Integrating the HSM into the Highway Project Development Process

HSM
Highway Safety Manual
AASHTO

May 2012

U.S. Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
Investment in roadway safety saves lives

Technical Report Documentation Page

1. Report No. FHWA-SA-11-50	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Integrating the HSM into the Highway Project Development Process		5. Report Date 6. Performing Organization Code	
7. Author(s) Van Schalkwyk, I.; Wemple, E.A., and Neuman, T.R.		8. Performing Organization Report No.	
9. Performing Organization Name and Address Cambridge Systematics, Inc. 100 CambridgePark Drive, Suite 400 Cambridge, MA 02140		10. Work Unit No. 11. Contract or Grant No. DTFH61-05-D-00026-T-10-001	
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Highway Administration Office of Safety E71-115 1200 New Jersey Ave, SE Washington, DC 20590		13. Type of Report and Period Covered 14. Sponsoring Agency Code	
15. Supplementary Notes FHWA: Esther Strawder, Office of Safety (COTM)			
16. Abstract This guide provides examples of opportunities for integrating the AASHTO Highway Safety Manual into the project development process. This includes integrating methods from the Highway Safety Manual into planning, alternatives development and analysis, design, operations, and maintenance. The guide provides a description of each of these steps in the project development process, and then provides a discussion of the methods from the Highway Safety Manual, and in some cases other resources, that support these steps. The application of safety analysis tools such as the Integrated Highway Safety Design Model, SafetyAnalyst, the CMF Clearinghouse, and example spreadsheet tools are discussed. Resources from FHWA and NCHRP are also presented. The purpose of this guide is to provide the practitioners with examples and ideas for integrating safety performance measures into the project development process.			
17. Key Words Safety, Highway Safety Manual	18. Distribution Statement		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No of Pages 38	22. Price N/A

Form DOT F 1700.7 (8-72) **Reproduction of completed pages authorized**

Table of Contents

List of Exhibits

Preface

This publication, *Integrating the HSM into the Highway Project Development Process*, describes and illustrates the application of the AASHTO Highway Safety Manual (HSM) into the highway project development process. The guide's purpose is to help practitioners understand how the HSM adds value to the project development process. This guide includes specific guidance for integrating the HSM into the disciplines of Planning, Environment, Design, and Operations that comprise highway project development.

Executive Summary

The AASHTO Highway Safety Manual (HSM), published in 2010, represents the culmination of 10 years of research and development by an international team of safety experts, academics, and practitioners. As a tool, the HSM allows planners, designers and traffic engineers to evaluate the safety impacts of decisions throughout the project development process on crash frequency and crash severity. The science-based approaches and tools in the HSM add value to the project development process by explicitly facilitating consideration of safety.

Whether the project purpose is safety-related or not, every project can benefit from applying the HSM to the development and evaluation of alternatives. Project decisions are based on full evaluation of costs, right-of-way, traffic operations, environmental factors, and safety. Prior to publication of the HSM, the area of safety lacked a common, science-based, and reliable means of quantification – which is what the HSM offers.

The *Integrating the HSM into the Highway Project Development Process* guide provides information for state and local practitioners on how to integrate the HSM into their project development process. Each section provides an overview of some of the implementation opportunities for the HSM during each stage of the project development process. The HSM, integrated into agency processes and considerations, will support regional, state, and national fatality reduction goals alongside the goals of mobility, the environment, and other competing needs.

Applying the HSM in Planning

Transportation planning legislation is increasingly emphasizing the importance of safety in transportation planning. When agencies are considering implementing or modifying policies, the HSM provides the ability to assess anticipated changes in crash frequency or severity, allowing explicit consideration of the safety impacts in addition to potential traffic operations and/or economic impacts. For example, if an agency is considering an access management policy on all arterial roadways throughout the community, the HSM provides crash modification factors that quantify the change in crash frequency or severity associated with changing driveway density. Therefore, safety can be a performance measure along with traffic operations and economic impacts. In terms of corridor-specific plans, the HSM can also assist with refinements to the plan by allowing planners and engineers to estimate the change in safety performance across different concepts and approaches considered for a corridor. For example, the HSM can be used to assess the influence of the type and frequency of intersections, driveways, parking, or median types on crash frequency for an urban or suburban arterial.

Applying the HSM in Alternatives Development and Analysis

Within the typical project development process and during environmental analysis, agencies can apply the HSM to include quantitative safety in alternatives development and analysis. The HSM provides methods for agencies to objectively define locations or projects for which the potential for safety improvement is indeed significant or not. With adoption of tools and methods in the HSM, agencies can incorporate the historic safety performance of the existing road into their designation of project type and support the identification of likely reasonable alternatives. Furthermore, agencies can apply the HSM to support explicit consideration of quantitative safety during alternatives development and analysis. In the event that agencies select an alternative that does not have the highest predicted safety performance (e.g., because environmental or other impacts were greater for the particular geometric configuration), agencies can use the HSM to identify mitigating strategies to improve safety performance for the selected alternative.

Applying the HSM in Design

With the scientific and the predictive method in the HSM, the designer is now able to perform safety performance-based design.[1] For example, the designer can assess the safety impact of a design parameter, evaluate the impact of design exceptions on safety performance, and review implemented projects to evaluate impacts of design criteria. The science-based human factors fundamentals in the HSM allow the designer to assess the interactions of the road user with the highway and evaluate design solutions based on user abilities and limitations.

The HSM does not require agencies to select a particular solution purely because it has the lowest associated crash frequency or severity. However, the tools in the HSM allow agencies to review a selected alternative (that may not have had the lowest associated crashes or severity) and evaluate opportunities to reduce the associated crash frequency or severity.

Applying the HSM in Operations and Maintenance

In the day-to-day operation and management of the transportation system, agencies are responsible for providing a safe and efficient transportation system for users. Within these programs, projects and activities the HSM offers data driven and science-based methods and tools to supplement system monitoring, identification of opportunities for improvement and assesses the safety impacts of operations and maintenance activities.

Typical applications include:

- Identifying safety performance measures across the system.
- Identifying typical locations in a geographical region that may particularly benefit from systemic treatments.
- Identifying and assessing changes in safety performance for different operational and site conditions.
- Evaluating and quantifying the impact of treatments, policies and programs on the safety performance of corridors, road segments, intersections, groups of treatments, or the roadway network.
- Inform and improve maintenance policies and priorities.
- Assessing tradeoffs between funding maintenance improvements to such areas as pavements, roadside facilities, and bridge facilities.

1 In this guide, the “predictive method” refers to the 18-step process outlined in the HSM. In summary these steps are select and apply the appropriate safety performance function and crash modification factors, apply a calibration factor if available, and apply the empirical Bayes method, if appropriate.

Safety Analysis Tools

A number of analysis tools and supporting developments are available to support implementation and use of the HSM in the project development process. These tools include, but are not limited to, AASHTOWare SafetyAnalyst, the IHSDM, the FHWA CMF clearinghouse, and guides FHWA developed to support implementation of the HSM (for example, training and additional resources). Links to these and other resources are available at the AASHTO Highway Safety Manual web site at http://www.highwaysafetymanual.org, the FHWA Office of Safety HSM web site at http://www.safety.fhwa.dot.gov/hsm, and the TRB Highway Safety Performance Committee web site at http://www.safetyperformance.org.

I. Introduction

The AASHTO Highway Safety Manual (HSM), published in 2010, represents the culmination of 10 years of research and development by an international team of safety experts, academics, and practitioners. Under leadership from the American Association of State Highway Officials (AASHTO), the National Cooperative Highway Research Program (NCHRP) and the Federal Highway Administration (FHWA), and with direction from a Task Force of the Transportation Research Board (TRB), a major research program provided the technical contents of the HSM and funded its development into a practitioner-friendly document.

The HSM provides a set of tools and knowledge to support a science-based approach to quantifying safety. As a tool, the HSM provides the ability to incorporate meaningful safety metrics – crash frequency and severity – into an agency's program planning and project development processes, whether the project's purpose is driven by a particular safety concern or not.

For the first time, there is standardized guidance for incorporating safety performance-based decision making into project development. Planners, designers, and traffic engineers are now able to evaluate the impacts of decisions about the roadway environment (e.g., roadway design or changes in traffic volume) on crash frequency and crash severity.

This guide provides information for state and local practitioners on how to integrate the HSM into their project development processes. Each section provides an overview of possible implementation opportunities for the HSM during each stage of the project development process.

1. How to Use the Guide

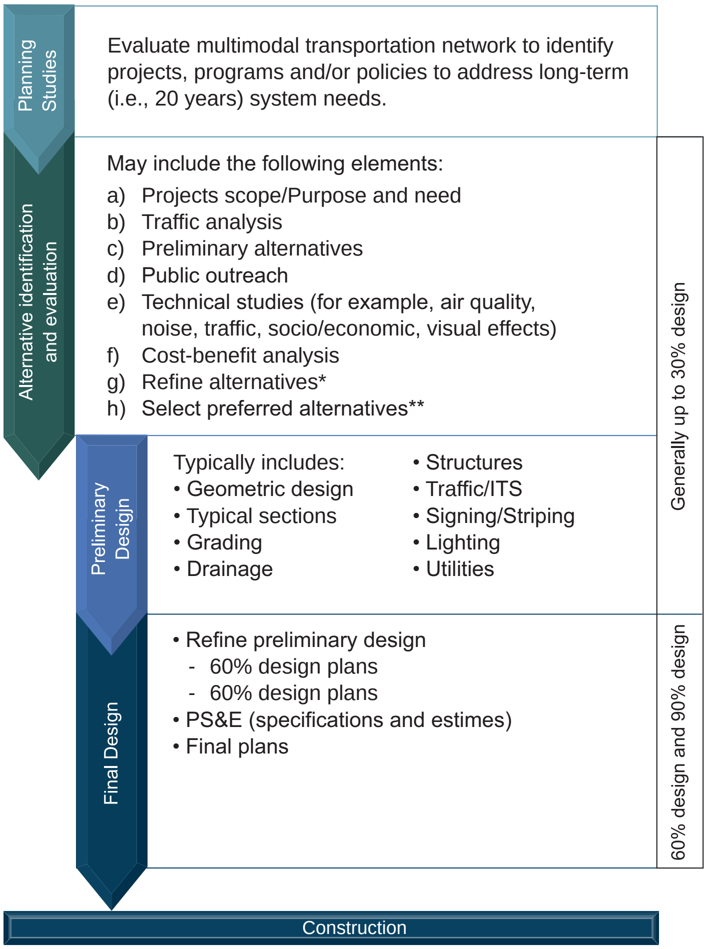
Exhibit 1 illustrates the major steps of the project development process and provides a simplified explanation of activities in each step. Each section in this guide provides discussion of how the HSM could be applied in this process. Practitioners who work on each step of this process will find specific chapters useful as they apply to their areas. Safety practitioners can use this guide to communicate these applications to their colleagues in other areas of the development process. To this end:

- Section II discusses how agencies can use the HSM in planning;
- Section III discusses the use of the HSM in alternative development and analysis;
- Section IV focuses on how agencies can apply the HSM in design;
- Section V presents the application of the HSM in the operation and maintenance of the roadway system; and
- Section VI provides a summary of this guide.

2. Overview of Applying HSM in the Project Development Process

EXHIBIT 1

Typical Highway Project Development Process



Note: The process outlined above is generic and for the purpose of discussions in this document only. The process may differ in terminology and process across project types and across agency-specific processes and procedures.

* Include mitigating impacts and the Draft EIS when an EIS is required.

** Include the Final EIS and Record of Decision when an EIS is required.

The HSM provides methods to allow agencies to incorporate safety throughout the project development process.

In the *Planning* phase, agencies (e.g., state departments of transportation or metropolitan planning organizations) assess existing conditions, establish goals and objectives, identify future travel characteristics, and evaluate the multimodal transportation network to develop programs, identify and prioritize projects, and institute policies to address long-term (i.e., 20 years) transportation system and community needs. During *Planning*, agencies may identify locations on the system that have potential for safety improvement or sites most likely to respond to particular treatments.

Agencies may also be interested in adopting policies across the jurisdiction or understanding the quantitative safety implication of one network versus another. When agencies include safety performance in planning, they are promoting longer-term approaches to support the reduction in the number and severity of crashes.

The inclusion of safety performance in planning supports strategic investments where the impact is likely to be the highest. When agencies use data driven processes that include consideration of safety performance, the likelihood of cost-effective expenditure of resources is increased. Section II discusses the application of the HSM in planning in further detail.

Individual projects are derived from agency planning efforts. Projects have defined limits, budgets, and schedules for completion, which constitute the project's scope. Every project has a fundamental purpose or objective, typically reflecting needs such as providing improvements to mobility, infrastructure repair or rehabilitation, expansion of modal choice, or improvements to public safety. Any of these may be expressed as a project's "purpose and need."

Once a project's scope and purpose and need are established, the project moves to the critical step of *Alternatives Development and Analysis*. Multiple alternatives within the project scope are developed based on addressing the stated purpose and need.

Whether the "purpose and need" is safety-related or not, every project can benefit from applying the HSM in the development and evaluation of alternatives. Project decisions are based on full evaluation of costs, right-of-way, traffic operations, environmental factors, and safety. Prior to publication of the HSM, there was no common, science-based, and reliable means of safety quantification within this process.

The HSM allows agencies to consider the existing potential a detailed engineering and environmental analyses of each alternative, results from safety diagnostic analyses (HSM Chapter 5) can be used to inform the development of concepts, and the predictive method can be used to estimate changes in crash frequency or severity between different options.

Safety Return on Investment

A return-on-investment evaluation provides information about whether the proposed action maximizes system benefit. With the HSM, safety can be considered as a benefit (alongside mobility, environment, etc.) included in the return on investment evaluation.

The predictive method can also be used as part of an alternatives evaluation process to estimate the changes in crash frequency or severity associated with a change in traffic volume or traffic control. Finally, the safety benefits of a preferred alternative compared with a no-build alternative can be readily estimated and incorporated into project documentation. Section III presents examples of opportunities for the application of the HSM in alternatives development and analysis and selection of a preferred alternative.

Once a preferred alternative is selected, the project typically moves into *Preliminary and Final Design*. A designer can use the knowledge and tools in the HSM to inform design decisions throughout *Final Design and Construction*. For example, designers can incorporate human factor considerations into designs (using Chapter 2 of the HSM). The need for *design exceptions* (use of a design element or dimension outside of the established criteria) is common on urban projects and reconstruction projects with extensive constraints. Analysis, decision making and documentation of the quantitative safety effects of a proposed design exception are among the most significant enhancements the HSM brings to project development.

In the daily operation of the roadway network, agencies can use the HSM in *Operations and Maintenance*. Agencies can incorporate safety into existing processes that monitor system per-formance, allowing for consideration of safety performance improvements along with com-peting needs. This approach supports strategic investment and improvement of the roadway system. For example, agencies can consider the impact of changes or upgrades in mobility, decisions related to access, setting maintenance policies and priorities, and other operational considerations on safety performance. When agencies apply the evaluation methods in the HSM to implemented projects and policies, they can identify opportunities to improve policies and future decision making based on the changes in crash frequency or severity.

In reviewing this guide, agencies will find the HSM provides opportunities to extend safety performance as a consideration into all decisions about the roadway environment (e.g., with maintenance, mobility, or preservation programs), rather than only considering safety in projects driven by safety needs.

3. Resources for Application of the HSM

Several tools and resources exist to support the application of the HSM. Tools for implementing the HSM include:

- The AASHTO*Ware SafetyAnalyst* software supports HSM Part B: Roadway Safety Management (http://www.safetyanalyst.org).
- The I*nteractive Highway Safety Design Model* (IHSDM) software (http://www.ihsdm.org) supports implementation of the HSM Part C Predictive Method.
- The *FHWA CMF Clearinghouse* (cmfclearinghouse.org) supports the use of HSM Part B: Roadway Safety Management and Part D: Crash Modification Factors.

Each HSM application example provided in this guide includes references to applicable tools.

Exhibit 2 lists and briefly describes different resources that support HSM implementation. Several web sites offer HSM guidance, technical assistance, case studies, and training opportunities:

- AASHTO web site at http://www.highwaysafetymanual.org.
- FHWA Safety web site at http://safety.fhwa.dot.gov/hsm.
- TRB Highway Safety Performance Committee web site at http://www.safetyperformance.org.

EXHIBIT 2

Resources to Support the Implementation and Institutionalization of the HSM

Implementation and Institutionalization

Guidance

- **Integrating the HSM into the Highway Project Development Process** (FHWA) – Presents opportunities for the integration of the HSM into agency functional areas for all projects not just those initiated to improve safety performance (http://safety.fhwa.dot.gov/hsm).
- **HSM Implementation Guide for Managers** (FHWA) – Guidance to amanagers of state and local agencies for the implementation of the HSM (http://safety.fhwa.dot.gov/hsm).
- **HSM User Guide** (NCHRP 17-50) – Step-by-step presentaetion of application of the HSM – *Forthcoming Spring 2012.*
- **HSM Training Guide** (FHWA) – Lists current training available to help institutionalize the HSM (http://safety.fhwa.dot.gov/hsm).
- **Human Factors Guidelines for Road Systems** (NCHRP Report 600):
- http://www.trb.org/Main/Blurbs/159691.aspx.
- **FHWA Guidance for Preparing and Processing Environmental and Section 4(F) Documents**, FHWA Technical Advisory T6640.8A: http://environment.fhwa.dot.gov/projdev/impTA6640.asp.
- **Integrating Road Safety into NEPA Analysis: A Primer for Safety and Environmental Professionals**: http://safety.fhwa.dot.gov/hsip/tsp/fhwasa1136/fhwasa1136.pdf.

Technical Support

- Highway Safety Manual web site: http://www.highwaysafetymanual.org.
- HSM User Discussion Forum offers technical assistance for the feedback from HSM users http://www.hsmforum.org.

Software Tools

- SafetyAnalyst AASHTOWare: http://www.safetyanalyst.org.
- Interactive Highway Safety Design Model: http://www.ihsdm.org.
- FHWA Crash Modification Factors Clearinghouse: http://www.cmfclearinghouse.org.

General Information

- HSM-related resouces: http://safety.fhwa.dot.gov/hsm.
- HSM Case Studies (FHWA) – Case studies of states applying the HSM and related software (http://safety.fhwa.dot.gov/hsm).
- Highway Safety Manual On Line Overview Course (FHWA-NHI-380106) (http://www.nhi.fhwa.dot.gov/training) additional HSM courses available.
- HSIP Manual: http://safety.fhwa.dot.gov/hsip/resources/fhwasa09029/fhwasa09029.pdf.
- TRB Highway Safety Performance Committee web site: http://www.safetyperformance.org – research and support activities for the HSM and the broader context of highway safety performance.

II. Applying the HSM in Planning

Planning is the first stage of the project development process. It is the stage in which broader community visions and goals are related to the transportation system and multimodal transportation network is evaluated to identify priorities, projects, programs, and/or policies to address long-term (i.e., 20 years) system needs. The broad range of potential needs can relate to such issues as enhancement of mobility and accessibility, policy recommendations, pedestrian and bicycle connectivity programs and projects, signal system coordination, transit improvements, freight systems, coordination of land use, intelligent transportation system improvements, safety needs, or parking system management.

Systems planning ranges from the initial definition of a community vision to the actual monitoring of the performance of the projects that have been implemented. The primary purpose of systems planning is to provide the information necessary and needed by decision-makers to make choices about investment in the transportation system consistent with a community's vision.[2] System planning often starts with policy-level documents leading to modal plans and programs. The modal plans and programs can be mode-specific (e.g., freight, transit, non-motorized, and highway) and documented in one comprehensive plan or by separate plans that focus on select topic areas. The planning process should consider the interaction among different modes in developing a multimodal system plan. At the regional level, the mode-specific and multimodal plans often culminate in a prioritized list of projects for the 20-year horizon of the plan. In some cases, the long range plans will also identify the need for additional refined analysis in a specific corridor or subarea within the community.

Quantitative performance measures in safety commonly include crash frequency, fatal and serious injury crashes, or percent changes in crash frequency or severity. Safety performance (e.g., crash frequency or crash severity) of alternative transportation networks under consideration can be estimated and compared to each other to evaluate safety conditions under different scenarios. The differences in safety performance between the various transportation networks should then be considered as one of the decision factors along with the differences in traffic operations (e.g., level of service), environmental impacts (e.g., air quality), or neighborhood livability (e.g., pedestrian access to transit).

This section discusses how agencies can use tools in the HSM to evaluate safety performance and support the integration of safety explicitly in long range transportation plans and more specifically in corridor studies. State departments of transportation have safety analysis business units that may be able to provide support to local agencies in acquiring the data and/or conducting safety analysis.

[2] NCHRP 541: Consideration of Environmental Factors in Transportation Systems Planning, page 9.

1. Integrating Highway Safety Manual Analysis Methods into a Long Range Transportation Plan

Federal legislation has increasingly emphasized the importance of safety in transportation planning. The intent is not just to identify safety-specific projects, but to explicitly consider the impact of planning decisions on crash frequency and severity. For example, if an agency is considering an access management policy on all arterial roadways throughout the community, the change in crash frequency or severity can be a consideration in the decision-making process in addition to potential traffic operations and/or economic impacts. Part D of the HSM provides crash modification factors (CMF) quantifying the effects of changing driveway density on urban and suburban arterials. Or if a community is considering a "roundabout first" policy, CMFs related to roundabouts and the effects of changing intersection traffic control to a roundabout are provided in the manual.

If a community is undertaking a long range planning process to identify 20-year transportation system needs, one of the early activities is to evaluate existing transportation conditions related to mobility and accessibility, pedestrian and bicycle connectivity, and transit service. Part B of the HSM provides network screening methods to identify sites with potential for safety improvement. These sites can be evaluated to identify specific improvements and subsequently prioritized alongside other sites with particular capacity, operational, or connectivity needs. The agency can then use the results from this process to develop a prioritized list of sites for project programming and forward some of these projects into the regional planning process.

NCHRP 546: Incorporating Safety Into Long Range Transportation Planning demonstrates the feasibility of estimating the safety performance of different transportation networks at the transportation analysis zone (TAZ) level. While not part of the HSM, the concepts from this research could be used as part of the future network evaluation stage of a long range transportation plan. Future versions of the software PlanSafe will simplify implementing these concepts.

2. Integrating the Highway Safety Manual into Corridor Planning

As an outcome of the long range planning process, an agency may undertake a refined corridor-specific plan. In this type of project, the effort may be focused on evaluating alternative cross-sections, functional classifications, access management concepts, use of a context-sensitive solutions, etc., for a specific corridor. For example, it may be that a community's long range plan identified the need for additional roadway capacity in a corridor without specific details on the proposed facility. The corridor-specific plan would examine additional considerations related to the corridor cross-section and interaction with adjoining land uses and stakeholders needs. Options for medians (including type and location), number of lanes, and/or provision of on-street parking are among the issues that may be considered in this process.

The HSM predictive method can be used to estimate the changes in crash frequency of many of these geometric features for different facility types. Alternatively, an agency can estimate the influence of the type and frequency of intersections, driveways, parking, or median types on the crash frequency for an urban or suburban arterial. Such information may be useful in assessing the effects of different land use plans for a subarea, each requiring a different road network characteristic

Further, a variety crash modification factors (CMF) from Part D of the Highway Safety Manual could be applied to the corridor to estimate the change in crash frequency on the corridor under possible alternative development concepts.

3. Tools to Support Application of the HSM in Planning

Tools to Support HSM Application in the Long Range System Planning Process

AASHTOWare SafetyAnalyst is a tool that can be used to perform planning-level screening. *SafetyAnalyst* allows the user to select from a variety of safety performance measures and screening methods (listed in Chapter 4, Part B of the HSM) to identify sites or corridors with potential for safety improvement. The agency can use this tool to screen the transportation network or part of the network, where the minimum required data are available for the analysis. For more information, visit http://www.safetyanalyst.org. Other agency-specific or commercial software may be available or under development to incorporate some or all of the performance measures and screening methods in the HSM.

FHWA developed a case study showing how Ohio DOT is using *AASHTOWare SafetyAnalyst* to assist with all steps of their safety management system, including: network screening, diagnosis, countermeasure selection, economic appraisal, prioritization, and countermeasure evaluation. More case studies can be found at http://www.safety.fhwa.dot.gov/hsm (FHWA 2012).

The FHWA Safety Performance Measure Primer is also available as a resource to help identify additional performance measures. http://www.safety.fhwa.dot.gov/hsip/tsp/fhwahep09043/sources.cfm

PlanSafe is a software tool that was developed through NCHRP. While macro-level safety prediction approaches (such as PlanSafe) are not included in the first edition of the HSM, agencies can use PlanSafe to compare differences in crash frequency or severity across different future development and network scenarios. More information about this tool is available at the TRB web site. An updated version of the software is anticipated in the summer of 2012.

Tools to Support HSM Application in Corridor Planning

Spreadsheets are available to perform basic HSM predictive analysis. This includes the spreadsheets developed as part of the NCHRP 17 38 HSM Training Materials project for training purposes. The Alabama Department of Transportation (ALDOT) and Virginia Department of Transportation (VDOT) released a set of spreadsheets that extends the functionality and ease of use of the NCHRP 17 38 spreadsheets. These spreadsheet tools are available from the TRB Highway Safety Performance Committee web site: http://www.safetyperformance.org. Other states, such as Illinois and Washington developed state-specific spreadsheet tools that can be used for corridor planning.

Most state departments of transportation have some type of safety analysis and/or crash data analysis unit. This group will manage statewide safety programs such as the state Strategic Highway Safety Plan. The group may also manage safe routes to schools, safety belts, commercial vehicle, or impaired driving programs. Most states will also have traffic records/data analysis units that work with state crash data records. The staff in data analysis units and the safety analysis units can be called upon to support local efforts to integrate safety into planning.

The FHWA CMF Clearinghouse is an on-line, free database of treatments and crash modification factors (http://www.cmfclearinghouse.org). The user can query specific treatments (also known as countermeasures) in the on-line database of over 4,000 CMFs. It includes all CMFs published in the HSM as well as those published since the HSM was released. The FHWA updates the Clearinghouse regularly.

4. Example Application: Long Range Transportation Plan

The following scenario presents an example of how a MPO would apply the HSM in a long range transportation plan. The example application introduces a hypothetical scenario to demonstrate an application of the HSM as part of a set of example discussions in subsequent sections. The examples in this guide are not provided to demonstrate how to perform the analysis but rather demonstrate how applying the HSM may be integrated into existing planning, design, and evaluation processes.

An MPO is developing their regional transportation plan. The local agency is conducting the needs assessment phase of the project. In addition to the pedestrian, bicycle, and congestion assessment, the MPO has conducted a network screening analysis on the major roadway systems (freeways and arterials) to identify particular corridors with potential for safety improvement. The MPO selected two performance measures from the HSM: equivalent property-damage only (EPDO), and excess expected crash frequency. Using the peak searching method, the analysis identified roadway segments where reported crashes exceeded the expected number of crashes based on the characteristics of the roadway and the safety performance function associated with that roadway type. This method took into account the variation in crash data from year to year. The agency identified several corridors that may benefit from investment and prioritized the corridors. Exhibit 3 summarizes the results. They identified the corridor on Route A, from milepost 5.6 to 8.1, as the corridor with the highest potential for safety improvement based on EPDO and excess expected crash frequency with forecasted future travel demand. The corridor will be studied further as part of the next stage in the regional planning process.

EXHIBIT 3
Example Application of the HSM in System Planning

Corridor Description	EPDO Score (PDO crashes per year)	Excess Expected Average Crash Frequency (fatal and injury crashes per year)
Route A, milepost 5.6 to 8.1	92	45
Route E, milepost 0 to 1.3	38	35
Route C, milepost 72.1 to 90.0	41	28

III. Applying the HSM in Alternatives Development and Analysis

1. Project Scoping and "Purpose and Need"

Planning agencies develop multiyear programs outlining system wide and corridor needs. From these efforts, an agency's project development process initiates actual implementation of elements of the program. A project will be identified to move forward within a set project scope. The project scope includes defined limits, resource budget and a schedule for eventual completion including construction.

Every project has a fundamental purpose or objective, typically reflecting the identified planning needs, such as providing improvements to mobility for a corridor or subarea, addressing infrastructure repair or rehabilitation based on input from asset management data, enabling expansion of modal choice (e.g., bus, bicycle, etc.), or improvements to address a public safety concern. Any of these objectives may be expressed as a project's purpose and need in an environmental evaluation document, also referred to as a NEPA document.

Once a project's scope and "purpose and need" are established, the project can move to the critical step of *Alternatives Development and Analysis*. Best project development practices emphasize development of multiple alternatives within the project scope, one of which is typically a "no-build" alternative.

As alternatives are proposed, they are first evaluated against the stated purpose and need. Multiple alternatives may be viable but may differ in meaningful ways that relate to their footprint, impacts to adjacent land use, design characteristics, traffic operational quality, and safety performance.

Within this typical project development process, agencies can apply the HSM to support explicit consideration of quantitative safety during alternatives development and analysis. In this stage of the project development process, agencies proceed with a detailed engineering and environmental analyses of each alternative, in an effort to understand the specific costs, impacts and attributes. This analysis will provide decision-makers with objective data to inform the decision on a preferred alternative, which is typically documented in a Categorical Exclusion (CE), or an Environmental Impact Statement (EIS).

> *"NEPA analysis frequently assumes safety will be maximized solely through adherence to roadway design standards. Yet traffic crashes continue to be a fre-quent occurrence, even on newly con-structed roadways; and nationally, tens of thousands die each year in traffic crashes. Addressing this problem requires considering more than standards to maximize the safety of new transportation projects."*
>
> *Integrating Road Safety into NEPA Analysis: A Primer for Safety and Environmental Professionals (FHWA 2011).*

In the past, agencies and technical professionals were readily able to assess project impacts by applying quantitative tools and methods to estimate measures of noise and air quality, wetlands, threatened and endangered species, and an array of other features important to society. Similarly, through the methodologies established in the *Highway Capacity Manual (HCM)*, transportation professionals have access to sophisticated traffic operational tools to estimate speeds, delay, hours of congestion, etc. Databases and tools were also available to develop quantitative dollar cost estimates for construction and right-of-way. What has been lacking until the HSM was a science-based method for estimating safety performance in meaningful quantitative terms. In the absence of such methods, safety has typically not been a distinguishing factor among alternatives; and hence, has not typically influenced the ultimate decision.

This section discusses applying the HSM to incorporate safety into decisions made during alternatives development and analysis stage of the project development process. While the section focuses in particular on the use of the HSM in the NEPA process, the HSM can be used in a similar way for any project, regardless of whether a formal environmental process is required or not.

2. Applying the HSM in Environmental Analysis

Projects requiring environmental analysis, as directed by the National Environmental Policy Act (NEPA), can particularly benefit from the use of the HSM in the following activities:

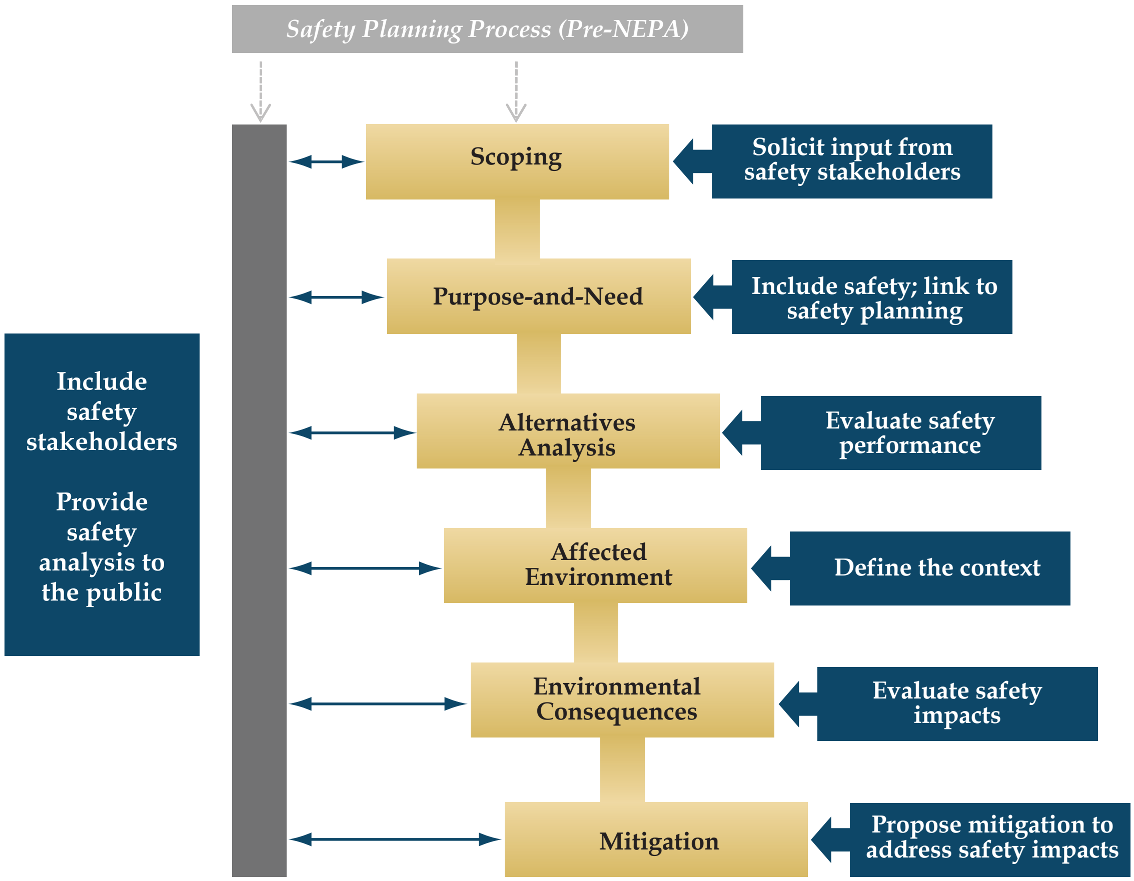
- Define purpose and need for the project.
- Define and refine the range of project alternatives.
- Analyze alternatives.
- Evaluate alternatives.
- Select alternative for implementation.

Exhibit 4, from the FHWA Practitioners' Primer: *Integrating Road Safety into NEPA Analysis* (2011), demonstrates the opportunities for integration of safety into NEPA analysis.

Define purpose and need for the project. Purpose and need statements can refer to providing or enhancing mobility, repairing or replacing infrastructure in poor condition, addressing modal choice, or improving safety. While most projects do not identify safety as a primary purpose and need, the HSM provides methods for agencies to objectively define locations or projects for which the potential for safety improvement is indeed significant. For projects with safety as a primary driver, the tools and methods in the HSM allow agencies to identify historic crash characteristics and probable contributing factors to crashes, particularly fatal and serious injury crashes. An agency can use the predicted method in the HSM to calculate the historic and anticipated future safety performance (calculated using the predictive methods in the HSM) and the fundamentals of human factors in the HSM to identify safety-specific needs for a project and estimate the potential for safety improvement. Such an approach increases the likelihood that safety investments will be cost-effective. For other projects with different purpose and need statements, the HSM still has value as discussed below.

EXHIBIT 4

Integrating Safety into NEPA Analysis



Source: FHWA, *Integrating Road Safety into* NEPA *Analysis*, 2011.

Determine project scope. An important part of a project's scope is the designation of the type of project. This designation translates to applicable design criteria. For projects involving an existing road in need of some improvement, there are two fundamental project types, reconstruction and rehabilitation. Reconstruction is associated with major change to the road cross-section, alignment, or both. Applicable design criteria often exceed that of the older road, necessitating significant and costly reconstruction. Most agencies have adopted alternative design criteria for road projects primarily driven by infrastructure repair, referred to by some as "3R" criteria (resurfacing, restoration, and rehabilitation). However, the use of full reconstruction criteria is often promoted as necessary or desirable to enhance safety. With adoption of tools and methods in the HSM, agencies can incorporate the historic safety performance of the existing road into their decision on the designation of project type. By designating a project as "3R" based on a review of its historic safety performance compared with expected performance per HSM information, agencies can reduce project costs and impacts by avoiding more costly reconstruction aimed at improving safety, when no such improvement is expected.

Define and refine the range of project alternatives. The HSM can support the identification of likely reasonable alternatives. Documentation for NEPA requires a discussion of the approach and rationale for selecting the reasonable alternatives for detailed analysis and an explanation for eliminating alternatives (*FHWA Technical Advisory T6640.8A: Guidance for Preparing and Processing Environmental and Section 4(F) Documents*). Agencies can use the predictive method in the HSM or use CMFs to quantify the anticipated change in crash frequency and/or severity across alternatives. This process can be iterative, allowing agencies to select feasible alternatives during the identification and screening of the alternatives. For example, an agency may consider reconstructing a two-lane rural highway. Using the HSM, the agency can perform a quick initial assessment of the order of magnitude of change in crashes for different combinations of lane and shoulder widths for given geometric and environmental conditions. If the assessment is conducted for a safety-specific project and the assessment indicates the likely benefit of some alternatives may be negligible or even adversely affect safety performance, the agency can eliminate some alternatives initially considered. The information derived from the HSM could then be part of the documentation needed to support the elimination of these alternatives.

Analyze alternatives. Tools and methods in the HSM support quantifying safety performance during alternative analysis. For urban and suburban arterials, the predictive method in the HSM offers the ability to assess the impacts of changes in geometric features or traffic volume on pedestrian and bicycle crashes.

Evaluate alternatives. The predictive methods in the HSM Part C provide the ability to quantify the anticipated safety performance for each alternative in terms of its anticipated crash frequency and severity. This evaluation can also include comparison with a no-build alternative and, if desired, translation of crash reductions into economic benefits based on guidance in Part B of the HSM.

Select alternative for implementation. For the first time, agencies are now able to make relative comparisons between alternatives based on the number of crashes or combinations of particular crash severities by using the predictive methods of Part C of the HSM. In the event that agencies select an alternative that does not have the highest predicted safety performance (e.g., because environmental or other impacts were greater for the particular geometric configuration), agencies can use the HSM to identify safety mitigation strategies to increase safety performance for the selected alternative.

Project decision making can be complex. It inherently involves tradeoffs among alternatives with differing performance attributes. Using the HSM to inform the decision making process does ***not*** place any requirements on an agency to select the alternative with the best safety performance any more than would making a decision solely based on capital cost. Furthermore, absent application of HSM and quantification of safety, the decision-maker has no way of knowing what if any safety tradeoffs exist.

The HSM is neither intended to be, nor does it establish, a legal standard of care for users or professionals. No standard of conduct or any duty toward the public or any person shall be created or imposed by the publication and use or nonuse of the HSM. Documentation used, developed, compiled or collected for analyses conducted in connection with the HSM may be protected under Federal law (23 USC 409).

3. Tools to Support Application of the HSM in Alternatives Development and Analysis

Applying the HSM in alternatives development and analysis primarily relies on using the HSM predictive method and CMFs.

> Florida DOT District 6 (Tampa) analyzed a corridor-widening project on SR 574. As part of the analysis the DOT used the HSM to evaluate a design variation. The analysis quantified the anticipated impact of the design variation, resulting in a $1.6 million reduction in overall project right-of-way costs.
>
> More information about this case study is available at http://www.safety.fhwa.dot.gov/hsm/casestudies/fl_cstd.pdf (FHWA 2012).

Agencies can select from a variety of tools to perform a predictive analysis using the HSM. FHWA developed the IHSDM software tool that can perform several other analyses that are of value during the alternatives analysis process. More information is available at http://www.ihsdm.org. Agencies can also use spreadsheets to perform basic HSM predictive analysis. The NCHRP 17 38 spreadsheets and those from ALDOT and VDOT are available on-line from the TRB Highway Safety Performance Committee web site: http://www.safetyperformance.org. Other states, such as Illinois and Washington have developed state-specific spreadsheet tools that these agencies use during alternatives development and analysis.

The *FHWA CMF Clearinghouse* is an on-line, free database of CMFs to quantify the impact of treatments. Agencies can query the database on-line at http://www.cmfclearinghouse.org. FHWA updates the Clearinghouse regularly.

4. Example Application: Alternative Analysis

This example application continues the hypothetical example presented in Section II.

The MPO is now conducting a corridor study, consistent with NEPA requirements, on the corridor selected (Route A) with potential for safety improvement. The following demonstrates how such a study might be conducted and how the results might be summarized in a NEPA document.

Exhibit 5 illustrates and describes the three project alternatives: a no-build scenario, Alternative 1 and Alternative 2.

EXHIBIT 5
Project Alternatives for the Example Application

No-Build Facility Description:

- Urban arterial
- Commercial land use, with multiple direct access points
- Five lanes and 14-foot center two-way left-turn lane
- On-street parallel parking
- Sidewalk exists, 3 feet minimum in some locations

Alternative 1 Facility Description:

- Urban arterial
- Commercial land use
- Partial, four lanes with raised 14-foot median
- Partial, five lanes with center two-way left-turn lane
- Remove on-street parallel parking
- Provide bus pullouts at selected locations
- Modify to 12-foot sidewalk with 4-foot landscaped buffer

Alternative 2 Facility Description:

- Urban arterial
- Commercial land use, and consolidated driveways
- Two lanes in each direction with dedicated HOV lane
- Additional right-of-way for raised median and left-turn pockets at specific locations along entire corridor
- Remove on-street parallel parking
- Provide bus pullouts at selected locations
- Four-foot landscaped buffer with 5-foot pedestrian path

Source: (Graphics: CH2M HILL).

Note: The project information and analysis results in these examples are hypothetical and for illustration purposes only. It does not reflect results from an actual analysis nor does it intends to serve as an example of the relative anticipated safety performance of these three alternatives for an actual project.

The agency used the HSM Part C to assess the current and future anticipated safety performance for the no-build conditions, Alternative 1, and Alternative 2.

Exhibit 6 presents the different components evaluated in the corridor safety study.

EXHIBIT 6
Safety Analysis Approach for Alternatives in the Example Application

Alternative	Description of Alternative-Specific Features and Analysis Approach Using the HSM
No-Build	The Purpose and Need Statement was developed in part by evaluating existing crash data, including identifying an overrepresentation of fatal and serious injury crashes involving parked vehicles and vehicles turning left into driveways along the most southern section of the corridor. The agency used the predictive method in Chapter 12 of the HSM Part C to quantify the safety performance (expressed in crashes in this example) for the existing and future traffic volumes for the current corridor configuration. This method accounts for the presence of on-street parking, the particular driveway density of the project, and the presence of the two-way left-turn lane. The agency used the analysis results and updated the Purpose and Need Statement, so that it specifically refers to the need to reduce the fatal and serious injury crashes involving parked vehicles and left-turning vehicles on the southernmost section of the corridor.
Alternative 1	The agency used the predictive method in Chapter 12 of the HSM Part C to identify the crash frequency associated with Alternative 1 compared to the no-build option. Alternative 1 represents the following changes from the no-build: • Removal of on-street parallel parking, • Use of street-trees, • Consolidation of a subset of driveways on a particular part of the corridor, and • Installation of a median where left-turning driveway-related crashes areoverrepresented. The FHWA CMF Clearinghouse provides insight into the likely impact of dedicated bus pullout locations along the corridor.
Alternative 2	The agency used the predictive method in Chapter 12 of the HSM Part C to estimate the change in crash frequency associated with Alternative 2 compared to the no-build option. Alternative 2 represents the following changes from the no-build: more comprehensive consolidation of driveways (as compared to Alternative 1) and a raised median throughout the corridor with left-turn pockets at predetermined locations. • **Note:** The agency did not consider the HOV as a lane that adds capacity (additional general-purpose volume).

Exhibit 7 summarizes the analysis results for the evaluation of the 2025 anticipated safety performance for the no-build option, Alternative 1, and Alternative 2.

EXHIBIT 7
Safety Analysis Results for Future Safety Performance for Alternatives in the Example Application

Alternative	Results of Safety Analysis (2025)
No-Build	$N_{expected}^{\ddagger}$ = 110 fatal and injury crashes per year *Discussion of results:* It is anticipated that the existing facility will experience, on average, 110 fatal and injury crashes per year in 2025. A corridor with similar volumes and characteristics is anticipated to experience, on average, 62 crashes per year. The no-build option has an average potential for improvement of 48 fatal and injury crashes per year.
Alternative 1	$N_{expected}$ = 65 fatal and injury crashes per year *Discussion of results:* It is anticipated that the existing facility will experience, on average, 65 fatal and injury crashes per year in 2025. A corridor with similar volumes and characteristics is anticipated to experience, on average, 45 fatal and injury crashes per year, indicating an anticipated average potential for improvement of 20 fatal and injury crashes per year. Alternative 1 is anticipated to experience 45 fewer fatal and injury crashes on average per year than the no-build option.
Alternative 2	$N_{expected}$ = 45 fatal and injury crashes per year *Discussion of results:* It is anticipated that the existing facility will experience, on average, 45 fatal and injury crashes per year in 2025. A corridor with similar volumes and characteristics is anticipated to experience, on average, 34 crashes per year, indicating an anticipated average potential for safety improvement of 20 fatal and injury crashes per year. Alternative 2 is anticipated to experience 65 fewer fatal and injury crashes on average per year than the no-build option, and 20 fewer fatal and injury crashes on average per year when compared to Alternative 1.

$^{\pm}$ $N_{expected}$ represents the anticipated expected average crash frequency.[3]

Based on Exhibit 7 the agency concludes:

- *Without improvement, it is anticipated the no-build alternative will experience, on average, 110 fatal and injury crashes per year in 2025.*
- *If the agency implements Alternative 1, on average, 65 fatal and injury crashes per year in 2025 are anticipated to occur.*
- *If the agency implements Alternative 2, on average, 45 fatal and injury crashes per year in 2025 are anticipated to occur.*
- *The difference in safety performance between the no-build and Alternative 1 is 45 average fatal and injury crashes on the corridor per year in 2025.*
- *The difference in safety performance between Alternative 1 and Alternative 2 is 20 average fatal and injury crashes on the corridor per year in 2025.*

---

[3] The HSM defines the expected average crash frequency as the number of crashes anticipated per year, if the long-term average number of crashes at a site could be determined for a particular site (a segment or intersection) with a given set site conditions.

Note: The analysis summary only reports on the analytical results for the anticipated future safety performance of the different options. The agency did not make any recommendations for the implementation of one particular alternative based solely on results from the safety performance analysis. The HSM does not require an agency to implement a particular alternative based solely on the safety performance evaluation, and *is not intended to be a substitute for the exercise of sound engineering judgment* (AASHTO 2010; page 2 of the *Preface to the Highway Safety Manual*).

IV. Applying the HSM in Design

1. Safety Performance-Based Design

The highway design process has historically centered around applying established design criteria, such as published in the AASHTO Policy on Geometric Design. Highway engineers identify design controls – some of which are predetermined (e.g., terrain, design-year traffic, classification of the road), while others are selected (design level of service, design vehicles, design speed).

Historically, the geometric design criteria have been viewed as the means by which an acceptable level of safety is provided. However, as FHWA and AASHTO both note (Flexibility in Design, AASHTO Guide to Achieving Flexibility in Design) the basis behind geometric criteria includes many factors, (e.g., cost, maintainability, traffic operations) with safety being just one. Moreover, two designers using the same controls and same criteria may create two different alignment and cross-section solutions, with different expected safety performance.

With the HSM, the designer is now able to develop solutions based not just on design criteria, but also on quantitative safety performance, as measured by crash frequency and severity alongside operational and project-specific considerations. The designer can also apply science-based human factors fundamentals from Chapter 2 in the HSM to identify and assess design solutions based on user abilities and limitations. As a result, the HSM now allows agencies to perform what is referred to as "safety performance-based design."

This section discusses three such activities that agencies may implement to explicitly consider safety in design:

- Assess the safety impact of a design parameter.
- Evaluate the impact of design exceptions on safety performance.
- Review implemented projects to evaluate impacts of design criteria.

Assessing safety impact of a design parameter. During the design process, the designer considers options across multiple geometric elements (e.g., lane and shoulder width, curve radii, grade, etc.). The geometric, cross-section, and other project features are selected based on the applicable design criteria, with the primary goal of meeting the project-specific needs in a cost-effective manner. This design process involves choices and tradeoffs. While design manuals and standards are important in this process, balancing quantitative, science-based safety impacts of a design parameter against traffic operations and cost, allows the designer to make overall cost-effective system performance choices. With the HSM tools and approaches, designers can prepare preliminary plans, evaluate their safety performance, refine or adjust one or more elements and reevaluate the performance in a manner similar to balancing cut and fill. The inclusion or exclusion of features such as medians can be tested for safety performance. The predictive method and the CMFs in the HSM provide insight into the impact of individual parameters for particular highway types, as well as individual treatments.

Evaluating the impact of design exceptions on safety performance. Design standards, guidelines and criteria are important; these provide consistency of roadway system deployment and benefits to quality control and ease of construction. Restrictions based on environmental concerns and available right-of-way may require a designer to consider *design exceptions* (also referred to as *deviation[s]*) from the established design guidelines and criteria. Design exceptions are common on urban and reconstruction projects with extensive constraints. Analysis, decision making and documentation of the quantitative safety effects of a proposed design exception are among the most significant enhancements the HSM brings to project development. Using the predictive method, the designer can now quantify the impact of a particular exception in terms of crash frequency or severity. This allows for a quantitative assessment of the relative impact of the exception. If a particular exception affects the safety performance of a project negatively, and there is a desire to proceed with the project, CMFs in the HSM may offer options for mitigation. FHWA's publication *Mitigation Strategies for Design Exceptions* (FHWA-SA-07-011) describes how such analyses can be done. Finally, the design exception process includes documentation in the form of a report and acceptance by a responsible party such as an agency's Chief Engineer. Documenting the basis for a design exception decision, including the quantitative safety analysis, is a valuable risk management tool for agencies.

Reviewing implemented projects to evaluate impacts of design criteria. Agencies regularly update geometric design standards, guidelines, and criteria to reflect advances in the science of operations, safety, and other related fields. The evaluation methods discussed in Chapter 9 of the HSM offer approaches to evaluate projects or bundles of similar projects to quantify the impact of variation in design criteria on safety performance. The HSM discusses different study designs, strengths and limitations of each, and particular considerations. By evaluating completed projects, agencies can update design criteria to incorporate and reflect their relative impact on project safety performance, thus providing continual opportunity for proactive approaches to lower crash or injury risk on the system. There are HSM methods that account for regression-to-the-mean (RTM), and, therefore, provide more accurate estimates.

The tools used to quantify safety performance in the activities described above are similar to those used in alternative identification and analysis (see Section III).

2. Design Decisions and the HSM

The HSM does not require agencies to select a particular solution purely because it has the lowest associated crash frequency or severity. However, the tools in the HSM allow agencies to review a selected alternative (that may not have had the lowest associated crashes or severity) and evaluate opportunities to improve safety performance by using Part C or Part D of the HSM.

3. Example Application: Design Exception Evaluation

Exhibit 8 continues the hypothetical example from Section III of this Guide for a design exception evaluation.

EXHIBIT 8

Safety Analysis Results for a Design Exception Evaluation

The state DOT design standards require median installation and driveway consolidation for urban corridors anticipated to have AADTs in excess of 25,000 vehicles per day. In addition the DOT requires multimodal integration as part of project development process.

Based on an environmental assessment of the alternatives presented in Section III, the local agency concludes the additional public right-of-way required for Alternative 2 would adversely impact the environment. There are historic buildings located next to the existing facility limiting the width available for consideration to extend the existing right-of-way. In addition, the agency found that existing driveway configurations and legislation limits the ability of the local agency to consolidate private driveways as part of the project.

The agency selected Alternative 1 as the most feasible alternative. Because Alternative 1 does not meet all the design standards of the state (full median and consolidation of private driveways), the agency requested a design exception.

The agency then used the HSM predictive method and CMFs to identify mitigation options for the impact of the design exceptions on safety performance in Alternative 1. The safety-related mitigation strategies the agency identified included:

- Consolidating selected number of driveways,
- Installing a raised median on the most southern section of the corridor where right-of-way is available and where the majority of fatal and severe left-turning driveway-related crashes historically occurred,
- Modifying the specification for street trees alongside the corridor with species anticipated to have mature trunk diameters less than 3 inches and reducing the density of these trees along the corridor, and
- Replacing proposed street trees in the median with alternative vegetation that would not increase crash severity outcomes or restrict sight distance.

Based on the predictive analysis the agency anticipates that Alternative 1 and the mitigation strategies for Alterative 1 will likely improve the safety performance of the corridor to an average of 45 fatal and serious injury crashes per year compared to the no-build alternative, which also equals the safety performance of Alternative 2.

V. Applying the HSM in Operations and Maintenance

In the day-to-day operation and management of the transportation system, agencies are responsible for providing a safe and efficient transportation system for users. Within this context, the term operations refers to the use of *programs, technology, and business processes [to] support the flow of vehicles, travelers, and goods on the existing transportation infrastructure* (FHWA, 2012a). Operations include asset management; activities and technologies for managing and minimizing recurring congestion; reducing the risk and extent of nonrecurring congestion; managing incidents, weather events, construction work zones, or special events; integrating freight mobility and capacity needs into the system; and managing and mitigating day-to-day traffic operations as appropriate at intersections, and along roadway segments.

The HSM offers data driven and science-based methods and tools that can be used to monitor and identify treatments likely to improve the safety performance of the roadway network. The following items represent typical applications:

- Identify measures agencies use to identify, quantify and evaluate safety performance across the system.
- Identify and implement countermeasures to reduce overall crash severity on corridors, segments, or intersections.
- Identify typical locations in a geographical region (local, county, or state level) that may particularly benefit from systemic treatments to reduce overall crash severity and crash risk, such as systemically planning to install roundabouts.
- Identify and assess changes in safety performance for different operational conditions.
- Evaluate and quantify the impact of treatments, policies, and programs on the safety performance of corridors, segments, intersections, groups of treatments, or the roadway network.
- Inform maintenance improvement policies and priorities.

The remainder of the section presents a discussion of each of these applications alongside applicable tools and HSM references.

1. Performance Measures

Chapter 4 of the HSM presents a number of alternative measures to quantify safety performance. While the HSM does not identify particular performance measures as preferred approaches, the manual outlines the strengths and limitations associated with each. Such information can be particularly useful in the selection of one or a combination of performance measures agencies use to quantify safety performance. While, crash frequency (from crash history) and crash rates were traditionally used as performance measures, the HSM presents performance measures with a higher reliability than these measures. Using a higher reliability performance measure increases the likelihood that locations most likely to benefit from safety treatments are selected for further evaluation.

2. Operations

Using Part B of the HSM, agencies can measure the safety performance of corridors, segments and intersections using any one or a combination of the performance measures in HSM Chapter 4. A safety performance assessment may represent an annual or tri-annual assessment alongside other performance assessments, such as operational conditions (recurring congestion, nonrecurring congestion, etc.), pavement conditions, or bridge conditions. Using these results, agencies can apply approaches discussed in HSM Chapter 5 to diagnose site and crash characteristics. Agencies can use HSM Chapter 6 to identify likely countermeasures that can be considered to reduce overall crash severity. Once countermeasures are identified, the methods in Chapter 7 of the HSM can be used to assess the economic costs and benefits associated with each alternative. After an assessment of other impacts associated with each of the alternatives (e.g., environmental, public acceptance, and legislative framework) agencies can identify and implement the treatment or group of treatments at the particular location or group of locations. Chapter 8 of the HSM includes methods that an agency can use to prioritize a set of locations for treatment – a typical approach to support decision making within a particular program or financial year.

Within operations, agencies often consider a collection of sites for typical improvements based on similarity of characteristics and particular operational needs. These treatments may vary in cost and operational impact. The HSM methods allow an agency to also include safety performance as criteria for selecting the sites and identifying treatments, particularly where the crash experience suggest potential for safety improvement. Part D of the HSM or information from the FHWA CMF Clearinghouse may provide insight as to the safety impact of operational-based changes. Examples may include, conversion of signalized intersections into roundabouts, change in signal change intervals, changes in signal phasing (e.g., changing permissive to protected-permissive phasing, changes to phasing to a protected-permissive phasing with flashing yellow arrow for the permissive phase). When operational treatments also represent systemic safety treatments, implementation often offers a relatively low-cost solution to lower fatal and serious injury risk on the system.

Decisions in operations and maintenance often include assessments of anticipated changes in performance for different operational and site characteristics. The HSM and related tools allow an agency to assess the change in safety performance (measured in crash frequency and severity) due to operational changes. For example, on high-volume freeway corridors shoulder running may be under consideration as a traffic management strategy. Forthcoming HSM freeway research results provide information about the quantitative safety impacts of such operational changes. With the use of the HSM predictive method (and in this case the anticipated additional chapter on freeway safety prediction) agencies can quantify the relative change in crash frequency and severity for such alternatives. Part D of the HSM and the FWHA CMF Clearinghouse provide information for a variety of such alternatives.

Chapter 9 of the HSM presents state of the practice methods in safety performance evaluation. These methods include methods that are associated with higher reliability than traditional approaches.

Once an agency implements operational changes to corridors or sites, Chapter 9 in the HSM can be used to incorporate safety into monitoring activities at these treated sites. Results from these evaluations may serve as input to accountability reports to the legislature and public.

Past evaluations for safety consisted of naive before-after studies, in which the crash performance before implementation is compared to the crash performance after implementation. The more advanced methods in Chapter 9 of the HSM offer particular value in that they improve the reliability of results compared to the traditional approach. Some of these methods, (e.g., the empirical Bayes method with comparison sites) also allow an agency to control for systemwide changes that may be difficult to detect otherwise.

3. Maintenance

Agencies often have to make trade-offs between funding maintenance improvements to such items as pavement, roadside facilities (e.g., guardrail, signs, lighting), and bridge facilities. The HSM provides tools (i.e., crash modification factors, and the predictive method) to quantify the effects of maintenance decisions on changes in crash frequency or severity on the transportation system. This information could be extended to a benefit/cost analysis using methods from Part B of the Highway Safety Manual.

VI. Summary

Tools and methods in the AASHTO HSM provide value throughout the planning, project development, operations, and maintenance processes of a highway project. As a toolbox, the HSM offers the opportunity to explicitly consider safety as a key consideration along with other critical agency needs. Integrating safety into agency business, particularly during planning and early on in the project development process, will result in overall improved system safety performance.

The HSM provides planners and engineers with quantitative tools to evaluate safety impacts and safety performance. Safety performance can be a meaningful consideration for both projects funded with safety-specific funding and projects funded with nonsafety funding. The quantitative safety analysis tools in the HSM enables agencies to assess the likely effectiveness of a project and justify investments for improving safety performance. Safety can now have equal standing in programmatic and design decision making along with asset condition, environmental effects and costs.

The HSM also offers opportunities to include safety in performance measurement and performance-based design and implementation. Integrating the HSM and data driven performance-based solutions into the day-to-day decision making processes at an agency will contribute to overall improvements in system performance.

Safety analysis tools to support HSM application are currently available and new versions are under development. These tools include, but are not limited to, AASHTOWare SafetyAnalyst, the IHSDM, and the FHWA CMF clearinghouse. Links to these and other tools are available at the AASHTO Highway Safety Manual web site at http://www.highwaysafetymanual.org. Additional resources and training opportunities for the HSM are posted at the FHWA HSM web site located at http://www.safety.fhwa.dot.gov/hsm.

Integrating the HSM into agency processes and considerations, will support regional, state, and national fatality reduction goals alongside the goals of mobility, the environment, and other competing needs.

References

AASHTO, 2010. *The Highway Safety Manual*, American Association of State Highway Transportation Professionals, Washington, D.C., http://www.highwaysafetymanual.org.

FHWA, 1987. *FHWA Technical Advisory T6640.8A: Guidance for Preparing and Processing Environmental and Section 4(F) Documents*, Federal Highway Administration: Planning, Environment, and Realty, Washington, D.C., http://environment.fhwa.dot.gov/projdev/impTA6640.asp.

FHWA, 2012a. *FHWA About Operations Website*, Washington, D.C., http://ops.fhwa.dot.gov/aboutus/aboutus.htm.

FHWA, 2012b. FHWA *Safety Program Website*, Washington, D.C., http://safety.fhwa.dot.gov.

FHWA, 2012c. *HSM Case Study 1: Using Predictive Methods for a Corridor Study in Idaho*, Federal Highway Administration: Office of Safety, Washington, D.C., http://safety.fhwa.dot.gov/hsm/casestudies/id_cstd.cfm.

FHWA, 2012d. *HSM Case Study 2: Implementing a New Roadway Safety Management Process with SafetyAnalyst in Ohio*, Federal Highway Administration: Office of Safety, Washington, D.C., http://safety.fhwa.dot.gov/hsm/casestudies/oh_cstd.cfm.

FHWA, 2012e. *HSM Case Study 3: Using Predictive Methods for Alternative Selection in Florida*, Federal Highway Administration: Office of Safety, Washington, D.C., http://safety.fhwa.dot.gov/hsm/casestudies/fl_cstd.cfm.

FHWA, 2012f. *HSM Case Study 4: Development of Safety Performance Functions for Network Screening in Illinois*, Federal Highway Administration: Office of Safety, Washington, D.C., http://safety.fhwa.dot.gov/hsm/casestudies/il_cstd.cfm.

FHWA, 2012g. *HSM Case Study 5: HSM Implementation Plans – New Hampshire DOT Experience,* Federal Highway Administration: Office of Safety, Washington, D.C., http://safety.fhwa.dot.gov/hsm/casestudies/nh_cstd.cfm.

FHWA, 2011. *FHWA Practitioners' Primer: Integrating Road Safety into NEPA Analysis*, Washington D.C., http://safety.fhwa.dot.gov/hsip/tsp/fhwasa1136/fhwasa1136.pdf.

FHWA, 2011. *Integrating Road Safety into NEPA Analysis: A Primer for Safety and Environmental Professionals*, Federal Highways: Office of Safety, Washington D.C., http://safety.fhwa.dot.gov/hsip/tsp/fhwasa1136/fhwasa1136.pdf.

Herbel, S., Laing, L., and McGovern, C., 2010. FHWA *Highway Safety Improvement Program Manual*, FHWA Office of Safety, Washington, D.C., http://safety.fhwa.dot.gov/hsip/resources/fhwasa09029/fhwasa09029.pdf.

McGovern, C., and Van Schalkwyk, I., 2010. *HSM Training Guide*, prepared for the Federal Highway Administration: Office of Safety, Washington, D.C., http://safety.fhwa.dot.gov/hsm/training/hsmguide.pdf.

NCDOT, 2012. *NCDOT Safety Evaluation Group: Completed Projects* – Completed Projects, Report: Completed Projects, North Carolina Department of Transportation, Raleigh, North Carolina, http://www.ncdot.org/doh/preconstruct/traffic/safety/Reports/completed.html.

NCHRP 2010. *Lead States Initiative for Implementing the Highway Safety Manual*, Transportation Research Board, National Academies, Washington, D.C., http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2974.

NCHRP 2012. *Human Factors Guidelines for Road Systems*, Transportation Research Board, National Academies, Washington, D.C., forthcoming, project information available at http://www.trb.org/Main/Blurbs/159691.aspx.

Neuman, T., and Van Schalkwyk, I., 2011. *FHWA HSM Implementation Guide for Managers*, prepared for the Federal Highway Administration: Office of Safety, Washington, D.C., http://safety.fhwa.dot.gov/hsm/hsm_mgrsguide/hsm_mngrguide.pdf.

Stein, W.J. and Neuman, T.R. 2007. *Mitigation Strategies for Design Exceptions*, prepared for Federal Highway Administration, Report No. FHWA-SA-07-011, Office of Safety, Washington, D.C., http://safety.fhwa.dot.gov/geometric/pubs/mitigationstrategies/fhwa_sa_07011.pdf.

List of Acronyms

AASHTO	American Association of State Highway Transportation Officials
ALDOT	Alabama Department of Transportation
CMF	Crash Modification Factor
CVSP	Commercial Vehicle Safety Plan
DOT	State Department of Transportation (a general term used to describe the state agency that is responsible for the design and maintenance of the state transportation highway network)
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
HSM	Highway Safety Manual
HSIP	Highway Safety Improvement Program
HSP	State Section 402 Highway Safety Plan and Annual Performance Plan
IHSDM	Interactive Highway Safety Design Model
NCHRP	National Cooperative Highway Research Program
NCDOT	North Carolina Department of Transportation
NEPA	National Environmental Policy Act of 1969
SHSP	Strategic Highway Safety Plan
SPFs	Safety Performance Functions
TRB	Transportation Research Board

U.S. Department of Transportation
Federal Highway Administration
Office of Safety E71-115
1200 New Jersey Avenue, SE
Washington, DC 20590

FHWA-SA-11-47