R_a is the weighted average crash rate for the reference population and R_i is the observed crash rate at location i.

$$R_{c,i} = R_a + \left[P \times \sqrt{\frac{R_a}{Exposure_i}}\right] + \left[\frac{1}{2 \times (Exposure_i)}\right] \tag{2-8}$$

where,

$R_{c,i}$ = critical crash rate for location *i*,
R_a = weighted average crash rate for the reference population, and
P = p-value for corresponding confidence level.

6. Excess Predicted Average Crash Frequency Using Method of Moments (Source: HSM Part B, pp. 4-40 to 4-44)

A site's observed average crash frequency is adjusted based on the variance in the crash data and average crash frequency for the site's reference population. The adjusted observed average crash frequency for the site is compared to the average crash frequency for the reference population. Table 2-8 summarizes the strengths, limitations, data needs, and output of the *Excess Predicted Average Crash Frequency Using Method of Moments* performance measure.

Table 2-8: Excess Predicted Average Crash Frequency Using Method of Moments

Strengths	• Establishes a threshold of predicted performance for a site • Considers variance in crash data • Allows sites of all types to be ranked in one list • Uses method concepts similar to EB methods
Limitations	• Does not account for RTM bias • Does not account for traffic volume • Some sites may be identified for further study because of unusually low frequency of non-target crash types • Ranking results are influenced by reference populations; sites near boundaries of reference populations may be overemphasized
Data Needs	• Crash data (crash location, crash type, crash severity, crash time) • Reference populations
Output	The locations are ranked based on their potential for safety improvement

The procedure involves the following four major steps:

Step 1 – Calculate Average Crash Frequency per Reference Population: First, identify reference population by organizing historical crash data of the study period based on factors such as facility type, location, and other geometric characteristics. For each reference population, calculate the average crash frequency using the following equation:

$$N_{observed\ rp} = \frac{\sum_{i=1}^{n} N_{observed,i}}{n_{sites}} \tag{2-9}$$

where,

$N_{observed\ rp}$ = average crash frequency per reference population,
$N_{observed,i}$ = observed crash frequency at location *i*, and

n_{sites} = number of locations per reference population.

Step 2 – Calculate Crash Frequency Variance per Reference Population: For each reference population, calculate the average crash frequency variance using the following equation:

$$Var(N) = \frac{\sum_{i=1}^{n} (N_{observed,i} - N_{observed\ rp})^2}{n_{sites} - 1} \tag{2-10}$$

where,

$Var(N)$ = variance of crash frequency,
$N_{observed\ rp}$ = average crash frequency per reference population,
$N_{observed,i}$ = observed crash frequency per year at location *i*, and
n_{sites} = number of locations per reference population.

Step 3 – Calculate Adjusted Observed Crash Frequency per Site: Calculate the adjusted crash frequency per site using the following equation:

$$N_{observed,i(adj)} = N_{observed,i} + \frac{N_{observed\ rp}}{Var(N)} \times \left(N_{observed\ rp} - N_{observed,i}\right) \tag{2-11}$$

where,

$N_{observed,i(adj)}$ = adjusted observed number of crashes per year at location *i*,
$Var(N)$ = variance of crash frequency,
$N_{observed\ rp}$ = average crash frequency per reference population, and
$N_{observed,i}$ = observed crash frequency per year at location *i*.

Step 4 – Calculate Potential for Improvement per Site: As shown in the equation below, subtract the average crash frequency per reference population from the adjusted observed average crash frequency per site to obtain the potential for improvement per site.

$$PI_i = N_{observed,i(adj)} - N_{observed\ rp} \tag{2-12}$$

where,

PI_i = potential for improvement at location *i*,
$N_{observed,i(adj)}$ = adjusted observed number of crashes per year at location *i*, and
$N_{observed\ rp}$ = average crash frequency per reference population.

7. Level of Service of Safety
(Source: HSM Part B, pp. 4-44 to 4-48)

The predicted average crash frequency for sites with similar characteristics is predicted from an SPF calibrated to local conditions. The observed crash frequency is compared to the predicted average crash frequency. Each site is placed into one of four LOSS classifications, depending on the degree to which the observed average crash frequency is different than the predicted average crash frequency. Table 2-9 summarizes the strengths, limitations, data needs, and output of the *LOSS* performance measure. Table 2-10 summarizes the four LOSS categories; in this table, the standard deviation, σ, is calculated using the following equation.

$$\sigma = \sqrt{N_{predicted} + k \times N_{predicted}^{2}} \tag{2-13}$$

where,

σ = standard deviation,
$N_{predicted}$ = predicted average crash frequency from the SPF, and
k = overdispersion parameter (ODP) of the SPF.

Table 2-9: LOSS

Strengths	• Considers variance in crash data • Accounts for volume • Establishes a threshold for measuring potential to reduce crash frequency
Limitations	• Effects of RTM bias may still be present in the results
Data Needs	• Crash data by location • Traffic data (AADT) • Calibrated SPFs and ODP
Output	The observed crash frequency at each location is compared to the LOSS limits, and the locations are assigned a LOSS level; the locations are ranked based on their LOSS levels.

Table 2-10: LOSS Categories

LOSS	Condition	Description
I	$\sigma < N_{observed} < (N - 1.5\times(\sigma))$	Indicates a low potential for crash reduction
II	$(N - 1.5\times(\sigma)) \le N_{observed} < N$	Indicates low to moderate potential for crash reduction
III	$N \le N_{observed} < (N + 1.5\times(\sigma))$	Indicates moderate to high potential for crash reduction
IV	$N_{observed} \ge (N + 1.5\times(\sigma))$	Indicates a high potential for crash reduction

8. Excess Predicted Average Crash Frequency Using SPFs (Source: HSM Part B, pp. 4-48 to 4-52)

Excess predicted crash frequency is the difference between the observed and predicted crash frequencies. Note that predicted average crash frequency is estimated from an SPF. Table 2-11 summarizes the strengths, limitations, data needs, and output of the *Excess Predicted Average Crash Frequency Using SPFs* performance measure. The excess predicted crash frequency is calculated using the following equation:

$$Excess(N) = N_{observed,i} - N_{predicted,i} \tag{2-14}$$

where,

$Excess(N)$ = excess predicted average crash frequency,
$N_{observed,i}$ = observed average crash frequency for location i, and

$N_{predicted,i}$ = predicted average crash frequency from the SPF for location *i*.

Table 2-11: Excess Predicted Average Crash Frequency Using SPFs

Strengths	• Accounts for traffic volume • Estimates a threshold for comparison
Limitations	• Effects of RTM bias may still be present in the results
Data Needs	• Crash data by location • Roadway data (roadway location and facility type) • AADT • Calibrated SPFs
Output	The locations are ranked based on the excess predicted crash frequency

9. Probability of Specific Crash Types Exceeding Threshold Proportion (Source: HSM Part B, pp. 4-52 to 4-57)

Sites are prioritized based on the probability that the true proportion, p_i, of a particular crash type or severity (e.g., long-term predicted proportion) is greater than the threshold proportion, p_i^*. A threshold proportion (p_i^*) is selected for each population, typically based on the proportion of the target crash type or severity in the reference population. Table 2-12 summarizes the strengths, limitations, data needs, and output of the *Probability of Specific Crash Types Exceeding Threshold Proportion* performance measure.

Table 2-12: Probability of Specific Crash Types Exceeding Threshold Proportion

Strengths	• Can also be used as a diagnostic tool • Considers variance in data • Not affected by RTM bias
Limitations	• Does not account for traffic volume • Some sites may be identified for further study because of unusually low frequency of non-target crash types
Data Needs	• Crash data by location and type • Roadway data (roadway location and facility type)
Output	The locations are ranked based on the probability of a specific crash type exceeding threshold proportion

The procedure involves the following six major steps.

Step 1 – Calculate Observed Proportions: Calculate the observed proportion of the target crash type or crash severity for each site that has experienced two or more crashes of the target crash type or crash severity using the following equation.

$$p_i = \frac{N_{observed,i}}{N_{observed,i(total)}} \tag{2-15}$$

where,

p_i = observed proportion at location *i*,
$N_{observed,i}$ = number of observed target crashes at location *i*, and
$N_{observed,i(total)}$ = total number of crashes at location *i*.

Step 2 – Estimate a Threshold Proportion: Select the threshold proportion of crashes, p^*_i, for a specific crash type. The proportion of a specific crash type in the entire population is calculated using the following equation.

$$p_i^* = \frac{\sum N_{observed,\ i}}{\sum N_{observed,i(total)}} \tag{2-16}$$

where,

p_i^* = threshold proportion,
$\sum N_{observed,\ i}$ = sum of observed target crash frequency within the population, and
$\sum N_{observed,i(total)}$ = sum of total observed crash frequency within the population.

Step 3 – Calculate Sample Variance (s^2): Calculate the sample variance for each subcategory using the following equation.

$$Var(N) = \left(\frac{1}{n_{sites}-1}\right) \times \left[\sum_{i=1}^{n}\left(\frac{N^2_{observed,i} - N_{observed,i}}{N^2_{observed,i(total)} - N_{observed,i(total)}}\right) - \left(\frac{1}{n_{sites}}\right) \times \left(\sum_{i=1}^{n}\left(\frac{N_{observed,i}}{N_{observed,i(total)}}\right)^2\right)\right] \tag{2-17}$$

for $N_{observed,i(total)} \geq 2$

where,

$Var(N)$ = sample variance,
n_{sites} = total number of sites in the subcategory,
$N_{observed,i}$ = observed target crashes for a location *i*, and
$N_{observed,i(total)}$ = total number of crashes for a location *i*.

Step 4 – Calculate Alpha and Beta Parameters: Calculate the sample mean proportion of target crashes by crash type or crash severity for all sites under consideration using the following equation.

$$\overline{p_i^*} = \frac{\sum p_i}{n_{sites}}, \quad N_{observed,i} \geq 2 \tag{2-18}$$

where n_{sites} is the total number of sites in the subcategory, and $\overline{p_i^*}$ is the mean proportion of target crashes by crash type or crash severity. Next, calculate alpha (α) and beta (β) for each subcategory using the following equations.

$$\alpha = \frac{\overline{p_i^*}^2 - \overline{p_i^*}^3 - s^2(\overline{p_i^*})}{s^2} \quad (2\text{-}19)$$

$$\beta = \frac{\alpha}{\overline{p_i^*}} - \alpha \quad (2\text{-}20)$$

where s^2 is variance and $\overline{p_i^*}$ is mean proportion of target crash types.

Step 5 – Calculate the Probability: Calculate the probability using the following equation.

$$P(p_i > p_i^* | N_{obs,i}, N_{obs,i(total)}) = 1 - \text{betadist}\,(p_i^*, \alpha + N_{obs,i}, \beta + N_{obs,i(total)} - N_{obs,i}) \quad (2\text{-}21)$$

where,

p_i^*	=	threshold proportion,
p_i	=	observed proportion,
$N_{obs,i}$	=	observed target crashes at location *i*, and
$N_{obs,i(total)}$	=	total number of crashes at location *i*.

Step 6 – Rank Locations: Rank sites based on the probability of target crashes occurring at the site.

10. Excess Proportions of Specific Crash Types
(Source: HSM Part B, pp. 4-57 to 4-58)

This performance measure is very similar to the *Probability of Specific Crash Types Exceeding Threshold Proportion* performance measure except sites are prioritized based on the excess proportion. The excess proportion is the difference between the observed proportion of a specific crash type or severity and the threshold proportion from the reference population. The largest excess value represents the greatest potential for reduction in average crash frequency. Table 2-13 summarizes the strengths, limitations, data needs, and output of the *Excess Proportion of Specific Crash Types* performance measure.

Table 2-13: Excess Proportions of Specific Crash Types

Strengths	• Can also be used as a diagnostic tool • Considers variance in data • Not affected by RTM bias
Limitations	• Does not account for traffic volume • Some sites may be identified for further study because of unusually low frequency of non-target crash types
Data Needs	• Crash data by location and type • Roadway data (roadway location and facility type)
Output	The locations are ranked in descending order based on the difference between the observed and threshold proportion.

The procedure involves the following seven steps:

- Step 1 – Calculate Observed Proportions

- Step 2 – Estimate a Threshold Proportion
- Step 3 – Calculate Sample Variance (s^2)
- Step 4 – Calculate Alpha and Beta Parameters
- Step 5 – Calculate the Probability
- Step 6 – Calculate the Excess Proportion
- Step 7 – Rank Locations

Steps 1 through 5 are similar to the steps discussed on pages 12 through 14 to calculate the *Probability of Specific Crash Types Exceeding Threshold Proportion* performance measure. Therefore, only Steps 6 and 7 that are unique for this performance measure are discussed below.

Step 6 – Calculate the Excess Proportion: Calculate the difference between the true observed proportion and the threshold proportion for each site using the following equation.

$$P_{DIFF} = p_i - p_i^* \qquad (2\text{-}22)$$

where p_i^* is the threshold proportion and p_i is the observed proportion.

Step 7 – Rank Locations: Rank locations in descending order by the value of P_{DIFF}. The greater the difference between the observed and threshold proportion, the greater the likelihood that the site will benefit from a countermeasure targeted at the crash type under consideration.

11. Expected Average Crash Frequency with EB Adjustment (Source: HSM Part B, pp. 4-58 to 4-65)

The observed average crash frequency and the predicted average crash frequency from an SPF are weighted together using the EB method to calculate an expected average crash frequency that accounts for RTM bias. Table 2-14 summarizes the strengths, limitations, data needs, and output of the *Expected Average Crash Frequency with EB Adjustment* performance measure.

Table 2-14: Expected Average Crash Frequency with EB Adjustment

Strengths	• Accounts for RTM bias
Limitations	• Requires SPFs calibrated to local conditions
Data Needs	• Crash data (crash location, crash type, crash severity, crash time) • Roadway data (roadway location and facility type) • Basic site characteristics • Calibrated SPFs for the reference population and overdispersion parameter
Output	The locations are ranked based on the expected average crash frequencies.

The procedure involves the following six steps.

Step 1 – Calculate the Predicted Average Crash Frequency from an SPF: Using the predictive method discussed in Part C of the HSM, calculate the predicted average crash frequency, $N_{predicted,n}$, for each year n, where $n = 1,2,\ldots,Y$.

Step 2 – Calculate Annual Correction Factor: The annual correction factor is the predicted average crash frequency from an SPF for year *n* divided by the predicted average crash frequency from an SPF for year *1*. Calculate the annual correction factor using the following equation.

$$C_{n(total)} = \frac{N_{predicted,n(total)}}{N_{predicted,1(total)}} \tag{2-23}$$

where,

$C_{n(total)}$	=	annual correction factor for total crashes,
$N_{predicted,n(total)}$	=	predicted number of total crashes for year *n*, and
$N_{predicted,1(total)}$	=	predicted number of total crashes for year *1*.

Step 3 – Calculate Weighted Adjustment: Calculate the weighted adjustment factor using the following equation. The weighted adjustment accounts for the reliability of the safety performance function that is applied. Larger weighting factors place a heavier reliance on the SPF estimate.

$$w_{total} = \frac{1}{1 + k_{total} \times \sum_{n=1}^{N} N_{predicted,n(total)}} \tag{2-24}$$

where,

w	=	empirical Bayes weight,
k	=	overdispersion parameter of the SPF, and
$N_{predicted,n(total)}$	=	predicted average total crash frequency from the SPF in year *n*.

Step 4 – Calculate First Year EB-adjusted Expected Average Crash Frequency: Calculate the base EB-adjusted expected average crash frequency for year *1*, $N_{expected,1}$, using the following equation.

$$N_{expected,1(total)} = w_{total} \times N_{predicted,1(total)} + (1 - w_{total}) \times \left[\frac{\sum_{n=1}^{N} N_{observed,y(total)}}{\sum_{n=1}^{N} C_{n(total)}}\right] \tag{2-25}$$

where,

$N_{expected,1}$	=	EB-adjusted estimated average crash frequency for year *1*,
w	=	weight
$N_{predicted,1(total)}$	=	estimated average crash frequency for year *1* at the site,
$N_{observed,n}$	=	observed crash frequency at the site,
C_n	=	annual correction factor at the site, and
n	=	year.

Step 5 – Calculate Final Year EB-adjusted Expected Average Crash Frequency: Calculate the EB-adjusted expected number of crashes for the final year using the following equation.

$$N_{expected,n(total)} = N_{expected,1(total)} \times C_{n(total)} \tag{2-26}$$

where,

$N_{expected,n}$ = EB-adjusted estimated average crash frequency for final year *n*,
$N_{expected,1}$ = EB-adjusted expected average crash frequency for year *1*, and
C_n = annual correction factor for year *n*.

Step 6 – Rank Locations: Rank locations based on the EB-adjusted expected average crash frequency for the final year in the analysis calculated in Step 5.

12. EPDO Average Crash Frequency with EB Adjustment (Source: HSM Part B, pp. 4-65 to 4-74)

In this method, crashes by severity are predicted using the EB procedure. The expected crashes by severity are converted to EPDO crashes using the EPDO procedure, and the resulting EPDO values are ranked. Table 2-15 summarizes the strengths, limitations, data needs, and output of the *EPDO Average Crash Frequency with EB Adjustment* performance measure.

Table 2-15: EPDO Average Crash Frequency with EB Adjustment

Strengths	• Accounts for RTM bias • Considers crash severity
Limitations	• Requires SPFs calibrated to local conditions • May overemphasize locations with a small number of severe crashes depending on weighting factors used
Data Needs	• Crash data (crash location, crash type, crash severity, crash time) • Roadway data (roadway location and facility type) • Basic site characteristics • Traffic volume (AADT) • Calibrated SPFs for the reference population and overdispersion parameter • EPDO weights
Output	The locations are ranked based on the expected EPDO values.

The procedure involves the following steps.

Step 1 – Calculate Weighting Factors for Crash Severity: Calculate the EPDO weights for fatal and injury crashes using the following equation.

$$f_{y(weight)} = \frac{CC_y}{CC_{PDO}} \tag{2-27}$$

where,

$f_{y(weight)}$ = EPDO weighting factor for crash severity *y* (i.e., fatal crash, injury crash);
CC_y = crash cost for crash severity *y*; and
CC_{PDO} = crash cost for PDO crash severity.

Step 2 – Calculate the Predicted Average Crash Frequency from an SPF: Using the predictive method discussed in Part C of the HSM, calculate the predicted average crash frequency, $N_{predicted,n}$, for each year *n*, where n = 1,2,…,Y.

Step 3 – Calculate Annual Correction Factor: The annual correction factor is obtained by dividing predicted average crash frequency from an SPF for year *n* by predicted average crash frequency from an SPF for year *1*. Calculate the annual correction factor using the following equation.

$$C_{n(total)} = \frac{N_{predicted,n(total)}}{N_{predicted,1(total)}} \tag{2-28}$$

where,

$C_{n(total)}$ = correction factor for total crashes for year *n*,
$N_{predicted,n(total)}$ = number of predicted total crashes for year *n*, and
$N_{predicted,1(total)}$ = number of predicted total crashes for year *1*.

Step 4 – Calculate Weighted Adjustment: Calculate the weighted adjustment using the following equation. The weighted adjustment accounts for the reliability of the SPF that is applied. Larger weighting factors place a heavier reliance on the SPF estimate.

$$w_{total} = \frac{1}{1 + k_{total} \times \sum_n N_{predicted,n(total)}} \tag{2-29}$$

where,

w_{total} = EB weight for total crashes,
k_{total} = overdispersion parameter of the SPF for total crashes, and
$N_{predicted,n(total)}$ = predicted average total crash frequency from the SPF in year *n*.

Step 5 – Calculate First Year EB-adjusted Expected Average Crash Frequency: Calculate the base EB-adjusted expected average crash frequency for year 1, $N_{expected,1}$, using the following equation.

$$N_{expected,1(total)} = w_{total} \times N_{predicted,1(total)} + (1\text{-}w_{total}) \times \left[\frac{\sum_n N_{observed,n(total)}}{\sum_n C_{n(total)}}\right] \tag{2-30}$$

where,

$N_{expected,1(total)}$ = EB-adjusted expected frequency of total crashes for year *1*,
w_{total} = EB weight for total crashes,
$N_{predicted,1(total)}$ = number of predicted total crashes for year *1*,
$N_{observed,n(total)}$ = number of observed total crashes for year *n*, and
$C_{n(total)}$ = correction factor for total crashes for year *n*.

Step 6 – Calculate Final Year EB-adjusted Expected Average Crash Frequency: Calculate the EB-adjusted expected number of fatal and injury crashes and total crashes for the final year using the following equation.

$$N_{expected,n(total)} = N_{expected,1(total)} \times C_{n(total)} \tag{2-31}$$

where,

$N_{expected,n(total)}$ = EB-adjusted expected frequency of total crashes for final year *n*,
$N_{expected,1(total)}$ = EB-adjusted expected frequency of total crashes for year *1*, and
$C_{n(total)}$ = correction factor for total crashes for year *n*.

Step 7 – Calculate the Proportion of Fatal and Injury Crashes: Using the following equations, calculate the proportion of fatal crashes with respect to all non-PDO crashes in the reference population and injury crashes with respect to all non-PDO crashes in the reference population.

$$P_F = \frac{\sum N_{observed,(F)}}{\sum N_{observed,(FI)}} \tag{2-32}$$

$$P_I = \frac{\sum N_{observed,(I)}}{\sum N_{observed,(FI)}} \tag{2-33}$$

where,

$N_{observed,(F)}$ = observed number of fatal crashes from the reference population,
$N_{observed,(I)}$ = observed number of injury crashes from the reference population,
$N_{observed,(FI)}$ = observed number of fatal and injury crashes from the reference population,
P_F = proportion of observed number of fatal crashes out of fatal and injury crashes from the reference population, and
P_I = proportion of observed number of injury crashes out of fatal and injury crashes from the reference population.

Step 8 – Calculate the Weight of Fatal and Injury Crashes: Calculate the EPDO weight of fatal and injury crashes compared to PDO crashes using the following equation.

$$w_{EPDO,FI} = P_F \times f_{k(weight)} + P_I \times f_{inj(weight)} \tag{2-34}$$

where,

$f_{k(weight)}$ = EPDO fatality weighting factor,
$f_{inj,(weight)}$ = EPDO injury weighting factor,
P_F = proportion of observed number of fatal crashes out of fatal and injury crashes from the reference population, and
P_I = proportion of observed number of injury crashes out of fatal and injury crashes from the reference population.

Step 9 – Calculate the Final Year EPDO Expected Average Crash Frequency: Calculate the EPDO expected average crash frequency for the final year for which data exist for the site using the following equation.

$$N_{expected,n(EPDO)} = N_{expected,1(PDO)} + W_{EPDO,FI} \times N_{expected,n(FI)} \tag{2-35}$$

Step 10 – Rank Sites by EB-adjusted EPDO Score: Order the database from highest to lowest by EB-adjusted EPDO score. The highest EPDO score represents the greatest opportunity to reduce the number of crashes.

13. Excess Expected Average Crash Frequency with EB Adjustment (Source: HSM Part B, pp. 4-75 to 4-83)

The observed average crash frequency and the predicted average crash frequency from an SPF are weighted together using the EB method to calculate an expected average crash frequency that accounts for RTM bias. The difference between the EB-adjusted average crash frequency and the predicted average crash frequency from an SPF is the excess expected average crash frequency. Table 2-16 summarizes the strengths, limitations, data needs, and output of the *Excess Expected Average Crash Frequency with EB Adjustment* performance measure.

Table 2-16: Excess Expected Average Crash Frequency with EB Adjustment

Strengths	• Accounts for RTM bias • Identifies a threshold to indicate sites experiencing more crashes than expected for sites with similar characteristics.
Limitations	• Requires SPFs calibrated to local conditions
Data Needs	• Crash data (crash location, crash type, crash severity, crash time) • Roadway data (roadway location and facility type) • Basic site characteristics • Traffic volume (AADT) • Calibrated SPFs for the reference population and overdispersion parameter
Output	The locations are ranked based on the excess expected crash frequency

The procedure involves the following seven steps:

- Step 1 – Calculate the Predicted Average Crash Frequency from an SPF
- Step 2 – Calculate Annual Correction Factor
- Step 3 – Calculate Weighted Adjustment
- Step 4 – Calculate First Year EB-adjusted Expected Average Crash Frequency
- Step 5 – Calculate Final Year EB-adjusted Expected Average Crash Frequency
- Step 6 – Calculate the Excess Expected Average Crash Frequency
- Step 7 – Rank Locations

Steps 1 through 5 are similar to the steps discussed on pages 15 through 17 to calculate the *Expected Average Crash Frequency with EB Adjustment* performance measure. Therefore, only Steps 6 and 7 that are unique for this performance measure are discussed below.

Step 6 – Calculate the Excess Expected Average Crash Frequency: The difference between the predicted estimates and EB-adjusted estimates for each site is the excess expected average crash frequency, as shown in the following equation.

$$Excess_y = \left(N_{expected,n(PDO)} - N_{predicted,n(PDO)}\right) + \left(N_{expected,n(FI)} - N_{predicted,n(FI)}\right) \quad (2\text{-}36)$$

where,

$Excess_y$ = excess expected crashes for year *n*,
$N_{expected,n}$ = EB-adjusted estimated average crash frequency for year *n*, and
$N_{predicted,n}$ = SPF-predicted average crash frequency for year *n.*

Step 7 – Rank Locations: Rank locations based on excess expected crash frequency calculated in Step 6.

2.1.2 Screening Methods

As discussed previously, there are five major steps in network screening:

- Step 1: Establish Focus
- Step 2: Identify Network and Establish Reference Populations
- Step 3: Select Performance Measures
- Step 4: Select Screening Method
- Step 5: Screen and Evaluate Results

This section focuses on Step 4: Select Screening Method. Screening roadway segments requires identifying the location within the roadway segment or ramp that is most likely to benefit from a countermeasure intended to result in a reduction in crash frequency or severity. The location (i.e., sub-segment) within a segment that shows the most potential for improvement is used to specify the critical crash frequency of the entire segment and subsequently select segments for further investigation. The HSM discusses the following three screening methods for segments:

- *Simple Ranking Method:* "The performance measures are calculated for all of the sites under consideration, and the results are ordered from high to low." (Source: HSM Part B, p. 4-18)

- *Sliding Window Method:* "A window of a specified length is conceptually moved along the road segment from beginning to end in increments of a specified size. The performance measure chosen to screen the segment is applied to each position of the window, and the results of the analysis are recorded for each window. A window pertains to a given segment if at least some portion of the window is within the boundaries of the segment. From all the windows that pertain to a given segment, the window that shows the most potential for reduction in crash frequency out of the whole segment is identified and is used to represent the potential for reduction in crash frequency of the whole segment. After all segments are ranked according to the respective highest sub-segment value, those segments with the greatest potential for reduction in crash frequency or severity are studied in detail to identify potential countermeasures." (Source: HSM Part B, p. 4-15)

- *Peak Searching Method:* "In the peak searching method each individual roadway segment is subdivided into windows of similar length, potentially growing incrementally in length until the length of the window equals the length of the entire roadway segment. The windows do not span multiple roadway segments. 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 the potential for reduction in crashes of that site (i.e., whole roadway segment) relative to the other sites being screened." (Source: HSM Part B, p. 4-16)

2.2 Diagnosis

Diagnosis is the second step in the roadway safety management process. It is used to diagnose the nature of safety problems at specific sites. It helps safety engineers understand the crash patterns, past studies, and physical characteristics before potential countermeasures are selected. It also helps identify the crash causes, potential safety concerns, and crash patterns that need further evaluation. As discussed in Chapter 5 of the HSM, the diagnosis procedure includes the following three broad steps:

1. Safety Data Review
    a. Review crash types, severities, and environmental conditions to develop summary descriptive statistics for pattern identification.
    b. Review crash locations.
2. Assess Supporting Documentation
    a. Review past studies and plans covering the site vicinity to identify known issues, opportunities, and constraints.
3. Assess Field Conditions
    a. Visit the site to review and observe multimodal transportation facilities and services in the area, particularly how users of different modes travel through the site.

2.3 Countermeasure Selection

Countermeasure selection is the third step in the roadway safety management process. Once the locations with the greatest potential for safety improvement (PSI) are identified, and the locations are diagnosed, the next step is to select appropriate countermeasures to reduce crash frequency and severity at specific sites. As discussed in Chapter 6 of the HSM, there are three main steps in selecting a countermeasure(s) for a site:

- Step 1: Identify factors contributing to the cause of crashes at the subject site
- Step 2: Identify countermeasures that may address the contributing factors
- Step 3: Conduct cost–benefit analysis, if possible, to select preferred treatment(s)

2.4 Economic Appraisal

Economic appraisal is the fourth step in the roadway safety management process. It is conducted after the highway network is screened, the selected sites are diagnosed, and potential countermeasures for reducing crash frequency or crash severity are selected. Economic appraisal is used to estimate the monetary benefit of safety improvements. It compares the benefits of a potential crash countermeasure to its project costs. Project costs are addressed in monetary terms, and the project benefits are expressed as the estimated change in crash frequency or severity of crashes, as a result of implementing a countermeasure. Chapter 7 of the HSM discusses the following three economic appraisal methods:

1. Benefit–Cost Analysis Using Net Present Value (NPV)
2. Benefit–Cost Analysis Using Benefit–Cost Ratio (BCR)
3. Cost-Effectiveness Analysis Using Cost Effectiveness Index

2.4.1 Benefit–Cost Analysis Using Net Present Value

The net present value method, also referred to as the net present worth (NPW) method, is "used to express the difference between discounted costs and discounted benefits of an individual improvement project in a single amount. The term "discount" indicates that the monetary costs and benefits are converted to a present value using a discount rate. A project with a NPV greater than zero indicates a project with benefits that are sufficient enough to justify implementation of the countermeasure. Countermeasure(s) are ordered from the highest to lowest NPV." (Source: HSM Part B, p. 7-8)

2.4.2 Benefit–Cost Analysis Using Benefit–Cost Ratio

"A benefit–cost ratio is the ratio of the present-value benefits of a project to the implementation costs of the project (BCR = Benefits/Costs). If the ratio is greater than 1.0, then the project is considered economically justified. Countermeasures are ranked from highest to lowest BCR." (Source: HSM Part B, p. 7-9)

2.4.3 Cost-Effectiveness Analysis Using Cost Effectiveness Index

"The cost-effectiveness of a countermeasure implementation project is expressed as the annual cost per crash reduced. Both the project cost and the estimated average crash frequency reduced must apply to the same time period, either on an annual basis or over the entire life of the project. This method requires an estimate of the change in crashes and cost estimate associated with implementing the countermeasure. However, the change in estimated crash frequency is not converted to a monetary value." (Source: HSM Part B, p. 7-10)

2.5 Project Prioritization

Project prioritization is the fifth step in the roadway safety management process. As discussed in Chapter 8 of the HSM, this step provides a priority ranking of sites and proposed improvement projects based on the benefit and cost estimates determined in the economic appraisal step. Prioritization could be performed based on:

1. Ranking by economic effectiveness measures
    a. Project costs
    b. Monetary value of project benefits
    c. Number of total crashes reduced
    d. Number of fatal and incapacitating injury crashes reduced
    e. Number of fatal and injury crashes reduced
    f. Cost-effectiveness index

    g. Net present value
2. Incremental benefit–cost ranking
3. Optimization methods

2.6 Safety Effectiveness Evaluation

Safety effectiveness evaluation is the final step in the roadway safety management process. "It leads to an assessment of how crash frequency or severity has changed due to a specific treatment, or a set of treatments or projects. In situations where one treatment is applied at multiple similar sites, safety evaluation can also be used to estimate a crash modification factor (CMF) for the treatment. Finally, safety effectiveness evaluations have an important role in assessing how well funds have been invested in safety improvements. Each of these aspects of safety effectiveness evaluation may influence future decision making activities related to allocation of funds and revisions to highway agency policies." (Source: HSM Part B, p. 9-1) Chapter 9 of the HSM discusses the following safety effectiveness evaluation methods:

1. Observational before/after study
    a. Naïve (Simple) study
    b. Using SPFs – the EB method
    c. Using the comparison-group method
    d. To evaluate shifts in collision crash type proportions
2. Observational cross-sectional study

2.6.1 Naïve (Simple) Observational Before/After Study

This approach uses crash frequency in the before period as the expected crash frequency in the after period had the safety treatment not been implemented.

2.6.2 Observational Before/After Evaluation Study Using SPFs – The EB Method

This approach combines a site's observed crash frequency and SPF-based predicted average crash frequency to estimate the expected average crash frequency for that site in the after period had the treatment not been implemented. (Source: HSM Part B, pp. 9-7 to 9-9)

2.6.3 Observational Before/After Evaluation Study Using the Comparison-Group Method

The comparison group consists of a number of non-treatment sites that exhibit a close agreement with the treatment sites with regard to the yearly rate of change in crash frequencies during the before period and also are comparable in site characteristics such as traffic volume and geometric to the treatment sites, but without the specific improvement being evaluated. (Source: HSM Part B, pp. 9-9 to 9-12)

2.6.4 Observational Before/After Evaluation Study to Evaluate Shifts in Collision Crash Type Proportions

This approach uses crash frequency data by collision types only for treatment sites and does not require data for non-treatment or comparison sites. (Source: HSM Part B, pp. 9-12 to 9-13)

2.6.5 Observational Cross-Sectional Study

This approach is applied when before data at treatment sites are not available. It uses statistical modeling techniques that consider the crash experience of sites with and without a particular treatment of interest (such as roadway lighting or a shoulder rumble strip) or with various levels of a continuous variable that represents a treatment of interest (such as lane width). (Source: HSM Part B, p. 9-14)

2.7 Summary

This chapter summarized the six steps in the roadway safety management process:

1. Network Screening
2. Diagnosis
3. Countermeasure Selection
4. Economic Appraisal
5. Project Prioritization
6. Safety Effectiveness Evaluation

All the methods provided in the HSM are discussed in this chapter. More specifically, the 13 different performance measures and the three segment screening methods to perform network screening, and the available methods to conduct economic appraisal and safety effectiveness evaluation are discussed.

Table 2-17 summarizes the data requirements for the 13 network screening performance measures. According to that table, the performance measures that require calibrated SPFs and overdispersion parameters are the most data-intensive measures. Table 2-18 summarizes the reliability of the 13 network screening performance measures based on two criteria: whether the measure accounts for RTM bias, and whether the method estimates a performance threshold.

Finally, Table 2-19 summarizes the data needs for the five safety effectiveness evaluation methods discussed in the HSM. From the table, a simple before/after method requires minimum data, while the methods that require SPFs are the most data-intensive methods.

Table 2-17: Data Requirements for Network Screening Performance Measures

Performance Measure	Crash Data	Roadway Data	Traffic Volume	Calibrated SPFs and ODP	Other
Average Crash Frequency	Y	Y			
Crash Rate	Y	Y	Y		
EPDO Average Crash Frequency	Y	Y			EPDO Weighting Factors
Relative Severity Index	Y	Y			Reference Population
Critical Crash Rate	Y	Y	Y		
Excess Predicted Average Crash Frequency using Method of Moments	Y	Y	Y[1]		
Level of Service of Safety	Y	Y	Y	Y	
Excess Predicted Average Crash Frequency Using SPFs	Y	Y	Y	Y	
Probability of Specific Crash Types Exceeding Threshold Proportion	Y	Y			
Excess Proportion of Specific Crash Types	Y	Y			
Expected Average Crash Frequency with EB Adjustment	Y	Y	Y	Y	
EPDO Average Crash Frequency with EB Adjustment	Y	Y	Y	Y	EPDO Weighting Factors
Excess Expected Average Crash Frequency with EB Adjustment	Y	Y	Y	Y	

Source: AASHTO 2010a

[1] Traffic volume is needed to apply Method of Moments to establish the reference populations based on ranges of traffic volumes as well as site geometric characteristics.

Table 2-18: Reliability of Network Screening Performance Measures

Performance Measure	Accounts for RTM	Method Estimates a Performance Threshold
Average Crash Frequency	No	No
Crash Rate	No	No
EPDO Average Crash Frequency	No	No
Relative Severity Index	No	Yes
Critical Crash Rate	Considers data variance but does not account for RTM	Yes
Excess Predicted Average Crash Frequency using Method of Moments	Considers data variance but does not account for RTM	Yes
Level of Service of Safety	Considers data variance but does not account for RTM	Expected average crash frequency ± 1.5 standard deviations
Excess Predicted Average Crash Frequency Using SPFs	No	Predicted average crash frequency at the site
Probability of Specific Crash Types Exceeding Threshold Proportion	Considers data variance; not affected by RTM	Yes
Excess Proportion of Specific Crash Types	Considers data variance; not affected by RTM	Yes
Expected Average Crash Frequency with EB Adjustment	Yes	Expected average crash frequency at the site
EPDO Average Crash Frequency with EB Adjustment	Yes	Expected average crash frequency at the site
Excess Expected Average Crash Frequency with EB Adjustment	Yes	Expected average crash frequency at the site

Source: AASHTO 2010a

Table 2-19: Safety Effectiveness Evaluation Method Data Needs

Data Needs and Inputs	Simple B–A	B–A using SPFs	B–A with Comparison Group	B–A Shift in Proportion	Cross-Sectional
10–20 Treatment Sites		Y	Y	Y	Y
10–20 Comparable Non-treatment Sites			Y		Y
A Minimum of 650 Aggregate Crashes in Non-treatment Sites			Y		
3–5 Years of Crash and Volume “Before” Data	Y	Y	Y	Y	
3–5 Years of Crash and Volume “After” Data	Y	Y	Y	Y	Y
SPF for Treatment Site Types		Y	Y		
SPF for Non-treatment Site Types			Y		
Target Crash Type				Y	

Source: AASHTO 2010a

CHAPTER 3
REVIEW OF THE STATES' EXISTING PRACTICES IN SAFETY MANAGEMENT

This chapter focuses on the states' current practices in improving safety on public roads. It provides a review of the 2014 Highway Safety Improvement Program reports of all the 50 states and the District of Columbia (D.C.).

3.1 HSIP

The Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) established the Highway Safety Improvement Program as a core Federal-aid program with the objective to achieve a significant reduction in traffic fatalities and serious injuries on all public roads through the implementation of highway safety improvement projects. In 2012, Congress passed a new transportation re-authorization bill, the Moving Ahead for Progress in the 21st Century Act (MAP-21). MAP-21 continued the HSIP as a core program, along with many of the previous requirements from SAFETEA-LU. As per 23 United States Code (U.S.C.) 148(h) and 23 Code of Federal Regulations (CFR) 924.15, states are required to report annually on the progress being made to advance HSIP implementation and evaluation efforts. The format of the annual HSIP reports is consistent with the HSIP MAP-21 Reporting Guidance dated February 13, 2013, and consists of four sections (FHWA, 2013):

- Program Structure
  - Program Administration
  - Program Methodology

- Progress in Implementing HSIP Projects
  - HSIP Funds Programmed
  - General Listing of Projects

- Progress in Achieving Safety Performance Targets
  - Overview of General Highway Safety Trends
  - Application of Special Rules

- Assessment of the Effectiveness of the Improvements
  - Strategic Highway Safety Plan (SHSP) Emphasis Areas
  - Groups of Similar Types of Projects
  - Systemic Treatments

The 2014 HSIP annual reports of all the 50 states and D.C. were reviewed to understand the states' current practices in improving safety on public roads (FHWA, 2016). Particularly, the following information was collected:

- Software applications (if any) used
- New practices adopted to implement the 2014 HSIP
- Crash, exposure, and roadway data types used
- Performance measures (also known as project identification methods) used

- Whether or not local roads were included in the analysis (If yes, the methods used to improve safety on local roads)
- Processes used to prioritize projects
- Processes used to identify potential countermeasures
- Program methodology practices used to implement HSIP that have changed recently

3.2 HSIP Focus Areas

In the 2014 HSIP reports, the states chose one or more critical focus areas (i.e., program areas) from the following list:

- Median Barrier
- Intersection
- Safe Corridor
- Horizontal Curve
- Bicycle Safety
- Rural State Roads
- Skid Hazard
- Crash Data
- Red Light Running (RLR) Program
- Roadway Departure
- Low-cost Spot Improvements
- Sign Replacement and Improvements
- Local Safety
- Pedestrian Safety
- Right-angle Crash
- Left-turn Crash
- Shoulder Improvements
- Segment

From Table 3-1, intersections and roadway departure crashes were the two most commonly identified focus areas, followed by local safety and pedestrian safety.

Table 3-1: States' Focus Areas Identified in the HSIP Reports

	Median Barrier	Intersection	Safe Corridor	Horizontal Curve	Bicycle Safety	Rural State Roads	Skid Hazard	Crash Data	RLR* Prevention	Roadway Departure	Low-cost Spot Improvements	Sign Replacement & Improvements	Local Safety	Pedestrian Safety	Right-angle Crash	Left-turn Crash	Shoulder Improvements	Segment
Alabama	Y	Y		Y		Y	Y	Y		Y	Y	Y	Y				Y	Y
Arizona										Y							Y	
Arkansas	Y			Y		Y	Y	Y		Y	Y	Y						
California	Y									Y								
Connecticut													Y					
District of Columbia		Y	Y		Y		Y	Y	Y		Y	Y	Y	Y	Y	Y		Y
Delaware								Y						Y				Y
Florida		Y			Y		Y	Y						Y				Y
Georgia	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		
Hawaii								Y										
Illinois		Y		Y						Y		Y	Y	Y				Y
Indiana	Y	Y		Y		Y		Y		Y		Y	Y	Y				
Iowa		Y		Y						Y								
Kansas		Y										Y	Y					
Kentucky	Y	Y					Y			Y	Y	Y						
Louisiana		Y								Y			Y					
Maine		Y		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y
Maryland	Y	Y		Y		Y	Y			Y	Y			Y	Y	Y		Y
Massachusetts		Y			Y			Y		Y		Y		Y				
Missouri	Y	Y		Y			Y			Y			Y					
Nebraska		Y								Y								
Nevada		Y				Y												
New Hampshire	Y	Y		Y				Y		Y	Y	Y	Y		Y	Y		Y
New Jersey		Y	Y							Y			Y	Y	Y	Y		
New Mexico	Y	Y			Y	Y				Y	Y		Y	Y				
New York		Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y			Y
North Carolina	Y	Y	Y	Y	Y					Y				Y				
North Dakota		Y								Y								
Oklahoma	Y	Y				Y				Y								
Oregon		Y										Y						
Pennsylvania	Y	Y		Y	Y		Y			Y	Y		Y	Y		Y	Y	
Rhode Island											Y			Y				
Tennessee		Y						Y		Y			Y				Y	
Utah											Y							
Vermont											Y		Y					
Virginia		Y			Y			Y		Y				Y				
Washington			Y															
West Virginia										Y								
Wyoming	Y	Y		Y				Y		Y	Y	Y	Y					
Total	14	28	6	14	10	10	11	15	2	27	15	14	18	16	7	7	5	9

* RLR: Red Light Running.

Note: The 2014 HSIP reports from the following states did not provide information about the categories included in the analysis: Alaska, Colorado, Idaho, Michigan, Minnesota, Mississippi, Montana, Ohio, South Carolina, South Dakota, Texas, Wisconsin.

3.3 Network Screening

3.3.1 Project Identification Methods

As discussed previously, the HSIP reports first list all the programs that are administered under the HSIP. For each program administered under the HSIP, the project identification methods (i.e., performance measures) used were listed. The following 13 methods were included in the report. Note that all these 13 methods except *Systemic Improvements* are discussed in Part B of the HSM (Chapter 4 – Network Screening). More discussion about these methods is provided in Chapter 2 of this report.

- Crash Frequency
- Crash Rate
- EPDO Crash Frequency
- Relative Severity Index
- Critical Crash Rate
- Level of Service of Safety
- EPDO Crash Frequency with EB Adjustment
- Excess Proportion of Specific Crash Types
- Probability of Specific Crash Types
- Excess Expected Crash Frequency using SPFs
- Excess Expected Crash Frequency with EB Adjustment
- Expected Crash Frequency with EB Adjustment
- Systemic Improvements

Table 3-2 summarizes the project development methods (i.e., performance measures) used to identify projects. From the table, crash frequency is the most commonly used method, followed by crash rates and relative severity index. It is interesting to find that the advanced methods that involve EB analysis were very rarely used.

Table 3-2: Performance Measures Used to Conduct Network Screening

Method	Frequency
Crash Frequency	47
Crash Rate	37
Relative Severity Index	19
Excess Proportion of Specific Crash Types	14
Probability of Specific Crash Types	14
Critical Crash Rate	13
EPDO Crash Frequency	12
Excess Expected Crash Frequency using SPFs	5
Excess Expected Crash Frequency with EB Adjustment	5
Expected Crash Frequency with EB Adjustment	4
LOSS	4
Systemic Improvements	4
EPDO Crash Frequency with EB Adjustment	2
Others	14

Note: Multiple states were found to use more than one method to perform network screening.

3.3.2 Data Used

This section discusses the different types of exposure and crash data used by states to generate their HSIP reports in 2014. As shown in Table 3-3, traffic volume was the most commonly used exposure, followed by lane miles. States were often found to use population to evaluate pedestrian and bicyclist safety. One state used pedestrian and bicyclist traffic volumes to evaluate the safety of vulnerable road users.

Table 3-3: Exposure Data Used to Conduct Analysis for HSIP Reports

Exposure	Frequency
Traffic Volume	43
Lane Miles	14
Population	7
Pedestrian and Bicyclist Volumes	1
Congestion	1

Note: Seven states did not provide information on the exposure used. Multiple states were found to use more than one type of exposure.

Table 3-4 summarizes the different types of crashes used by the states to conduct analysis for the HSIP reports in 2014. A majority of the states analyzed data based on total crashes (irrespective of crash severity and crash type). Analysis based on fatal and serious injury crashes was also found to be common. Very few states (3) stated that they conduct analysis based on crash type.

Table 3-4: Crash Data Used to Conduct Analysis for HSIP Reports

Crash Type	Frequency
All Crashes	41
Fatal and Serious Injury Crashes	28
Fatal Crashes	5
Crash Type	3
Fatal and Injury Crashes	3
Crash Severity Weighting	2
Priority Investigation Locations	1
Safety Index Rating System	1

Note: Multiple states were found to use more than one crash type.

3.3.3 Analysis of Local Roads

A total of 35 states indicated that they analyze safety on local roads. Of these 35 states, 28 states reported that they use the same methods that they use for analyzing state roads, while the remaining states noted that they use a different method than the one used for analyzing state roads. Lack of AADT data for local roads was considered as the main reason for states to use a different method than the one they were using for state roads. For example, Hawaii stated that its county roads were ranked based on crash frequencies and not crash rates because of lack of AADT data. Some of the reasons for using a different method for local roads were the following:

- Local roads are typically identified via local municipalities and the Metropolitan Planning Organization planning process.
- Crash frequency is used on local roads because of lack of exposure data.
- A different approach (e.g., geospatial locations) is used on local roads as there are no tools to do network screening based on roadway characteristics.
- If the problems on local roads are the same as those on state roads, then the same method as for state roads is used. If the problems on local roads are different from those experienced on state roads, different methods are used to analyze the issues on local roads.

3.4 Project Prioritization Methods

Table 3-5 lists the different methods used by the states to prioritize projects. As shown, projects were often prioritized based on funding availability. Benefit-to-cost ratio was also frequently used, followed by rank of priority consideration, and cost effectiveness. Although not as commonly used as the other methods, ranking based on net benefit value was also used by a few states.

Table 3-5: Methods Used to Prioritize Projects

Method	Frequency
Available Funding	35
Ranking based on Benefit-to-cost Ratio	32
Rank of Priority Consideration	18
Cost Effectiveness	16
Ranking based on Net Benefit Value	8

Note: Multiple states were found to use more than one method to prioritize projects.

3.5 Software Applications

The state DOTs used several software applications to conduct analysis for the HSIP reports. Table 3-6 summarizes the different software applications used by the states as reported in their 2014 HSIP reports. According to the table, a majority of the states (39) did not list any software applications in their HSIP reports. The software tools that were identified by the states are discussed below:

- Safety Analyst: The software application provides a suite of analytical tools to identify and manage system-wide highway safety improvements. Safety Analyst is designed to account for the RTM bias using the EB method. (AASHTO, 2010b)

- CARE: The Critical Analysis Reporting Environment (CARE) is a data analysis software package designed for problem identification and countermeasure development in traffic safety applications. It provides descriptive statistics, information mining, geographic information systems (GIS) access, roadway engineering support, and dashboard support. (Center for Advanced Public Safety [CAPS], 2009a).

- eCrash: eCrash is an electronic traffic crash reporting and transmission procedure system. It provides the necessary tools for officers to prepare a crash form, including both crash location functionality and crash diagram support (CAPS, 2009b).

- HSCA: "The Highway Safety Corridor Analysis (HSCA) project was implemented as one part of a new initiate of the Idaho Transportation Department called the Investment Corridor Analysis Planning System (ICAPS). ICAPS is a single transportation investment analysis framework design to identify potential new investments that can create a positive economic environment in the state." (ITDGISData, 2016)

- usRAP: The United States Road Assessment Program (usRAP) is an innovative and proactive tool for analyzing the safety of a roadway and generating data-driven solutions for correcting hazards. (Roadway Safety Foundation, 2016)

- SPIS: The Safety Priority Index System (SPIS) is a method originally developed in 1986 by the Oregon Department of Transportation (ODOT) for identifying potential safety problems on state highways. The system currently includes all on-state and off-state highways that have traffic volumes. (ODOT, n.d.)

- SAMS: The Safety Analysis Management System (SAMS) is used by Mississippi DOT (MDOT). It is an intranet portal used for nightly and weekly crash data loading, crash query, results display in map and data grid, crash data analysis, reporting, and collision diagramming. (MDOT, 2014)

Table 3-6: Software Applications Used to Conduct Analysis for HSIP Reports

Method	States
Safety Analyst	New Hampshire, Ohio, and Washington
eCrash and CARE	Alabama and Arkansas
GIS Tools	Florida
HSCA	Idaho
Safety Module Software which uses HSM Predictive Method	South Dakota
SPIS	Oregon
SAMS	Mississippi
usRAP	Illinois

Note: Thirty-nine states did not list any software applications.

3.6 Methods Used to Identify Potential Countermeasures

The HSIP reports include the methods used to identify potential countermeasures. As shown in Table 3-7, a majority of the states said that they conduct an engineering study to identify potential countermeasures. Road safety assessment was the next most frequent approach, followed by crash data evaluation.

Table 3-7: Processes Used to Identify Potential Countermeasures

Method	Frequency
Engineering Study	40
Road Safety Assessment	33
Crash Data Evaluation	3
Other	5

Note: Multiple states were found to use more than one method to identify potential countermeasures.

3.7 New Practices Adopted by States

The HSIP reports also document the new practices that the states are currently using to implement the HSIP. Only Alabama, Montana, and D.C. stated that they had adopted the following new practices since the last time they submitted their HSIP reports (i.e., 2013).

- Alabama: Pending development of SPFs and CMFs for use with the HSM.
- D.C.: Projects for design are automatically implemented through construction. These projects are advanced by "Decision Lens" and internal review of the annual crash statistics report and the Commercial Motor Vehicles report.
- Montana: Ability to query the local crash data based on local road route and milepost is very limited. Also, volume and roadway characteristics information are not available for local roads.

The states also documented new practices to implement HSIP that they have changed recently. As identified in Table 3-8, HSM was adopted by 16 states, while 14 states have started to use a systemic approach. A few states have also adopted Road Safety Audits (RSAs) for the first time in 2014.

Table 3-8: New Methods Adopted to Conduct Analysis for HSIP Reports

Method	Frequency
Highway Safety Manual	16
Systemic Approach	14
Road Safety Audits	5
Roadway data collection using usRAP protocol	1

Note: Twenty-nine states did not provide this information.

3.8 Summary

This chapter focused on the review results of the 2014 HSIP reports submitted by the states. This review helped develop an understanding of the states' current practices in improving safety. The review primarily focused on the approaches used by states to implement HSIP. The following are the key findings from the review:

- A majority of states focused on intersections, roadway departure crashes, safety on local roads, and pedestrian safety.
- States were still using traditional methods including crash frequencies and crash rates to perform network screening.
- AADT was the most common exposure to evaluate motor vehicle safety, and population was used frequently to evaluate pedestrian and bicyclist safety.
- A majority of states said that they analyzed safety on local roads. However, many states indicated that they used different methods to evaluate local and state roads, mainly due to lack of traffic and roadway characteristics data on local roads.
- Although several software applications are available, very few states were found to use software tools to implement HSIP.
- A majority of states used engineering studies to identify potential countermeasures.
- Several states were found to prioritize projects based on available funding.
- Several states had recently adopted HSM and systemic approaches.

From this review, it could be concluded that although advanced safety analysis methods are available, states are still using simple methods to manage safety on their public road network. As such, a major effort is needed to assist states in shifting to the newer methods discussed in the HSM.

CHAPTER 4
HSM-DMT APPLICATION

This chapter focuses on the Highway Safety Manual Decision Making Tool, the web-based application developed as part of this project to assist agencies in selecting the most appropriate method(s) among the ones discussed in the HSM. In this chapter, the development team briefly discusses the need for the application, and then explains the approach used to select the most suitable method(s). Finally, the user interface of the website is discussed in detail. This discussion assumes that the user is familiar with the general operation of a web browser.

4.1 Need for the Web-based Application

The HSM provides analytical tools for quantifying the effects of potential changes at individual sites. The manual is a comprehensive document that focuses on the six steps in the roadway safety management process (i.e., network screening, diagnosis, countermeasure selection, economic appraisal, project prioritization, and safety effectiveness evaluation). At each stage in the roadway safety management process, the HSM discusses different available methods and provides no specific guidance on which methods an agency should use. As agencies have different needs and limitations, a one-size-fits-all approach toward selecting appropriate methods is not suitable. With minimal guidance, as with the current version of the manual, local agencies with staff that has limited access to roadway safety training, safety expertise, and the latest safety analysis tools may not select appropriate methods, resulting in inefficient use of limited safety resources. The process of selecting the most suitable method can be complex, involving multiple factors, including data availability, the available staff expertise, the method's robustness, the method's data requirements, etc. Therefore, sufficient guidance has to be provided to assist local agencies in selecting appropriate methods that are suitable to their needs.

4.2 Framework of the Web-based Application

The main goal of the HSM-DMT website is to assist agencies in tailoring the HSM to their needs by helping them select the most suitable method(s) among those discussed in the HSM. Of the six steps in the roadway safety management process, the following steps have multiple methods to choose from:

- Step 1: Network Screening
    - Performance Measures *(13 methods)*
    - Screening Methods *(3 methods)*
- Step 2: Diagnosis *(no specific methods)*
- Step 3: Countermeasure Selection *(no specific methods)*
- Step 4: Economic Appraisal *(3 methods)*
- Step 5: Project Prioritization *(no specific methods)*
- Step 6: Safety Effectiveness Evaluation *(5 methods)*

For the steps with multiple methods, the website includes questions on the agency's data availability; available statistical expertise; and the method's data requirements, robustness, and reliability. Depending on the responses to the questions, the website recommends the most suitable method(s). The logic used in selecting the most appropriate method(s) is provided below:

- Initially, all the available methods are recommended.
- Depending on the user's response to the first question, the list of recommended methods is shortened. For example, if an agency does not have traffic data, the methods that require traffic data are removed from the list of recommended methods.
- Again, depending on the user's response to the second question, the list of recommended methods is updated. For example, if an agency does not have specific crash location information, the methods that require specific crash location data are removed from the list of recommended methods.
- The process is continued until the user responds to all the questions.
- Finally, depending on the responses to the questions, one or more methods are recommended.

Appendix A provides the text included in the website. Appendix B lists all the questions included in the website. Finally, Appendix C provides the logic used to select the most suitable method(s).

4.3 User Interface

Figure 4-1 shows the *Home* page of the HSM-DMT website. The website has the following five main pages:

- Home
- Network Screening
- Screening Methods
- Economic Appraisal
- Safety Evaluation

4.3.1 Home

The *Home* page includes a brief description about the six steps in the roadway safety management process. It also discusses the need for this website.

4.3.2 Network Screening

The *Network Screening* page briefly discusses the network screening process (Figure 4-2). The following 13 performance measures are also listed on this page:

1. Average Crash Frequency
2. Crash Rate
3. Equivalent Property Damage Only Average Crash Frequency
4. Relative Severity Index
5. Critical Crash Rate
6. Excess Predicted Average Crash Frequency using Method of Moments
7. Level of Service of Safety

8. Excess Predicted Average Crash Frequency Using Safety Performance Functions
9. Probability of Specific Crash Types Exceeding Threshold Proportion
10. Excess Proportion of Specific Crash Types
11. Expected Average Crash Frequency with Empirical Bayes Adjustment
12. EPDO Average Crash Frequency with EB Adjustment
13. Excess Expected Average Crash Frequency with EB Adjustment

The criteria used to select the most suitable network screening performance measure(s) are divided into three broad categories.

- *General Factors:* These factors focus on the performance measure's robustness and data requirements.
- *Factors to Screen Segments:* These factors pertain to screening segments, and focus on the agency's data availability, staff expertise, and performance measure's robustness.
- *Factors to Screen Intersections:* These factors pertain to screening intersections, and focus on the agency's data availability, staff expertise, and performance measure's robustness.

Figures 4-3 through 4-5 show the screenshots of the three pages, *General Factors*, *Factors to Screen Segments*, and *Factors to Screen Intersections*, respectively. As shown in Figure 4-3, these webpages are divided into three sections. The top section, Section A, provides a brief overview of the factors being considered. Section B on the right includes the questions, and Section C on the left lists all the available methods. More information about the available methods is provided in a pop-up window, which opens when the user clicks on the icon next to the method. Figure 4-6 gives an example of the pop-up window for the *Average Crash Frequency* performance measure. As the figure shows, the following information is included in the pop-up window:

- Description
- Strengths
- Limitations
- Data Needs
- Output
- More Details

At the end of the questions, there are two buttons, **Clear** and **Export**. The **Clear** button allows the user to clear the responses to the questions. The **Export** button allows the user to export the responses and the recommended method(s) to the user's local drive as a PDF file.


HSM-DMT

Decision Making Tool
for Highway Safety Manual Implementation

HOME | NETWORK SCREENING | SCREENING METHODS | ECONOMIC APPRAISAL | SAFETY EVALUATION

The Highway Safety Manual (HSM), published by American Association of State Highway and Transportation Officials (AASHTO) in 2010, provides analytical tools for quantifying the safety effects of potential changes at individual sites or a roadway network. The HSM provides quantitative methods to reliably estimate crash frequencies and severities for a range of situations, and to provide related decision-making tools to use within the roadway safety management process (i.e., network screening, diagnosis, countermeasure selection, economic appraisal, project prioritization, and safety effectiveness evaluation).

At each stage in the roadway safety management process, the HSM discusses different available methods, but provides no specific guidance on which methods an agency should use. As agencies have different needs and limitations, a one-size-fits-all approach toward selecting appropriate methods is not suitable. With minimal guidance, as with the current version of the manual, local agencies with staff that has limited access to roadway safety training, safety expertise, and the latest safety analysis tools may not select appropriate methods resulting in inefficient use of limited safety resources. The process of selecting the most suitable method can be complex involving multiple factors, including data availability, the available staff expertise, the method's robustness, the method's data requirements, etc. Therefore, sufficient guidance has to be provided to assist local agencies in selecting appropriate methods that are suitable to their needs.

This website provides a decision-making tool to assist agencies in tailoring the HSM to their needs by helping them select the most suitable methods among those discussed in the HSM.

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Figure 4-1: ***Home*** **Page**

Figure 4-2: *Network Screening* Page

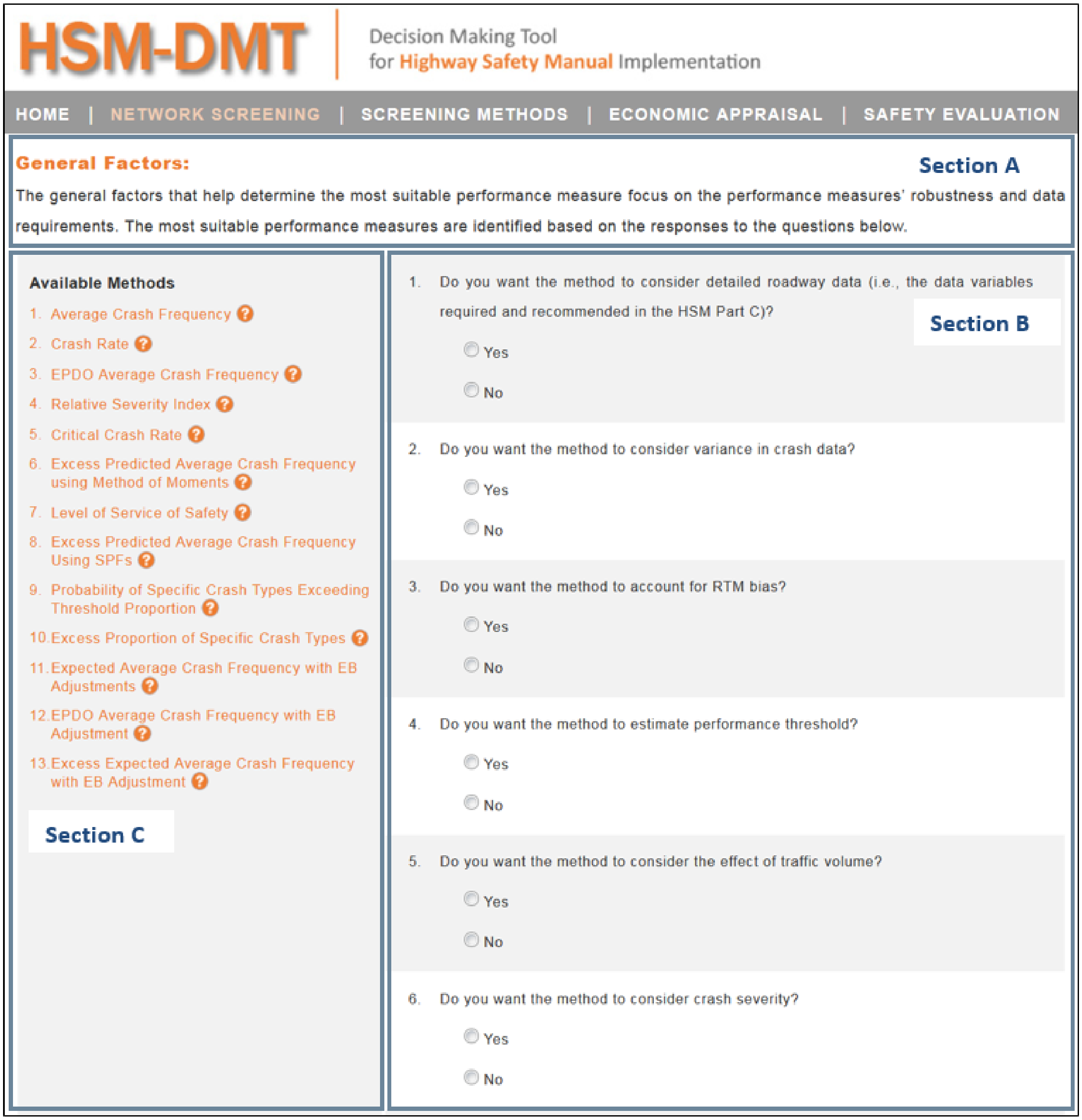
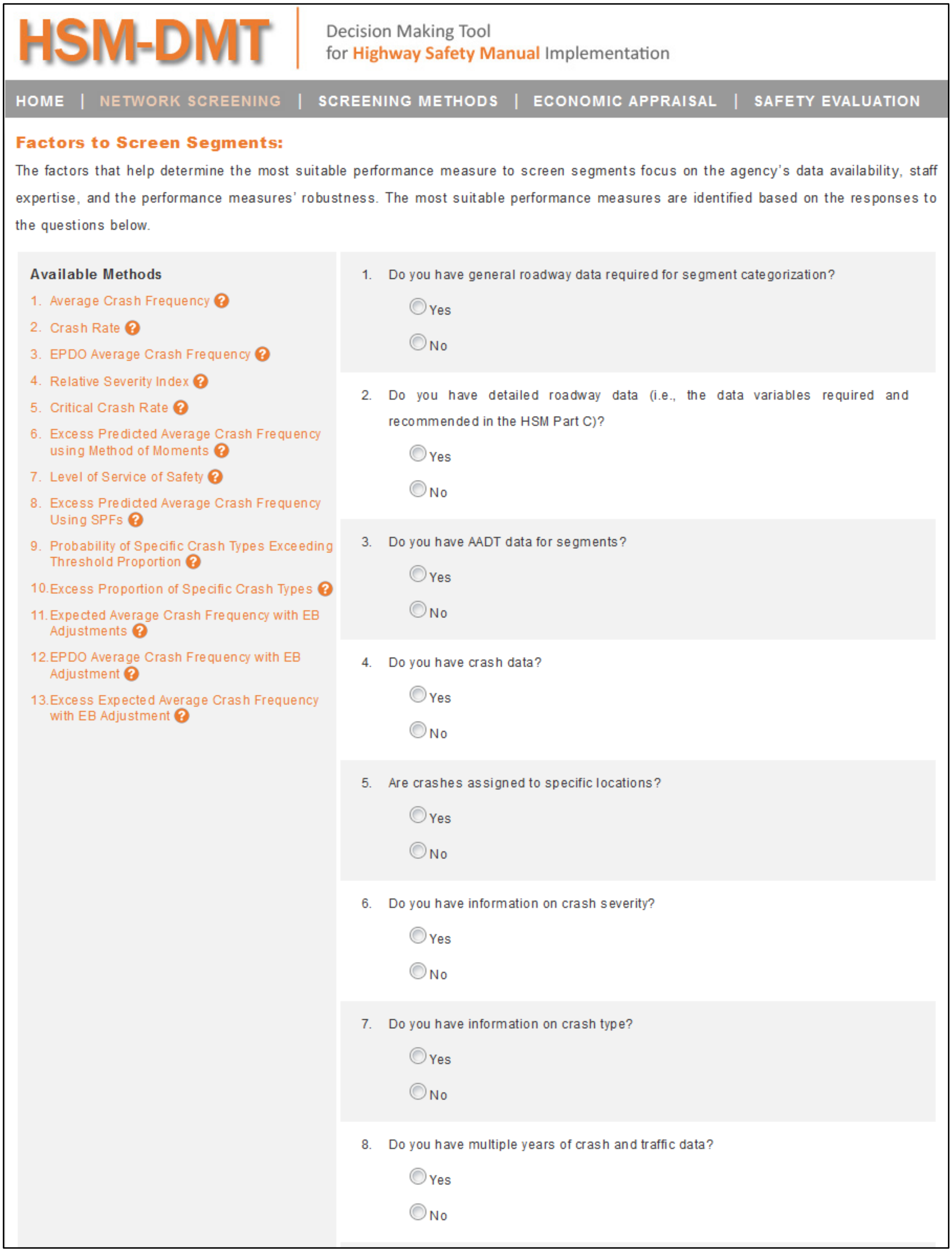


Figure 4-3: General Factors – *Network Screening* Page



HSM-DMT

Decision Making Tool
for Highway Safety Manual Implementation

HOME | NETWORK SCREENING | SCREENING METHODS | ECONOMIC APPRAISAL | SAFETY EVALUATION

Factors to Screen Segments:

The factors that help determine the most suitable performance measure to screen segments focus on the agency's data availability, staff expertise, and the performance measures' robustness. The most suitable performance measures are identified based on the responses to the questions below.

Available Methods

1. Average Crash Frequency
2. Crash Rate
3. EPDO Average Crash Frequency
4. Relative Severity Index
5. Critical Crash Rate
6. Excess Predicted Average Crash Frequency using Method of Moments
7. Level of Service of Safety
8. Excess Predicted Average Crash Frequency Using SPFs
9. Probability of Specific Crash Types Exceeding Threshold Proportion
10. Excess Proportion of Specific Crash Types
11. Expected Average Crash Frequency with EB Adjustments
12. EPDO Average Crash Frequency with EB Adjustment
13. Excess Expected Average Crash Frequency with EB Adjustment

1. Do you have general roadway data required for segment categorization?
   - Yes
   - No
2. Do you have detailed roadway data (i.e., the data variables required and recommended in the HSM Part C)?
   - Yes
   - No
3. Do you have AADT data for segments?
   - Yes
   - No
4. Do you have crash data?
   - Yes
   - No
5. Are crashes assigned to specific locations?
   - Yes
   - No
6. Do you have information on crash severity?
   - Yes
   - No
7. Do you have information on crash type?
   - Yes
   - No
8. Do you have multiple years of crash and traffic data?
   - Yes
   - No

Figure 4-4: Factors to Screen Segments – *Network Screening* Page

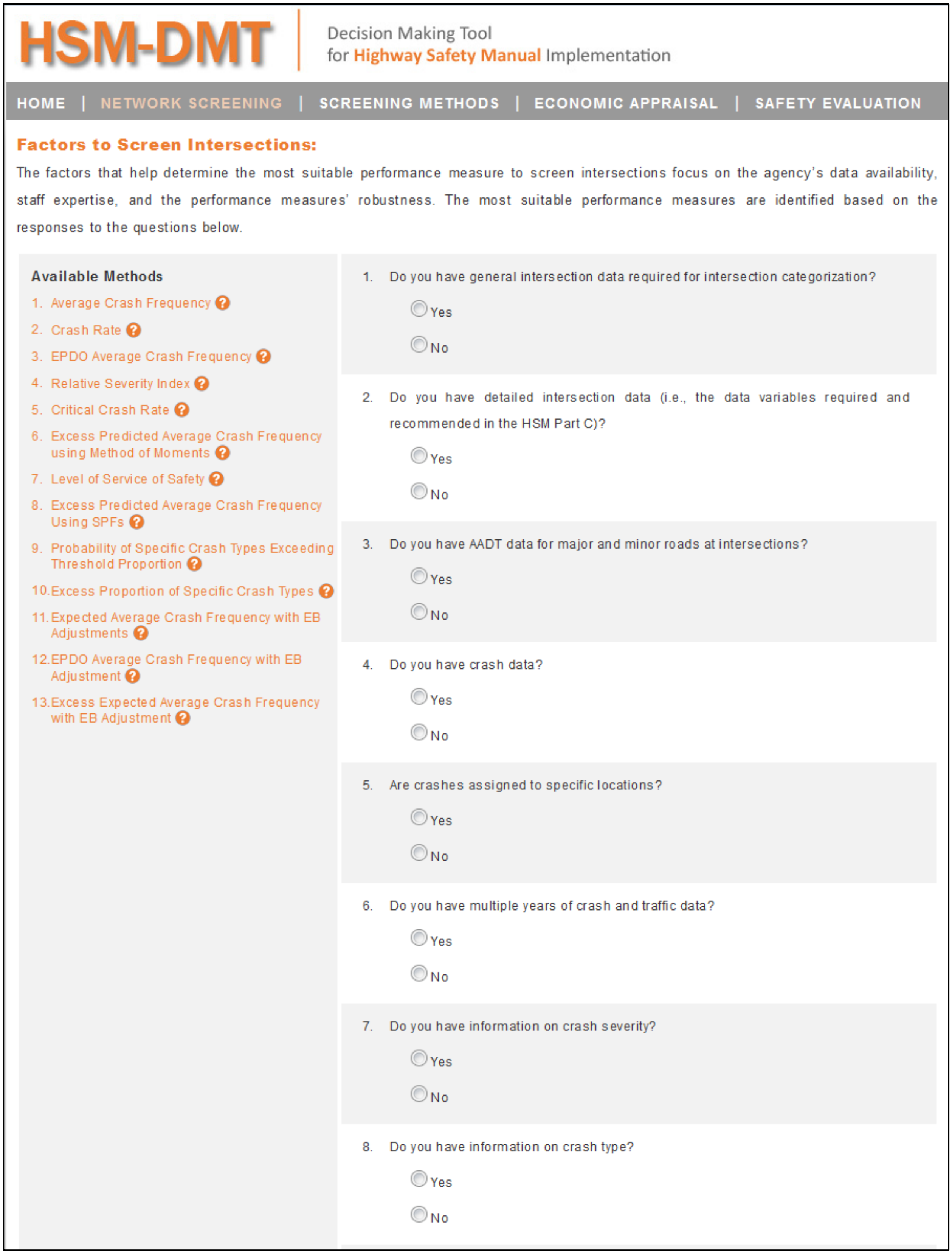
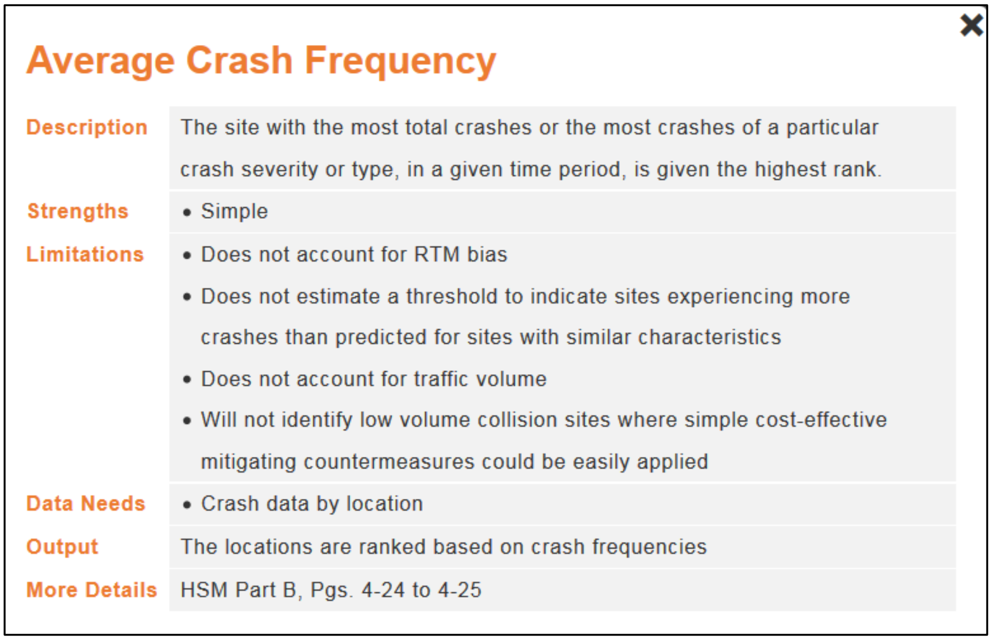


Figure 4-5: Factors to Screen Intersections – *Network Screening* Page



Average Crash Frequency

Description	The site with the most total crashes or the most crashes of a particular crash severity or type, in a given time period, is given the highest rank.
Strengths	• Simple
Limitations	• Does not account for RTM bias • Does not estimate a threshold to indicate sites experiencing more crashes than predicted for sites with similar characteristics • Does not account for traffic volume • Will not identify low volume collision sites where simple cost-effective mitigating countermeasures could be easily applied
Data Needs	• Crash data by location
Output	The locations are ranked based on crash frequencies
More Details	HSM Part B, Pgs. 4-24 to 4-25

Figure 4-6: Sample Pop-up Window with More Information About the Method

4.3.3 Screening Methods

Figure 4-7 shows a screenshot of the *Screening Methods* page. Similar to the *Network Screening* pages shown in Figures 4-3 through 4-5, this webpage is also divided into three sections. The top section provides a brief overview of the screening methods. The remaining two sections include the questions and the available methods. More information about the available methods is provided in a pop-up window, which opens when the user clicks on the icon next to the method. Figure 4-8 gives an example of the pop-up window for *Simple Ranking Method*.

4.3.4 Economic Appraisal

The *Economic Appraisal* page briefly discusses the process, and lists the following three economic appraisal methods discussed in the HSM:

- Benefit–Cost Analysis Using Net Present Value
- Benefit–Cost Analysis Using Benefit–Cost Ratio
- Cost-Effectiveness Analysis Using Cost Effectiveness Index

Figure 4-9 shows the screenshot of this page. Similar to the other pages, this webpage is also divided into three sections. The top section provides a brief overview of the Economic Appraisal step. The remaining two sections include the questions and the available methods. More information about the available methods is provided in a pop-up window, which opens when the user clicks on the icon next to the method.

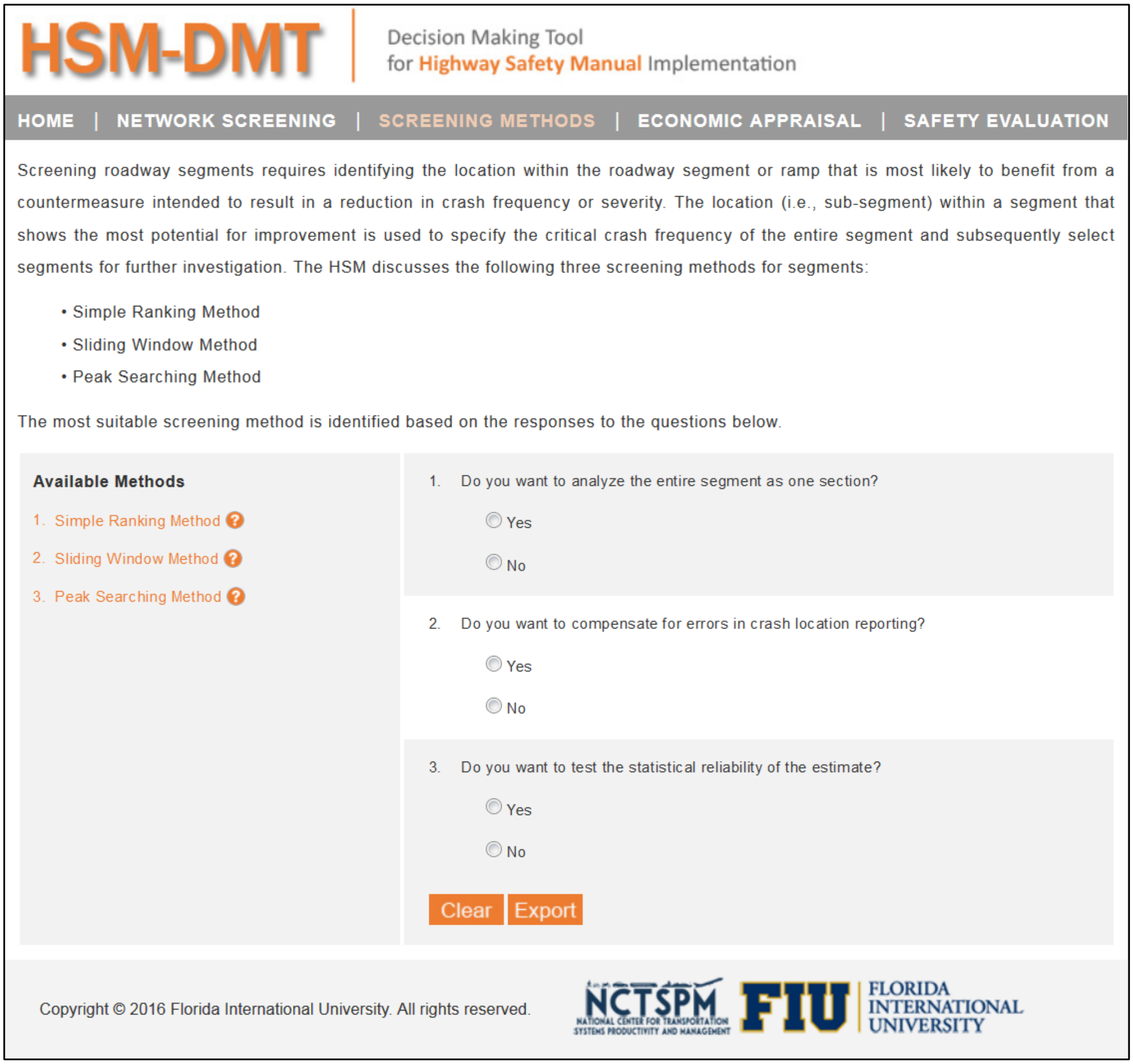


Figure 4-7: *Screening Methods* Page

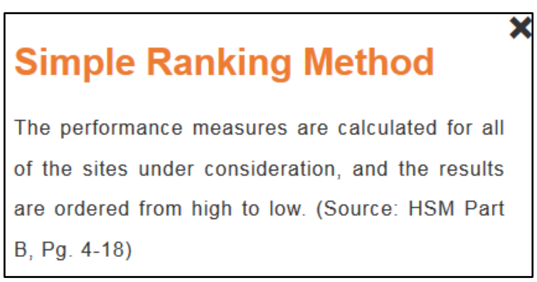
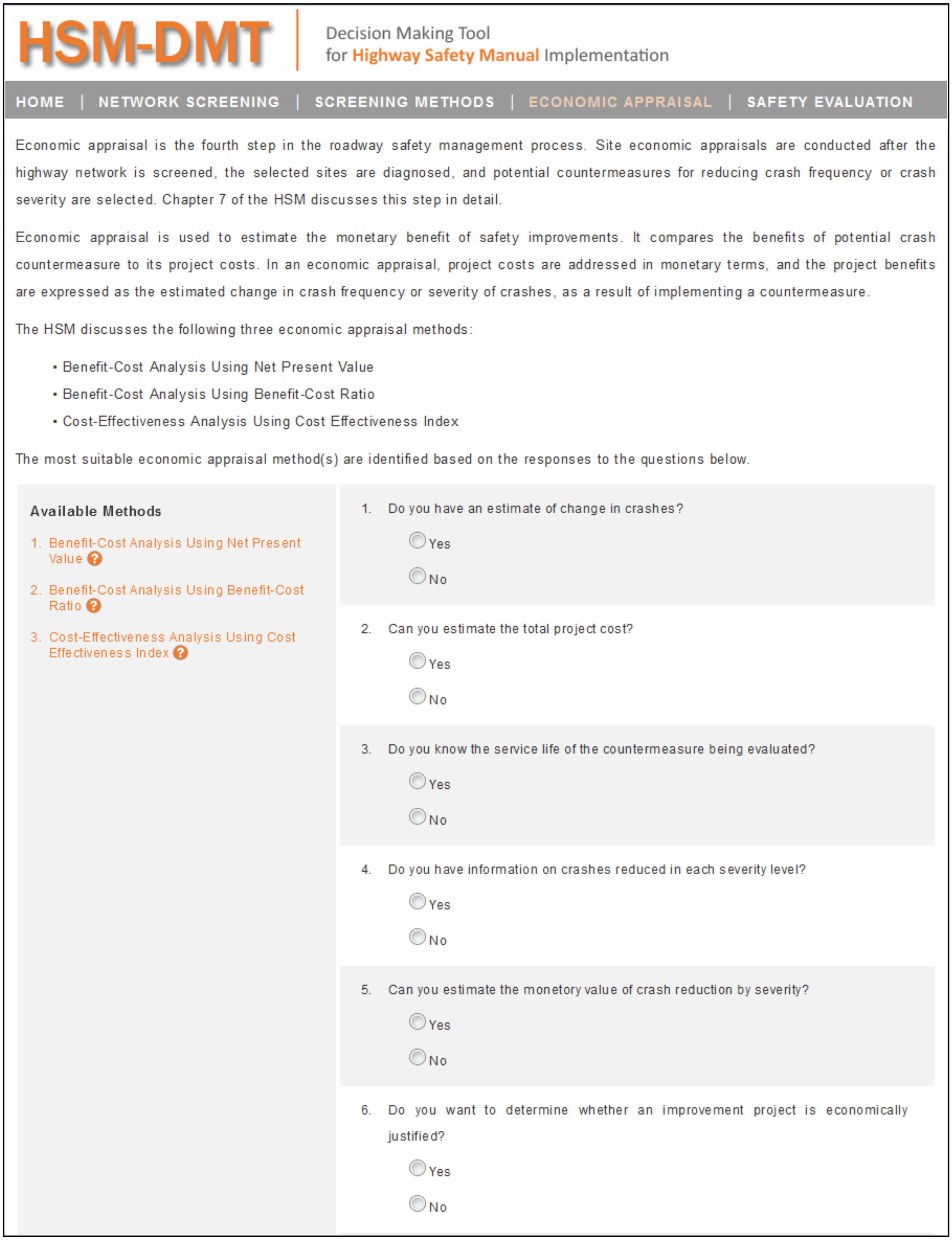


Figure 4-8: Sample Pop-up Window Describing the Screening Method



HSM-DMT

Decision Making Tool
for Highway Safety Manual Implementation

HOME | NETWORK SCREENING | SCREENING METHODS | ECONOMIC APPRAISAL | SAFETY EVALUATION

Economic appraisal is the fourth step in the roadway safety management process. Site economic appraisals are conducted after the highway network is screened, the selected sites are diagnosed, and potential countermeasures for reducing crash frequency or crash severity are selected. Chapter 7 of the HSM discusses this step in detail.

Economic appraisal is used to estimate the monetary benefit of safety improvements. It compares the benefits of potential crash countermeasure to its project costs. In an economic appraisal, project costs are addressed in monetary terms, and the project benefits are expressed as the estimated change in crash frequency or severity of crashes, as a result of implementing a countermeasure.

The HSM discusses the following three economic appraisal methods:

- Benefit-Cost Analysis Using Net Present Value
- Benefit-Cost Analysis Using Benefit-Cost Ratio
- Cost-Effectiveness Analysis Using Cost Effectiveness Index

The most suitable economic appraisal method(s) are identified based on the responses to the questions below.

Available Methods

1. Benefit-Cost Analysis Using Net Present Value ?
2. Benefit-Cost Analysis Using Benefit-Cost Ratio ?
3. Cost-Effectiveness Analysis Using Cost Effectiveness Index ?

1. Do you have an estimate of change in crashes?
   - Yes
   - No
2. Can you estimate the total project cost?
   - Yes
   - No
3. Do you know the service life of the countermeasure being evaluated?
   - Yes
   - No
4. Do you have information on crashes reduced in each severity level?
   - Yes
   - No
5. Can you estimate the monetory value of crash reduction by severity?
   - Yes
   - No
6. Do you want to determine whether an improvement project is economically justified?
   - Yes
   - No

Figure 4-9: Economic Appraisal Page

4.3.5 Safety Evaluation

As shown in Figure 4-10, the *Safety Evaluation* page briefly discusses the process and lists the following five evaluation methods discussed in the HSM:

- Naïve (Simple) Observational Before/After Study
- Observational Before/After Evaluation Study Using SPFs – the EB Method
- Observational Before/After Evaluation Study Using the Comparison-Group Method
- Observational Before/After Evaluation Study to Evaluate Shifts in Collision Crash Type Proportions
- Observational Cross-Sectional Study

The criteria used to select the most suitable method(s) are divided into two broad categories: data availability and method's robustness. In other words, the user can select the most appropriate safety effectiveness evaluation method(s) based on either data availability or method's robustness. Figures 4-11 and 4-12 show the screenshots of the two pages, data availability and method's robustness, respectively. Similar to the other pages, these webpages are also divided into three sections. The top section provides a brief overview of the factors being considered. The remaining two sections include the questions and the available methods. More information about the available methods is provided in a pop-up window, which opens when the user clicks on the icon next to the method.

HSM-DMT

Decision Making Tool
for Highway Safety Manual Implementation

HOME | NETWORK SCREENING | SCREENING METHODS | ECONOMIC APPRAISAL | SAFETY EVALUATION

As shown in the figure below, safety effectiveness evaluation is the final step in the roadway safety management process. "Safety effectiveness evaluation leads to an assessment of how crash frequency or severity has changed due to a specific treatment, or a set of treatments or projects. In situations where one treatment is applied at multiple similar sites, safety evaluation can also be used to estimate a crash modification factor (CMF) for the treatment. Finally, safety effectiveness evaluations have an important role in assessing how well funds have been invested in safety improvements. Each of these aspects of safety effectiveness evaluation may influence future decision-making activities related to allocation of funds and revisions to highway agency policies." (Source: HSM Part B, Pg. 9-1) Chapter 9 of the HSM discusses this step in detail.

The HSM discusses the following five safety effectiveness evaluation methods:

- Naïve (Simple) Observational Before/After Study
- Observational Before/After Evaluation Study Using Safety Performance Functions (SPFs)-the Empirical Bayes Method
- Observational Before/After Evaluation Study Using the Comparison-Group Method
- Observational Before/After Evaluation Study to Evaluate Shifts in Collision Crash Type Proportions
- Observational Cross-Sectional Study

The criteria used to select the most suitable safety effectiveness evaluation method(s) are divided into two broad categories.

- Data Availability
- Method's Robustness

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Figure 4-10: *Safety Evaluation* Page

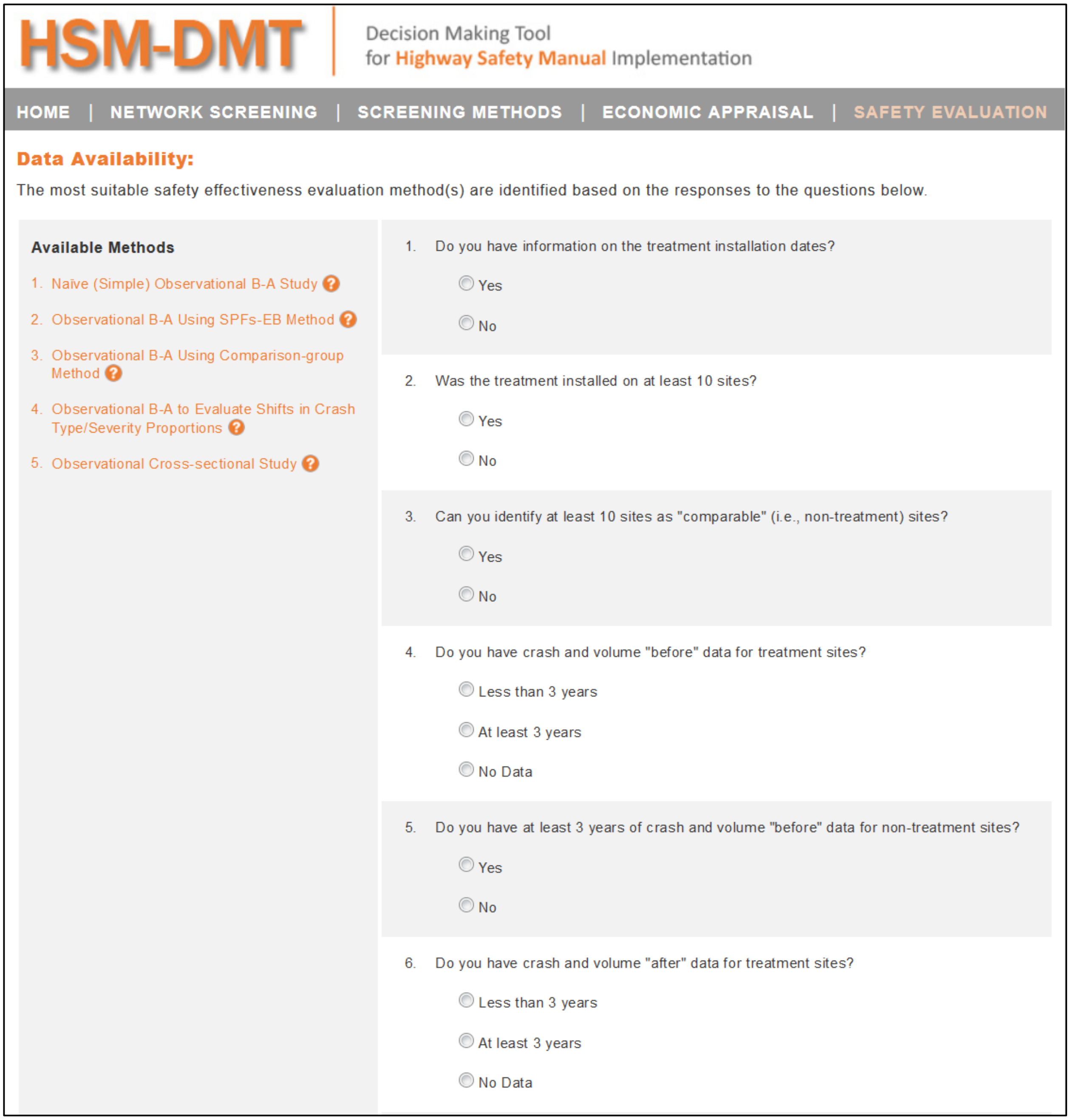

Figure 4-11: Data Availability – *Safety Evaluation* Page

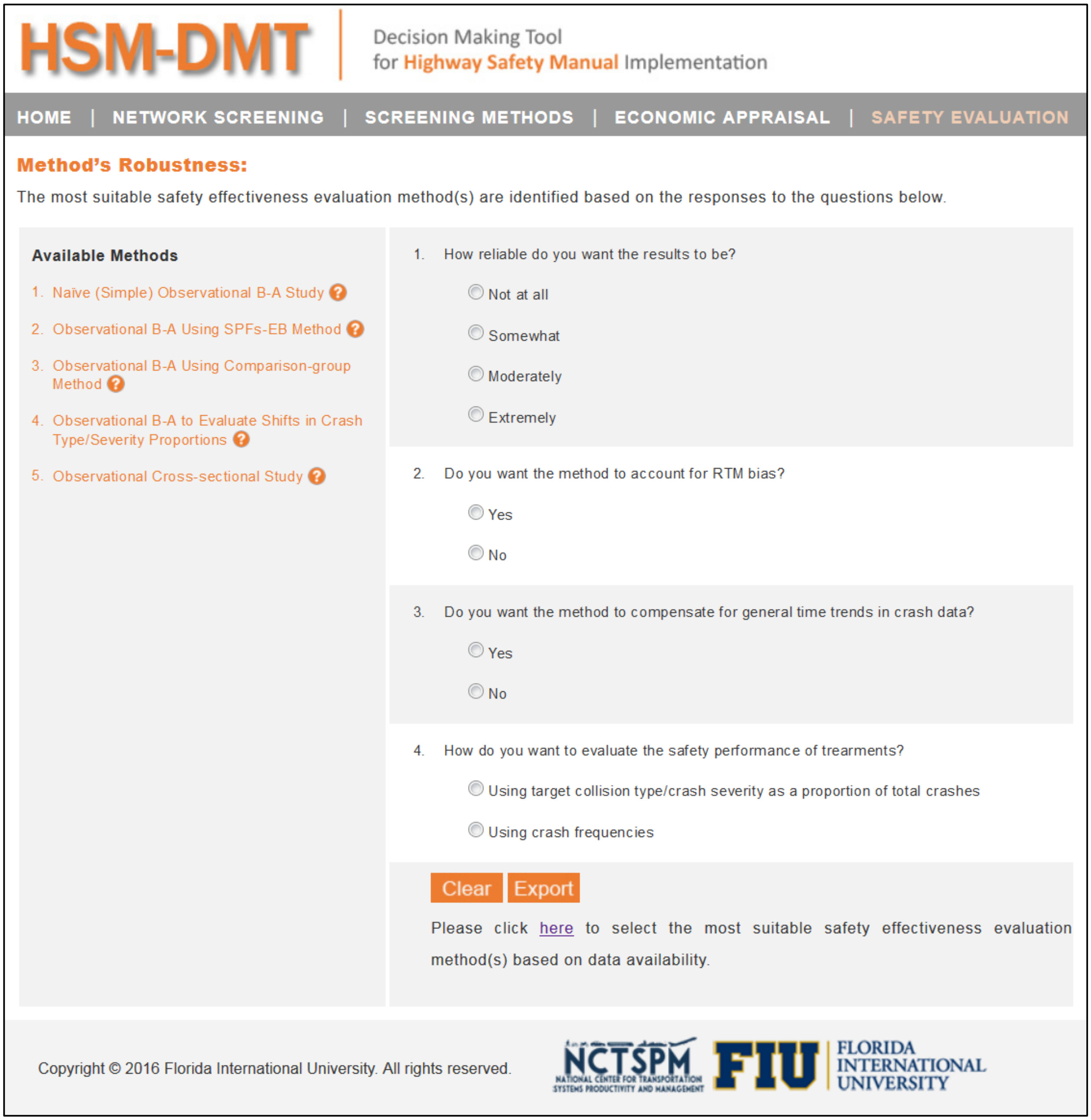

Figure 4-12: Method's Robustness – *Safety Evaluation* Page

CHAPTER 5
SUMMARY AND CONCLUSIONS

The Highway Safety Manual provides analytical tools to conduct quantitative safety analyses. For each step in the roadway safety management process, the manual simply discusses different available methods and provides no specific guidance on which methods an agency should use. Table 5-1 lists the different methods discussed in the HSM.

Table 5-1: Methods Discussed in the HSM

Roadway Safety Management Process	Available Methods
Step 1: Network Screening	*Performance Measures:* 1. Average Crash Frequency 2. Crash Rate 3. EPDO Average Crash Frequency 4. Relative Severity Index 5. Critical Crash Rate 6. Excess Predicted Average Crash Frequency using Method of Moments 7. Level of Service of Safety 8. Excess Predicted Average Crash Frequency Using SPFs 9. Probability of Specific Crash Types Exceeding Threshold Proportion 10. Excess Proportion of Specific Crash Types 11. Expected Average Crash Frequency with EB Adjustment 12. EPDO Average Crash Frequency with EB Adjustment 13. Excess Expected Average Crash Frequency with EB Adjustment
	Screening Methods: 1. Simple Ranking Method 2. Sliding Window Method 3. Peak Searching Method
Step 2: Diagnosis	Not Applicable
Step 3: Countermeasure Selection	Not Applicable
Step 4: Economic Appraisal	1. Benefit–Cost Analysis Using Net Present Value 2. Benefit–Cost Analysis Using Benefit–Cost Ratio 3. Cost-Effectiveness Analysis Using Cost Effectiveness Index
Step 5: Project Prioritization	Not Applicable
Step 6: Safety Effectiveness Evaluation	1. Naïve (Simple) Observational Before/After Study 2. Observational Before/After Evaluation Study Using SPFs – the EB Method 3. Observational Before/After Evaluation Study Using the Comparison-Group Method 4. Observational Before/After Evaluation Study to Evaluate Shifts in Collision Crash Type Proportions 5. Observational Cross-Sectional Study

The goal of this project was to develop a web-based decision making tool to help agencies in selecting the best method(s) among the ones discussed in the HSM. More specifically, the application recommends the most suitable method(s) based on an agency's data availability, available statistical expertise, and the method's data requirements and reliability.

As summarized from the table, the following steps in the roadway safety management process have multiple methods:

- Step 1: Network Screening
  - Performance Measures *(13 methods)*
  - Screening Methods *(3 methods)*
- Step 4: Economic Appraisal *(3 methods)*
- Step 6: Safety Effectiveness Evaluation *(5 methods)*

Accordingly, the *HSM-DMT (HSM Decision Making Tool)* website has the following five main pages:

- Home
- Network Screening
- Screening Methods
- Economic Appraisal
- Safety Evaluation

The *Home* page provides a brief description of the six steps in the safety management process. The *Network Screening* page includes a brief discussion about the network screening process. The page also includes links to the following three sets of questions used to select the best network screening performance measure(s):

- General factors that focus on the performance measure's robustness and data requirements.
- Factors to screen segments that pertain to screening segments and focus on the agency's data availability, staff expertise, and performance measure's robustness.
- Factors to screen intersections that pertain to screening intersections and focus on the agency's data availability, staff expertise, and performance measure's robustness.

The three pages, *General Factors*, *Factors to Screen Segments*, and *Factors to Screen Intersections*, include a brief overview of the factors being considered, the questions, and the list of recommended methods that changes dynamically based on the user's responses to the questions.

The *Screening Methods* page includes a brief overview of the screening methods, the questions to help select the best method(s), and the list of recommended methods that changes dynamically. Similarly, the *Economic Appraisal* page includes a brief overview of the economic appraisal step, the questions to help select the appropriate method(s), and the list of recommended methods that changes dynamically based on the user's responses to the questions.

Finally, the *Safety Evaluation* page includes a brief discussion about the safety effectiveness evaluation process. It also provides links to two sets of questions, based on data availability and method's robustness, to help select the best method(s). The *Data Availability* and the *Method's Robustness* pages include a brief overview of the factors being considered, the questions, and the list of recommended methods that changes dynamically based on the user's responses to the questions.

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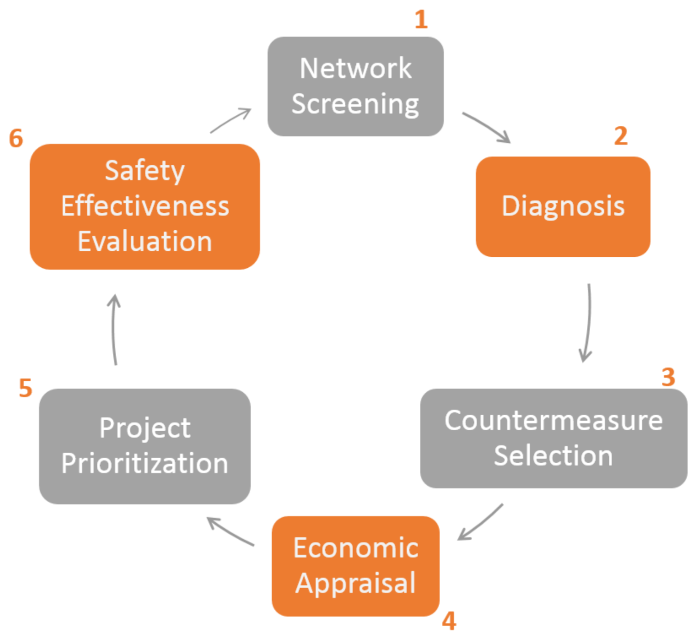
APPENDIX A:
TEXT INCLUDED IN THE WEBSITE

HOME

The Highway Safety Manual (HSM), published by American Association of State Highway and Transportation Officials (AASHTO) in 2010, provides analytical tools for quantifying the safety effects of potential changes at individual sites or a roadway network. The HSM provides quantitative methods to reliably estimate crash frequencies and severities for a range of situations, and to provide related decision-making tools to use within the roadway safety management process (i.e., network screening, diagnosis, countermeasure selection, economic appraisal, project prioritization, and safety effectiveness evaluation).



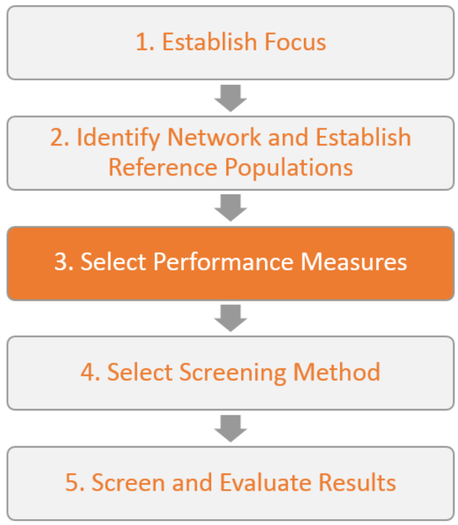
Roadway Safety Management Process

At each stage in the roadway safety management process, the HSM discusses different available methods, but provides no specific guidance on which methods an agency should use. As agencies have different needs and limitations, a one-size-fits-all approach toward selecting appropriate methods is not suitable. With minimal guidance, as with the current version of the manual, local agencies with staff that has limited access to roadway safety training, safety expertise, and the latest safety analysis tools may not select appropriate methods resulting in inefficient use of limited safety resources. The process of selecting the most suitable method can be complex involving multiple factors, including data availability, the available staff expertise, the method's robustness, the method's data requirements, etc. Therefore, sufficient guidance has to be provided to assist local agencies in selecting appropriate methods that are suitable to their needs.

This website provides a decision-making tool to assist agencies in tailoring the HSM to their needs by helping them select the most suitable methods among those discussed in the HSM.

NETWORK SCREENING

Network Screening is the process for reviewing a highway network to identify and rank sites likely to benefit from a safety improvement. Chapter 4 of the HSM discusses network screening in detail. The five major steps in network screening are:



Network Screening Steps

In the first step, the purpose and/or intended outcome of the network screening analysis is established. For example, a focus area could be to identify sites with potential to reduce the average crash frequency or crash severity, or to target specific crash types or severity for formulation of system-wide policy. In the second step, the network is identified and the reference populations are established. For example, the type of facilities to be screened could be identified. Next, as part of the third step, the most suitable performance measures are selected from a variety of performance measures. The selection depends on several factors, including study focus, data availability, etc. Once the appropriate performance measures are identified, the next step is to select a screening method. Finally, the last step is to screen the network and evaluate the results.

As discussed in Chapter 4 of the HSM, the third and fourth steps in the network screening process require analysts to select a performance measure and a screening method among the ones discussed in the manual. This page focuses on assisting agencies in selecting the most suitable performance measure among the 13 discussed in the HSM. The next page, "SCREENING METHODS," focuses on selecting the most suitable screening method to screen segments.

The HSM discusses the following 13 performance measures.

1. Average Crash Frequency
2. Crash Rate
3. Equivalent Property Damage Only (EPDO) Average Crash Frequency
4. Relative Severity Index
5. Critical Crash Rate
6. Excess Predicted Average Crash Frequency using Method of Moments

7. Level of Service of Safety
8. Excess Predicted Average Crash Frequency Using Safety Performance Functions (SPFs)
9. Probability of Specific Crash Types Exceeding Threshold Proportion
10. Excess Proportion of Specific Crash Types
11. Expected Average Crash Frequency with Empirical Bayes (EB) Adjustment
12. EPDO Average Crash Frequency with EB Adjustment
13. Excess Expected Average Crash Frequency with EB Adjustment

The criteria used to select the performance measures are divided into three broad categories.

- General Factors
- Factors to Screen Segments
- Factors to Screen Intersections

General Factors:

The general factors that help determine the most suitable performance measure focus on the performance measure's robustness and data requirements. The most suitable performance measures are identified based on the responses to the questions below.

Factors to Screen Segments:

The factors that help determine the most suitable performance measure to screen segments focus on the agency's data availability, staff expertise, and the performance measure's robustness. The most suitable performance measures are identified based on the responses to the questions below.

Factors to Screen Intersections:

The factors that help determine the most suitable performance measure to screen intersections focus on the agency's data availability, staff expertise, and the performance measure's robustness. The most suitable performance measures are identified based on the responses to the questions below.

Pop-up Windows

Average Crash Frequency

Description	The site with the most total crashes or the most crashes of a particular crash severity or type, in a given time period, is given the highest rank.
Strengths	• Simple
Limitations	• Does not account for RTM bias • Does not estimate a threshold to indicate sites experiencing more crashes than predicted for sites with similar characteristics • Does not account for traffic volume • Will not identify low-volume collision sites where simple cost-effective mitigating countermeasures could be easily applied
Data Needs	• Crash data by location
Output	The locations are ranked based on crash frequencies
More Details	HSM Part B, Pages 4-24 to 4-25

Crash Rate

Description	Crash rate normalizes the frequency of crashes with the exposure, usually traffic volume reported as 'million entering vehicles' for intersections and 'vehicle miles traveled' for segments.
Strengths	• Simple • Could be modified to account for severity if an EPDO or RSI-based crash count is used
Limitations	• Does not account for RTM bias • Does not identify a threshold to indicate sites experiencing more crashes than predicted for sites with similar characteristics • Comparisons cannot be made across sites with significantly different traffic volumes • Will mistakenly prioritize low-volume, low-collision sites
Data Needs	• Crash data by location • Roadway data (roadway location and facility type) • Traffic data (AADT)
Output	The locations are ranked based on their crash rates
More Details	HSM Part B, Pages 4-26 to 4-28

Equivalent Property Damage Only (EPDO) Average Crash Frequency

Description	The Equivalent Property Damage Only (EPDO) Average Crash Frequency performance measure assigns weighting factors to crashes by severity (fatal, injury, property damage only) to develop a combined frequency and severity score per site.
Strengths	• Simple • Considers crash severity
Limitations	• Does not account for RTM bias • Does not identify a threshold to indicate sites experiencing more crashes than predicted for sites with similar characteristics • Does not account for traffic volume • May overemphasize locations with a low frequency of severe crashes, depending on weighting factors used
Data Needs	• Crash data by location and severity • Crash severity weighting factors • Crash costs by crash severity
Output	The locations are ranked based on their EPDO scores
More Details	HSM Part B, Pages 4-28 to 4-31

Relative Severity Index

Description	Crash costs are assigned to each crash type and the total cost of all crashes is calculated for each location. An average crash cost per site is then compared to an overall average crash cost for the location's reference population. The resulting RSI shows whether or not a site is experiencing higher crash costs than the average for other sites with similar characteristics.
Strengths	• Simple • Considers collision type and crash severity
Limitations	• Does not account for RTM bias • May overemphasize locations with a small number of severe crashes depending on weighting factors used • Does not account for traffic volume • Will mistakenly prioritize low-volume, low-collision sites
Data Needs	• Crash data • Roadway data (roadway location and facility type) • Crash costs of each crash type • Reference population
Output	The locations are ranked based on their relative severity index
More Details	HSM Part B, Pages 4-31 to 4-35

Critical Crash Rate

Description	The critical crash rate depends on the average crash rate at similar sites, traffic volume, and a statistical constant that represents a desired level of significance. The observed crash rate at each site is compared to the calculated critical crash rate. Sites that exceed their respective critical crash rate are flagged for further review.
Strengths	• Reduces exaggerated effect of sites with low volumes • Considers variance in crash data • Establishes a threshold for comparison
Limitations	• Does not account for RTM bias
Data Needs	• Crash data by location • Roadway data (roadway location and facility type) • AADT
Output	The locations are ranked based on their critical crash rate
More Details	HSM Part B, Pages 4-35 to 4-39

Excess Predicted Average Crash Frequency using Method of Moments

Description	A site's observed average crash frequency is adjusted based on the variance in the crash data and average crash frequency for the site's reference population. The adjusted observed average crash frequency for the site is compared to the average crash frequency for the reference population.
Strengths	• Establishes a threshold of predicted performance for a site • Considers variance in crash data • Allows sites of all types to be ranked in one list • Method concepts are similar to EB methods
Limitations	• Does not account for RTM bias • Does not account for traffic volume • Some sites may be identified for further study because of unusually low frequency of non-target crash types • Ranking results are influenced by reference populations; sites near boundaries of reference populations may be overemphasized
Data Needs	• Crash data (crash location, crash type, crash severity, crash time) • Reference population
Output	The locations are ranked based on their potential for improvement
More Details	HSM Part B, Pages 4-40 to 4-44

Level of Service of Safety

Description	The predicted average crash frequency for sites with similar characteristics is predicted from an SPF calibrated to local conditions. The observed crash frequency is compared to the predicted average crash frequency. Each site is placed into one of four LOSS classifications, depending on the degree to which the observed average crash frequency is different than the predicted average crash frequency.
Strengths	• Considers variance in crash data • Accounts for volume • Establishes a threshold for measuring potential to reduce crash frequency
Limitations	• Effects of RTM bias may still be present in the results
Data Needs	• Crash data by location • AADT • Calibrated SPFs and overdispersion parameter
Output	The observed crash frequency at each location is compared to the LOSS limits, and the locations are assigned a LOSS level. Finally, the locations are ranked based on their LOSS levels.
More Details	HSM Part B, Pages 4-44 to 4-48

Excess Predicted Average Crash Frequency Using Safety Performance Functions (SPFs)

Description	The site's observed average crash frequency is compared to a predicted average crash frequency from an SPF. The difference between the observed and predicted crash frequencies is the excess predicted crash frequency using SPFs.
Strengths	• Accounts for traffic volume • Estimates a threshold for comparison
Limitations	• Effects of RTM bias may still be present in the results
Data Needs	• Crash data by location • Roadway data (roadway location and facility type) • AADT • Calibrated SPFs and overdispersion parameter
Output	The locations are ranked based on the excess predicted crash frequency
More Details	HSM Part B, Pages 4-48 to 4-52

Probability of Specific Crash Types Exceeding Threshold Proportion

Description	Sites are prioritized based on the probability that the true proportion, p_i, of a particular crash type or severity (e.g., long-term predicted proportion) is greater than the threshold proportion, p^*_i. A threshold proportion (p^*_i) is selected for each population, typically based on the proportion of the target crash type or severity in the reference population.
Strengths	• Can also be used as a diagnostic tool • Considers variance in data • Not affected by RTM bias
Limitations	• Does not account for traffic volume • Some sites may be identified for further study because of unusually low frequency of non-target crash types
Data Needs	• Crash data by crash location and crash type • Roadway data (roadway location and facility type)
Output	The locations are ranked based on the probability of specific crash type exceeding threshold proportion
More Details	HSM Part B, Pages 4-52 to 4-57

Excess Proportion of Specific Crash Types

Description	The sites are ranked based on excess proportion, which is the difference between the true proportion, p_i, and the threshold proportion, p^*_i. The excess is calculated for a site if the probability that a site's long-term observed proportion is higher than the threshold proportion, p^*_i, exceeds a certain limiting probability (e.g., 90 percent).
Strengths	• Can also be used as a diagnostic tool • Considers variance in data • Not affected by RTM bias
Limitations	• Does not account for traffic volume • Some sites may be identified for further study because of unusually low frequency of non-target crash types
Data Needs	• Crash data by crash location and crash type • Roadway data (roadway location and facility type)
Output	The locations are ranked in descending order based on the difference between the observed and threshold proportion
More Details	HSM Part B, Pages 4-57 to 4-58

Expected Average Crash Frequency with EB Adjustment

Description	The observed average crash frequency and the predicted average crash frequency from an SPF are weighted together using the EB method to calculate an expected average crash frequency.
Strengths	• Accounts for RTM bias
Limitations	• Requires SPFs calibrated to local conditions
Data Needs	• Crash data (crash location, crash type, crash severity, crash time) • Roadway data (roadway location and facility type) • Basic site characteristics • Calibrated SPFs for the reference population, overdispersion parameter
Output	The locations are ranked based on the expected average crash frequencies
More Details	HSM Part B, Pages 4-58 to 4-65

EPDO Average Crash Frequency with EB Adjustment

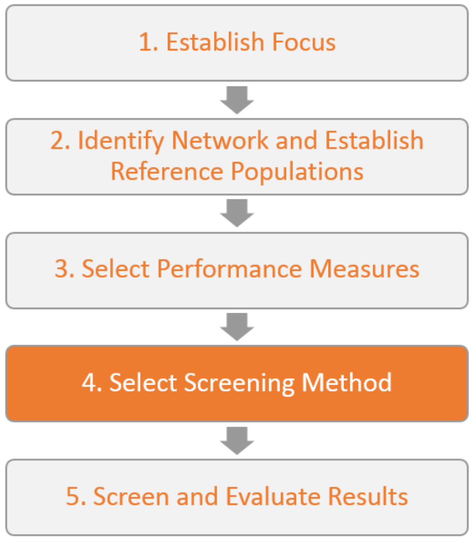
Description	Crashes by severity are predicted using the EB procedure. The expected crashes by severity are converted to EPDO crashes using the EPDO procedure.
Strengths	• Accounts for RTM bias • Considers crash severity
Limitations	• Requires SPFs calibrated to local conditions • May overemphasize locations with a small number of severe crashes depending on weighting factors used
Data Needs	• Crash data (crash location, crash type, crash severity, crash time) • Roadway data (roadway location and facility type) • Basic site characteristics • Calibrated SPFs for the reference population, overdispersion parameter • EPDO weights
Output	The locations are ranked based on the expected EPDO values
More Details	HSM Part B, Pages 4-65 to 4-74

Excess Expected Average Crash Frequency with EB Adjustment

Description	The observed average crash frequency and the predicted average crash frequency from an SPF are weighted together using the EB method to calculate an expected average crash frequency that accounts for RTM bias. The resulting expected average crash frequency is compared to the predicted average crash frequency from an SPF. The difference between the EB-adjusted average crash frequency and the predicted average crash frequency from an SPF is the excess expected average crash frequency.
Strengths	• Accounts for RTM bias • Identifies a threshold to indicate sites experiencing more crashes than expected for sites with similar characteristics.
Limitations	• Requires SPFs calibrated to local conditions
Data Needs	• Crash data (crash location, crash type, crash severity, crash time) • Roadway data (roadway location and facility type) • Basic site characteristics • Calibrated SPFs for the reference population, overdispersion parameter
Output	The locations are ranked based on the excess expected crash frequency.
More Details	HSM Part B, Pages 4-75 to 4-83

SCREENING METHODS FOR SEGMENTS

Network Screening is the process for reviewing a highway network to identify and rank sites likely to benefit from a safety improvement. Chapter 4 of the HSM discusses network screening in detail. The five major steps in network screening are:



Network Screening Steps

In the first step, the purpose and/or intended outcome of the network screening analysis is established. In the second step, the network is identified and the reference populations are established. Next, as part of the third step, the most suitable performance measures are selected from a variety of performance measures. Once the appropriate performance measures are identified, the next step is to select a screening method. Finally, the last step is to screen the network and evaluate the results.

As discussed in Chapter 4 of the HSM, the third and fourth steps in the network screening process require analysts to select a performance measure and a screening method among the ones discussed in the manual. This page focuses on selecting the most suitable screening method to screen segments.

Screening roadway segments requires identifying the location within the roadway segment or ramp that is most likely to benefit from a countermeasure intended to result in a reduction in crash frequency or severity. The location (i.e., sub-segment) within a segment that shows the most potential for improvement is used to specify the critical crash frequency of the entire segment and subsequently select segments for further investigation. The HSM discusses the following three screening methods for segments:

1. Simple Ranking Method
2. Sliding Window Method
3. Peak Searching Method

The most suitable screening method is identified based on the responses to the questions below.

Pop-up Windows

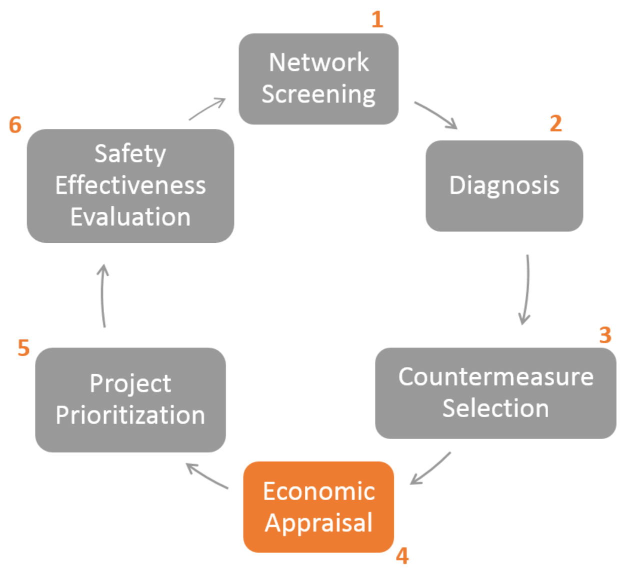
Simple Ranking Method: “The performance measures are calculated for all of the sites under consideration, and the results are ordered from high to low.” (Source: HSM Part B, Pg. 4-18)

Sliding Window Method: “A window of a specified length is conceptually moved along the road segment from beginning to end in increments of a specified size. The performance measure chosen to screen the segment is applied to each position of the window, and the results of the analysis are recorded for each window. A window pertains to a given segment if at least some portion of the window is within the boundaries of the segment. From all the windows that pertain to a given segment, the window that shows the most potential for reduction in crash frequency out of the whole segment is identified and is used to represent the potential for reduction in crash frequency of the whole segment. After all segments are ranked according to the respective highest sub-segment value, those segments with the greatest potential for reduction in crash frequency or severity are studied in detail to identify potential countermeasures.” (Source: HSM Part B, Pg. 4-15)

Peak Searching Method: “In the peak searching method each individual roadway segment is subdivided into windows of similar length, potentially growing incrementally in length until the length of the window equals the length of the entire roadway segment. The windows do not span multiple roadway segments. 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 the potential for reduction in crashes of that site (i.e., whole roadway segment) relative to the other sites being screened.” (Source: HSM Part B, Pg. 4-16)

ECONOMIC APPRAISAL

As shown in the figure below, economic appraisal is the fourth step in the roadway safety management process. Site economic appraisals are conducted after the highway network is screened, the selected sites are diagnosed, and potential countermeasures for reducing crash frequency or crash severity are selected. Chapter 7 of the HSM discusses this step in detail.



Roadway Safety Management Process

Economic appraisal is used to estimate the monetary benefit of safety improvements. It compares the benefits of a potential crash countermeasure to its project costs. In an economic appraisal, project costs are addressed in monetary terms, and the project benefits are expressed as the estimated change in crash frequency or severity of crashes, as a result of implementing a countermeasure.

The HSM discusses the following three economic appraisal methods:

- Benefit–Cost Analysis Using Net Present Value
- Benefit–Cost Analysis Using Benefit–Cost Ratio
- Cost-Effectiveness Analysis Using Cost Effectiveness Index

The most suitable economic appraisal method(s) are identified based on the responses to the questions below.

Pop-up Windows

Benefit–Cost Analysis Using Net Present Value: The net present value (NPV) method, also referred to as the net present worth (NPW) method, "is used to express the difference between discounted costs and discounted benefits of an individual improvement project in a single amount. The term "discount" indicates that the monetary costs and benefits are converted to a present value using a discount rate. A project with an NPV greater than zero indicates a project with benefits that are sufficient to justify implementation of the countermeasure. Countermeasure(s) are ordered from the highest to lowest NPV." (Source: HSM Part B, Pg. 7-8)

Benefit–Cost Analysis Using Benefit–Cost Ratio: "A benefit–cost ratio is the ratio of the present-value benefits of a project to the implementation costs of the project (BCR = Benefits/Costs). If the ratio is greater than 1.0, then the project is considered economically justified. Countermeasures are ranked from highest to lowest BCR." (Source: HSM Part B, Pg. 7-9)

Cost-Effectiveness Analysis Using Cost Effectiveness Index: "The cost-effectiveness of a countermeasure implementation project is expressed as the annual cost per crash reduced. Both the project cost and the estimated average crash frequency reduced must apply to the same time period, either on an annual basis or over the entire life of the project. This method requires an estimate of the change in crashes and cost estimate associated with implementing the countermeasure. However, the change in estimated crash frequency is not converted to a monetary value." (Source: HSM Part B, Pg. 7-10)

SAFETY EVALUATION

Safety effectiveness evaluation is the final step in the roadway safety management process. "Safety effectiveness evaluation leads to an assessment of how crash frequency or severity has changed due to a specific treatment, or a set of treatments or projects. In situations where one treatment is applied at multiple similar sites, safety evaluation can also be used to estimate a crash modification factor (CMF) for the treatment. Finally, safety effectiveness evaluations have an important role in assessing how well funds have been invested in safety improvements. Each of these aspects of safety effectiveness evaluation may influence future decision-making activities related to allocation of funds and revisions to highway agency policies." (Source: HSM Part B, Pg. 9-1) Chapter 9 of the HSM discusses this step in detail.

The HSM discusses the following five safety effectiveness evaluation methods:

- Naïve (Simple) Observational Before/After Study
- Observational Before/After Evaluation Study Using Safety Performance Functions (SPFs) – the Empirical Bayes Method
- Observational Before/After Evaluation Study Using the Comparison-Group Method
- Observational Before/After Evaluation Study to Evaluate Shifts in Collision Crash Type Proportions
- Observational Cross-Sectional Study

The criteria used to select the most suitable safety effectiveness evaluation method(s) are divided into two broad categories.

- Data Availability
- Method's Robustness

Data Availability:

The most suitable safety effectiveness evaluation method(s) are identified based on the responses to the questions below.

Method's Robustness:

The most suitable safety effectiveness evaluation method(s) are identified based on the responses to the questions below.

Pop-up Windows

Naïve (Simple) Observational Before/After Study: This approach uses crash frequency in the before period as the expected crash frequency in the after period had the safety treatment not been implemented.

Observational Before/After Evaluation Study Using SPFs – the EB Method: This approach combines a site's observed crash frequency and SPF-based predicted average crash frequency to estimate the expected average crash frequency for that site in the after period had the treatment not been implemented. For more details, please refer to HSM Part B, Pages 9-7 to 9-9.

Observational Before/After Evaluation Study Using the Comparison-Group Method: The comparison group consists of a number of non-treatment sites that exhibit a close agreement with the treatment sites with regard to the yearly rate of change in crash frequencies during the before period and also are comparable in site characteristics such as traffic volume and geometric to the treatment sites, but without the specific improvement being evaluated. For more details, please refer to HSM Part B, Pages 9-9 to 9-12.

Observational Before/After Evaluation Study to Evaluate Shifts in Collision Crash Type Proportions: This approach uses crash frequency data by collision types only for treatment sites and does not require data for non-treatment or comparison sites. For more details, please refer to HSM Part B, Pages 9-12 to 9-13.

Observational Cross-Sectional Study: This approach is applied when before data at treatment sites are not available. It uses statistical modeling techniques that consider the crash experience of sites with and without a particular treatment of interest (such as roadway lighting or a shoulder rumble strip) or with various levels of a continuous variable that represents a treatment of interest (such as lane width). For more details, please refer to HSM Part B, Pg. 9-14.

APPENDIX B:
QUESTIONS INCLUDED IN THE WEBSITE

NETWORK SCREENING

General Factors

1. Do you want the method to consider detailed roadway data (i.e., the data variables required and recommended in the HSM Part C)?
    - Yes
    - No

2. Do you want the method to consider variance in crash data?
    - Yes
    - No

3. Do you want the method to account for RTM bias?
    - Yes
    - No

4. Do you want the method to estimate performance threshold?
    - Yes
    - No

5. Do you want the method to consider the effect of traffic volume?
    - Yes
    - No

6. Do you want the method to consider crash severity?
    - Yes
    - No

7. On a scale of 1–10, how reliable do you want the results to be?

1 2 3 4 5 6 7 8 9 10

8. Do you want to analyze multiple facilities at one time (i.e., compare results for multiple facilities)?
    - Yes
    - No

9. Do you want the method to use calibrated SPFs and Overdispersion Parameters?
    - Yes
    - No

10. What is the available level of statistical expertise?
    - Basic
    - Intermediate
    - Advanced
    - Expert

11. How do you want to screen segments?
    - Simple Ranking
    - Sliding Window
    - Peak Searching

12. Do you want the method to use multiple years of crash and traffic data?
    - Yes
    - No

13. Do you want the method to use EPDO weighting factors, and crash cost estimation by severity/type?
    - EPDO Weighting Factors
    - Crash Costs by Severity
    - Crash Costs by Crash Type
    - No

Factors to Screen Segments

1. Do you have general roadway data required for segment categorization?
    - Yes
    - No

2. Do you have detailed roadway data (i.e., the data variables required and recommended in the HSM Part C)?
    - Yes
    - No

3. Do you have AADT data for segments?
    - Yes
    - No

4. Do you have crash data?
    - Yes
    - No

5. Are crashes assigned to specific locations?
    - Yes
    - No

6. Do you have information on crash severity?
    - Yes
    - No

7. Do you have information on crash type?
    - Yes
    - No

8. Do you have multiple years of crash and traffic data?
    - Yes
    - No

9. Do you have EPDO weighting factors, and crash cost estimation by severity/type?
    - EPDO Weighting Factors
    - Crash Costs by Severity
    - Crash Costs by Crash Type
    - No

10. Do you have calibrated SPFs and Overdispersion Parameters?
    - Yes
    - No

11. What is the available level of statistical expertise?
    - Basic
    - Intermediate
    - Advanced
    - Expert

12. How do you want to screen segments?
    - Simple Ranking
    - Sliding Window
    - Peak Searching

13. Do you want the method to consider the effect of traffic volume?
    - Yes
    - No

14. Do you want the method to consider variance in crash data?
    - Yes
    - No

15. Do you want the method to account for RTM bias?
    - Yes
    - No

16. Do you want the method to estimate performance threshold?
    - Yes
    - No

17. On a scale of 1–10, how reliable do you want the results to be?

    1 2 3 4 5 6 7 8 9 10

18. Do you want to analyze multiple facilities at one time (i.e., compare results for multiple facilities)?
    - Yes
    - No

Factors to Screen Intersections

1. Do you have general intersection data required for intersection categorization?
    - Yes
    - No

2. Do you have detailed intersection data (i.e., the data variables required and recommended in the HSM Part C)?
    - Yes
    - No

3. Do you have AADT data for major and minor roads at intersections?
    - Yes
    - No

4. Do you have crash data?
    - Yes
    - No

5. Are crashes assigned to specific locations?
    - Yes
    - No

6. Do you have multiple years of crash and traffic data?
    - Yes
    - No

7. Do you have information on crash severity?
    - Yes
    - No

8. Do you have information on crash type?
    - Yes
    - No

9. Do you have EPDO weighting factors or crash costs by severity/type?
    - EPDO Weighting Factors
    - Crash Costs by Severity
    - Crash Costs by Crash Type
    - No

10. Do you have calibrated SPFs and Overdispersion Parameters?
    - Yes
    - No

11. What is the available level of statistical expertise?
    - Basic
    - Intermediate
    - Advanced
    - Expert

12. Do you want the method to consider the effect of traffic volume?
    - Yes
    - No

13. Do you want the method to consider variance in crash data?
    - Yes
    - No

14. Do you want the method to account for RTM bias?
    - Yes
    - No

15. Do you want the method to estimate performance threshold?
    - Yes
    - No

16. On a scale of 1–10, how reliable do you want the results to be?

1 2 3 4 5 6 7 8 9 10

17. Do you want to analyze multiple facilities at one time (i.e., compare results for multiple facilities)?
    - Yes
    - No

SCREENING METHOD OF SEGMENTS

1. Do you want to analyze the entire segment as one section?
    - Yes
    - No

2. Do you want to compensate for errors in crash location reporting?
    - Yes
    - No

3. Do you want to test the statistical reliability of the estimate?
    - Yes
    - No

ECONOMIC APPRAISAL

1. Do you have an estimate of change in crashes?
    - Yes
    - No

2. Can you estimate the total project cost?
    - Yes
    - No

3. Do you know the service life of the countermeasure being evaluated?
    - Yes
    - No

4. Do you have information on crashes reduced in each severity level?
    - Yes
    - No

5. Can you estimate the monetary value of crash reduction by severity?
    - Yes
    - No

6. Do you want to determine whether an improvement project is economically justified?
    - Yes
    - No

7. Do you want to determine which alternative is most cost-effective?
    - Yes
    - No

8. Do you want to evaluate multiple projects across multiple sites?
    - Yes
    - No

9. Do you want to easily justify improvements funded through the Highway Safety Improvement Program (HSIP)?
    - Yes
    - No

10. Do you want to identify the most cost-effective mix of projects given a specific budget?
    - Yes
    - No

SAFETY EFFECTIVENESS EVALUATION

Data Availability

1. Do you have information on the treatment installation dates?
    - Yes
    - No

2. Was the treatment installed on at least 10 sites?
    - Yes
    - No

3. Can you identify at least 10 sites as "comparable" (i.e., non-treatment) sites?
    - Yes
    - No

4. Do you have crash and volume "before" data for treatment sites?
    - At least 3 years
    - Less than 3 years
    - No

5. Do you have at least 3 years of crash and volume "before" data for non-treatment sites?
    - Yes
    - No

6. Do you have crash and volume "after" data for treatment sites?
    - At least 3 years
    - Less than 3 years
    - No

7. Do you have at least 3 years of crash and volume "after" data for non-treatment sites?
    - Yes
    - No

8. Do you have SPFs for non-treatment (i.e., comparison group) site types?
    - Yes
    - No

9. What is the available level of statistical expertise?
    - Basic
    - Intermediate
    - Advanced
    - Expert

10. Do you want to evaluate ONLY a single project/treatment site?
- Yes
- No

11. Why do you want to evaluate multiple sites?
- To determine the treatment's safety effectiveness
- To determine CMFs

Method's Robustness

1. How reliable do you want the results to be?
    - Not At All
    - Somewhat
    - Moderately
    - Extremely

2. Do you want the method to account for RTM bias?
    - Yes
    - No

3. Do you want the method to compensate for general time trends in crash data?
    - Yes
    - No

4. How do you want to evaluate the safety performance of treatments?
    - Using crash frequencies
    - Using target collision type/crash severity as a proportion of total crashes

APPENDIX C:
LOGIC TO SELECT MOST SUITABLE METHOD(S)

Table C-1: Select Network Screening Performance Measure(s) based on General Factors

Question	A	B	C	D	E	F	G	H	I	J	K	L	M
Do you want the method to consider detailed roadway data (i.e., the data variables required and recommended in the HSM Part C)?	No	No	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes
Do you want the method to consider variance in crash data?	No	No	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Do you want the method to account for RTM bias?	No	No	No	No	No	No	No	No	Yes No	Yes No	Yes	Yes	Yes
Do you want the method to estimate performance threshold?	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Do you want the method to consider the effect of traffic volume?	No	Yes	No	No	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes
Do you want the method to consider crash severity?	No	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
On a scale of 1–10, how reliable do you want the results to be?	1 2	4	3	5	5	6	7	7	5	5	8	8	9 10
Do you want to analyze multiple facilities at one time (i.e., compare results for multiple facilities)?	No	Yes	No	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes
Do you want the method to use calibrated SPFs and Overdispersion Parameters?	No	No	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes
What is the available level of statistical expertise?[1]	Basic	Basic	Basic	Basic	Int	Int	Adv	Exp	Adv	Adv	Exp	Exp	Exp
How do you want to screen segments?[2]	SR SW	SR SW	SR SW	SR SW	SR SW	SR SW	SR SW	SR SW	SR SW	SR SW	SR SW PS	SR SW PS	SR SW PS
Do you want the method to use multiple years of crash and traffic data?	No	No	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes
Do you want the method to use EPDO weighting factors?	No	No	Yes	No	No	No	No	No	No	No	No	Yes	No
Do you want the method to use crash cost estimation by severity?	No	No	Yes	Yes	No	No	No	No	No	No	No	Yes	No
Do you want the method to use crash cost estimation by type?	No	No	No	Yes	No	No	No	No	No	No	No	No	No

Note: A: Average Crash Frequency; B: Crash Rate; C: EPDO Average Crash Frequency; D: Relative Severity Index; E: Critical Crash Rate; F: Excess Predicted Average Crash Frequency using Method of Moments; G: Level of Service of Safety; H: Excess Predicted Average Crash Frequency Using SPFs; I: Probability of Specific Crash Types Exceeding Threshold Proportion; J: Excess Proportion of Specific Crash Types; K: Expected Average Crash Frequency with EB Adjustment; L: EPDO Average Crash Frequency with EB Adjustment; M: Excess Expected Average Crash Frequency with EB Adjustment.

[1] Int: Intermediate; Adv: Advanced; Exp: Expert. [2] SR: Simple Ranking; SW: Sliding Window; PS: Peak Searching.

Table C-2: Select Network Screening Performance Measure(s) for Segments

Question	A	B	C	D	E	F	G	H	I	J	K	L	M
Do you have general roadway data required for segment categorization?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Do you have detailed roadway data (i.e., the data variables required and recommended in the HSM Part C)?	No	No	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes
Do you have AADT data for segments?	No	Yes	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Do you have crash data?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are crashes assigned to specific locations?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes No	Yes No	Yes No
Do you have information on crash severity?[1]	No	Yes No	Yes	Yes No[1]	Yes No	Yes No	Yes No	Yes No	Yes No[1]	Yes No[1]	Yes No	Yes	Yes No
Do you have information on crash type?	Yes No	Yes No	Yes No	Yes No[1]	Yes No	Yes No	Yes No	Yes No	Yes No[1]	Yes No[1]	Yes No	Yes No	Yes No
Do you have multiple years of crash and traffic data?	No	No	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes
Do you have EPDO weighting factors?	No	No	Yes	No	No	No	No	No	No	No	No	Yes	No
Do you have crash cost estimation by severity?	No	No	Yes	Yes	No	No	No	No	No	No	No	Yes	No
Do you have crash cost estimation by type?	No	No	No	Yes	No	No	No	No	No	No	No	No	No
Do you have calibrated SPFs and ODP?	No	No	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes
What is the available level of statistical expertise?[2]	Bas	Bas	Bas	Bas	Int	Int	Adv	Exp	Adv	Adv	Exp	Exp	Exp
How do you want to screen segments?[3]	SR SW	SR SW	SR SW	SR SW	SR SW	SR SW	SR SW	SR SW	SR SW	SR SW	SR SW PS	SR SW PS	SR SW PS
Do you want the method to consider the effect of traffic volume?	No	Yes	No	No	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes
Do you want the method to consider variance in crash data?	No	No	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Do you want the method to account for RTM bias?	No	No	No	No	No	No	No	No	Yes No	Yes No	Yes	Yes	Yes
Do you want the method to estimate performance threshold?	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
On a scale of 1–10, how reliable do you want the results to be?	1 2	4	3	5	5	6	7	7	5	5	8	8	9 10
Do you want to analyze multiple facilities at one time (i.e., compare results for multiple facilities)?	No	Yes	No	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes

Note: A: Average Crash Frequency; B: Crash Rate; C: EPDO Average Crash Frequency; D: Relative Severity Index; E: Critical Crash Rate; F: Excess Predicted Average Crash Frequency using Method of Moments; G: Level of Service of Safety; H: Excess Predicted Average Crash Frequency Using SPFs; I: Probability of Specific Crash Types Exceeding Threshold Proportion; J: Excess Proportion of Specific Crash Types; K: Expected Average Crash Frequency with EB Adjustment; L: EPDO Average Crash Frequency with EB Adjustment; M: Excess Expected Average Crash Frequency with EB Adjustment.

[1] Either crash severity or crash type. [2] SR: Simple Ranking; SW: Sliding Window; PS: Peak Searching. [3] Bas: Basic; Int: Intermediate; Adv: Advanced; Exp: Expert.

Table C-3: Select Network Screening Performance Measure(s) for Intersections

Question	A	B	C	D	E	F	G	H	I	J	K	L	M
Do you have general intersection data required for intersection categorization?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Do you have detailed intersection data (i.e., the data variables required and recommended in the HSM Part C)?	No	No	No	No	No	No	No	Yes	No	No	Yes	Yes	Yes
Do you have AADT data for major and minor roads at intersections?	No	Yes	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Do you have crash data?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are crashes assigned to specific locations?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes No	Yes No	Yes No
Do you have multiple years of crash and traffic data?	No	No	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes
Do you have information on crash severity?	No	Yes No	Yes	Yes No[1]	Yes No	Yes No	Yes No	Yes No	Yes No[1]	Yes No[1]	Yes No	Yes	Yes No
Do you have information on crash type?	Yes No	Yes No	Yes No	Yes No[1]	Yes No	Yes No	Yes No	Yes No	Yes No[1]	Yes No[1]	Yes No	Yes No	Yes No
Do you have EPDO weighting factors?	No	No	Yes	No	No	No	No	No	No	No	No	Yes	No
Do you have crash costs by severity?	No	No	Yes	Yes	No	No	No	No	No	No	No	Yes	No
Do you have crash costs by type?	No	No	No	Yes	No	No	No	No	No	No	No	No	No
Do you have calibrated SPFs and Overdispersion Parameters?	No	No	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes
What is the available level of statistical expertise?[2]	Bas	Bas	Bas	Bas	Int	Int	Adv	Exp	Adv	Adv	Exp	Exp	Exp
Do you want the method to consider the effect of traffic volume?	No	Yes	No	No	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes
Do you want the method to consider variance in crash data?	No	No	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Do you want the method to account for RTM bias?	No	No	No	No	No	No	No	No	Yes No	Yes No	Yes	Yes	Yes
Do you want the method to estimate performance threshold?	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
On a scale of 1–10, how reliable do you want the results to be?	1 2	4	3	5	5	6	7	7	5	5	8	8	9 10
Do you want to analyze multiple facilities at one time (i.e., compare results for multiple facilities)?	No	Yes	No	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes

Note: A: Average Crash Frequency; B: Crash Rate; C: EPDO Average Crash Frequency; D: Relative Severity Index; E: Critical Crash Rate; F: Excess Predicted Average Crash Frequency using Method of Moments; G: Level of Service of Safety; H: Excess Predicted Average Crash Frequency Using SPFs; I: Probability of Specific Crash Types Exceeding Threshold Proportion; J: Excess Proportion of Specific Crash Types; K: Expected Average Crash Frequency with EB Adjustment; L: EPDO Average Crash Frequency with EB Adjustment; M: Excess Expected Average Crash Frequency with EB Adjustment.

[1] Either crash severity or crash type. [2] Bas: Basic; Int: Intermediate; Adv: Advanced; Exp: Expert.

Table C-4: Select Screening Method(s) for Segments

Question	Simple Ranking Method	Sliding Window Method	Peak Searching Method
Do you want to analyze the entire segment as one section?	Yes	No	No
Do you want to compensate for errors in crash location reporting?	No	Yes	No
Do you want to test the statistical reliability of the estimate?	No	No	Yes

Table C-5: Select Economic Appraisal Method(s)

Question	Benefit–Cost Analysis Using Net Present Value	Benefit–Cost Analysis Using Benefit–Cost Ratio	Cost-Effectiveness Analysis Using Cost Effectiveness Index
Do you have an estimate of change in crashes?	Yes	Yes	Yes
Can you estimate the total project cost?	Yes	Yes	Yes
Do you know the service life of the countermeasure being evaluated?	Yes	Yes	Yes
Do you have information on crashes reduced in each severity level?	Yes	Yes	No
Can you estimate the monetary value of crash reduction by severity?	Yes	Yes	No
Do you want to determine whether an improvement project is economically justified?	Yes	Yes	No
Do you want to determine which alternative is most cost-effective?	No	No	Yes
Do you want to evaluate multiple projects across multiple sites?	Yes	No	Yes
Do you want to easily justify improvements funded through the Highway Safety Improvement Program (HSIP)?	No	Yes	No
Do you want to identify the most cost-effective mix of projects given a specific budget?	No	No	No

Table C-6: Select Safety Effectiveness Evaluation Method(s) based on Data Availability

Question	Naïve (Simple) Observational B–A Study	Observational B–A Using SPFs – EB Method	Observational B–A Using Comparison-group Method	Observational B–A to Evaluate Shifts in Crash Type/Severity Proportions	Observational Cross-sectional Study
Do you have information on the treatment installation dates?	Yes	Yes	Yes	Yes	No
Was the treatment installed on at least 10 sites?	No	Yes	Yes	Yes	Yes
Can you identify at least 10 sites as "comparable" (i.e., non-treatment) sites?	No	No	Yes	No	Yes
Do you have crash and volume "before" data for treatment sites?	Less than 3 years	At least 3 years	At least 3 years	At least 3 years	No Data
Do you have at least 3 years of crash and volume "before" data for non-treatment sites?	No	No	Yes	No	No
Do you have crash and volume "after" data for treatment sites?	Less than 3 years	At least 3 years	At least 3 years	At least 3 years	At least 3 years
Do you have at least 3 years of crash and volume "after" data for non-treatment sites?	No	Yes No[1]	Yes No[1]	No	Yes
Do you have SPFs for non-treatment (i.e., comparison group) site types?	No	Yes No[1]	Yes No[1]	No	No
What is the available level of statistical expertise?	Basic	Advanced	Intermediate	Intermediate	Advanced
Do you want to evaluate ONLY a single project/treatment site?	Yes	Yes	Yes	Yes	No
Do you want to evaluate multiple sites to determine the treatment's safety effectiveness?	Yes	Yes	Yes	Yes	No
Do you want to evaluate multiple sites to determine CMFs?	Yes	Yes	Yes	Yes	Yes

[1] Requires either data or SPF.

Table C-7: Select Safety Effectiveness Evaluation Method(s) based on Method's Robustness

Question	Naïve (Simple) Observational B–A Study	Observational B–A Using SPFs – EB Method	Observational B–A Using Comparison-group Method	Observational B–A to Evaluate Shifts in Crash Type/Severity Proportions	Observational Cross-sectional Study
How reliable do you want the results to be?	Not at all	Extremely	Extremely	Somewhat	Moderately
Do you want the method to account for RTM bias?	No	Yes	Yes	No	No
Do you want the method to compensate for general time trends in crash data?	No	Yes	Yes	Yes	Yes
Do you want to evaluate the safety performance of treatments using crash frequencies?	Yes	Yes	Yes	No	Yes
Do you want to evaluate the safety performance of treatments using target collision type/crash severity as a proportion of total crashes?	Yes	No	No	Yes	No