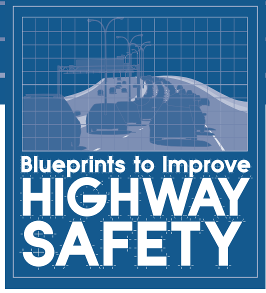



# The Highway Safety Manual

## *Improving Methods and Results*

JOHN C. MILTON

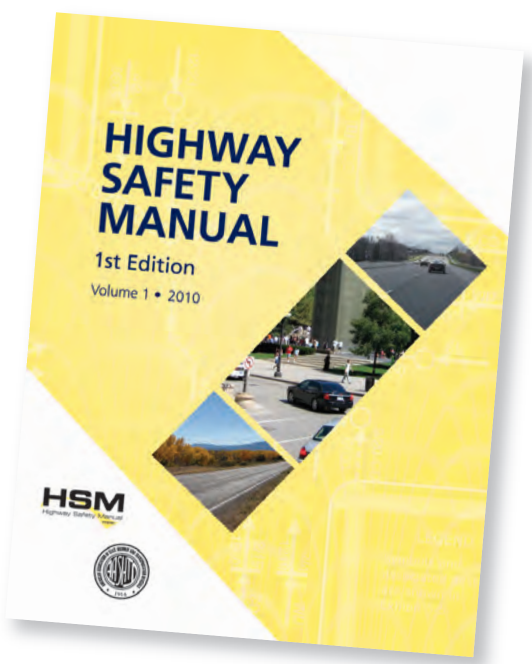
*The author is Director of Enterprise Risk and Safety Management, Washington State Department of Transportation, Olympia, and serves as Chair of the TRB Highway Safety Performance Committee and of the National Cooperative Highway Research Program Project Panel on Development of a Comprehensive Approach for Serious Traffic Crash Injury Measurement and Reporting Systems and of the Project Panel on Interchange Safety Analysis Tool Enhancement.*

In December 1999 a group of highway safety academics, practitioners, and agency representatives convened in Irvine, California, to discuss the creation of a comprehensive and authoritative manual that would serve the field of highway safety in the same way that the *Highway Capacity Manual* had served the field of operations. This group became the core of a larger team that has focused substantial amounts of professional and volunteer time on this vision.

The vision became reality 11 years later, with the publication of the *Highway Safety Manual* (HSM). The HSM represents a dedicated effort to create and drive the science of safety into practical use and to integrate safety as a key consideration in any highway project, program, or activity. The development of the HSM focused on the quantification of safety performance, beyond the traditional safety paradigm.

To succeed, the HSM had to become a tool for professionals in planning, design, operations, maintenance, and system management. The planner and designer would be able to consider reconstruction and upgrades to facilities and to compare the anticipated safety performance with that of the current facility. Summarizing crash history and relying on nominal assessments of what would improve safety performance no longer sufficed. The HSM had to improve the reliability of information, enabling substantive assessments that would reduce fatal and serious injuries. In addition, the HSM had to offer approaches to assess a facility's safety performance.

The HSM represents the cooperative efforts of the American Association of State Highway and Transportation Officials (AASHTO), the Federal Highway Administration (FHWA), and the Transportation Research Board (TRB). Technical content was developed through a major research effort funded and managed through the National Cooperative Highway Research Program (NCHRP). The TRB Highway Safety Performance Committee, the AASHTO HSM Task Force, and the FHWA Office of Safety continue the collaboration as new partners become involved in implementation and in the development of the second edition of the HSM.




The *Highway Safety Manual*, published in 2010, was developed as a comprehensive tool for the integration of safety into highway planning, design, operations, maintenance, and system management.

## Scientific Basis

Before the HSM, safety program and project decision making relied on a variety of sources and methods to assess steps and actions to reduce the potential for crashes. The assessments varied in effectiveness and did not maximize reductions in total crashes. Finding science-based, state-of-the-practice methods, approaches, and knowledge was difficult.

When safety decisions are not quantified, tradeoff decisions among traffic operations, environmental stewardship, or cost are difficult and often have been based on perception. A scientific basis was needed for decision making. Highway and roadway safety is a priority for most state DOTs, but budgets are shrinking for all programs. Decision making must be reliable and optimal.

Photo: National Highway Traffic Safety Administration


A first responder records information at the scene of a crash. From emergency response services to roadway design, highway safety decision making must be reliable.

The HSM was designed for use throughout a project's development. The intended users are professionals in planning, design, construction, operations, and maintenance of the roadway and highway systems at the state, county, and local levels.

Absolute safety does not exist; the primary objective of highway safety is to lower the risk for crash frequency and crash severity. The safety professional relies on three primary components to reduce risk: the human, the vehicle, and the roadway. The HSM focuses on the roadway but recognizes the importance of the vehicle, of human factors, and of the interventions of education, enforcement, and emergency medical services.

## Core Principles

Throughout the development of the HSM, particular attention was given to the reliability of the analysis as key to reducing fatalities. As a result, the HSM is a fundamentally unique document, presenting the evolution of approaches, methods, and knowledge in highway safety. At its core are two principles:

- ◆ Allow the user to base decisions on actual anticipated changes in crash frequency and severity; and
- ◆ Address the statistical issues that have a direct impact on reliability.

## Nominal and Substantive Safety

Most highway programs have addressed safety through the application of standards. Standards often generically refer to design policies, guidelines, and critieria that are part of an agency's design and traffic operations manuals; to the AASHTO *Policy on Geometric Design of Highways and Streets*; to the AASHTO *Roadside Design Guide*; and to the *Manual on Uniform Traffic Control Devices*. Each of these documents, however, differs in purpose, use, and interpretation.

The assumption was that the application of a design standard provided safety. Ezra Hauer aptly termed this "nominal safety" in the 1990s. Many of these standards were not developed to address crash frequency and severity but operational, environmental, economical, and other considerations.

Hauer advocated that "substantive safety" was more appropriate for addressing crashes. Substantive safety provides a statistically reliable assessment of safety performance to inform an agency's planning, project development, and traffic operations.

In applying design standards, the designer assumes that the resulting design will be safe—that meeting the design manual requirements equals safety. Within this context, however, the designed facility is only nominally safe. For example, 12-ft lanes are the design standard for a particular facility type; a design for 11-ft lane widths, which would require a design exception, represents an absolute change in safety—the nominal crash risk would be significantly higher.

Substantive safety, in contrast, relies on scientific findings for determining the anticipated safety performance, measured in crash frequency and severity. With the substantive safety approach, the designer

Efforts to reduce crash risk focus on the human, the vehicle, and the roadway.

Photo: iStock

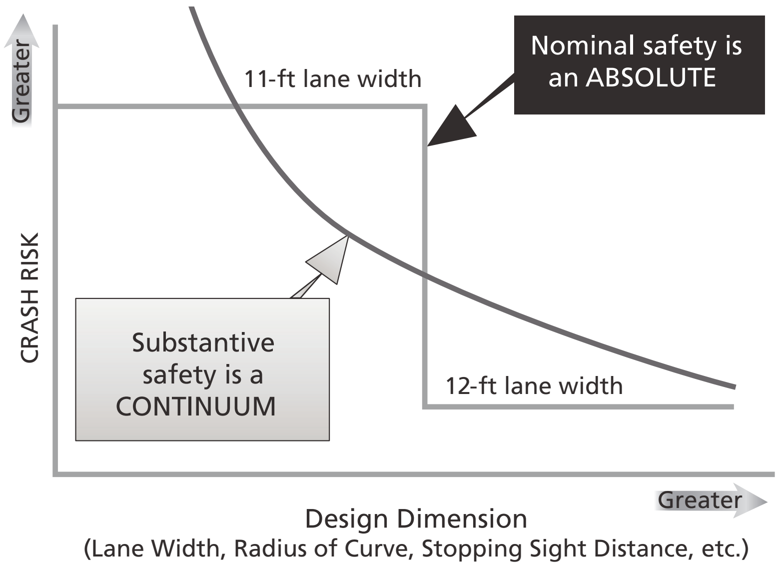



**FIGURE 1 Nominal versus substantive safety.** (Source: CH2M Hill, 2011.)

uses the HSM to determine the effect of a change in lane width on crash frequency and severity; for a given facility type and volume, the difference in the anticipated crash outcomes may be neglible. In the substantive safety approach to design and system management, crash frequency and severity are critical in decision making.

Figure 1 (above) illustrates the difference between nominal and substantive safety with the 12-ft versus 11-ft lane width example. The line labeled as nominal safety indicates that the crash risk associated with the 11-ft lane is substantially higher than that for the 12-ft lane. Under the nominal safety approach, the 11-ft lane would be deemed unsafe, and the 12-ft lane safe. The curve labeled substantive safety shows the actual anticipated crash performance as a continuum—as lane width increases, the crash risk decreases.

## Regression to the Mean

Historically, potential projects underwent a ranking of crash frequency or rate, followed by a "black spot" analysis that used short periods of observed crash history—typically two to five years—to identify locations that might benefit from changes to the road or roadside environment that would reduce crash frequency or severity. This method has been moderately successful, but using limited data can lead to large fluctuations in crash rates, as shown in Figure 2 (below, left).

Determining locations for safety intervention from small sets of data can lead to unreliable assumptions about safety performance if the analysis does not account for regression to the mean. An agency cannot know with certainty that the site will respond, or that any changes are directly caused by the treatment.

Crashes are random events; therefore crash frequency at a given site will vary from year to year; a project selected on the high side of this variance will show an average number of crashes that exceeds expectation. As shown in Figure 3 (below, right), accounting for regression to the mean produces a different expected average crash frequency, but one that is more indicative of the true safety performance at the site. Therefore the project is more likely to show a crash reduction with the appropriate countermeasure.

Accounting for regression to the mean and incorporating the substantive safety philosophy improves decision making. The result is fewer crashes on the highway system and a reduction in fatal and serious injuries. Improving an agency's ability to incorporate safety into decision making translates into increased effectiveness in expenditures, increased awareness of trade-offs, and the ability to inform the public—including stakeholders and elected officials—about the benefits and impacts of programs and projects.

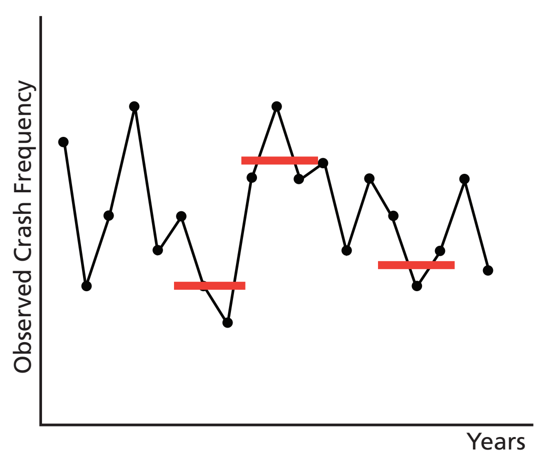



**FIGURE 2 Average short-term crash frequency (red horizontal rules).**

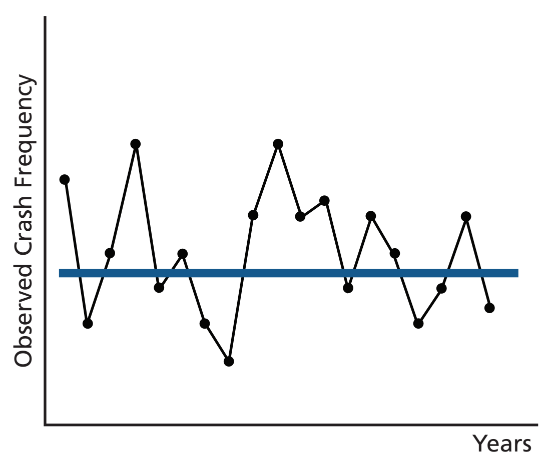



**FIGURE 3 Expected average crash frequency (blue horizontal rule).**

## *Highway Safety Manual* Contents



## New Thought Process

The HSM presents a new thought process for many organizations that will require some changes to policy, procedures, and methods. The document's structure follows the project development process for most transportation organizations. The three-volume HSM comprises 17 chapters sorted into four parts (see box, above).

### *Basic Concepts*

Part A introduces the basic concepts of highway safety, with chapters on human factors and safety fundamentals. Improving safety performance requires an awareness throughout the project development process of user capabilities, limitations, and interactions with the roadway.

Chapter 1—Introduction and Overview defines the purpose and intended audience of the HSM. The HSM is a technical document that requires a level of understanding for its use. The chapter highlights types of applications, the scope of the document, and its relationship to project development.

Chapter 2—Human Factors introduces the basic principles, indicating the effect of human factors and of the ways that designs and operations can account and compensate for limitations. The goal is to reduce the potential for errors—and consequently reduce crashes—related to human factors. The NCHRP Report 600 series, *Human Factors Guidelines for Road Systems*, supplements this chapter.[1]

Chapter 3 introduces the concepts that support the application of the methods, approaches, and knowledge presented in the HSM.

### *Road Safety Management*

Chapters 4 through 9 address road safety management, following the steps commonly taken in system and project planning, program management, preliminary engineering, and operations.

The first step generally involves screening for the projects most likely to respond to design modifications. Chapter 4—Network Screening outlines the process, which includes establishing the reason, determining the reference population, selecting performance measures, and selecting the screening methods. The chapter summarizes the state of the practice and shows how to incorporate safety into the ranking process, to focus resources where the return is highest.

After the projects are ranked, the next step is to understand the factors contributing to crashes across the location, corridor, or system. Chapter 5—Diagnosis describes how to analyze historic safety performance to gain insight into the circumstances contributing to observed crashes. Properly identifying the patterns, target crash types, and the contributing circumstances increases the probability that

[1] http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_600A.pdf.

PHOTO: AAA FOUNDATION FOR TRAFFIC SAFETY

A multilane, divided highway in a rural area. Understanding the specific factors that contribute to crashes in a highway system is an essential step in the project planning process.

Photo: Oregon Department of Transportation

Developed for training purposes as part of a National Cooperative Highway Research Program (NCHRP) project, spreadsheets incorporating locally derived values for Oregon can be used as a companion tool to Part C—Predictive Methods of the HSM. Part C assists practitioners in assessing the safety performance of rural, two-lane roads, as well as rural highways and urban and suburban arterials.

the factors contributing to crashes can be addressed in the best way possible.

Selection of a potential countermeasure is the third step, discussed in Chapter 6. Countermeasures aim to reduce the frequency and severity of crashes for a specific site, or they may represent a trade-off between crash severity and frequency. Selecting the appropriate countermeasures maximizes the potential for reducing crashes and their severity.

The economic analysis methods in the HSM allow comparisons of a countermeasure's anticipated benefits and costs. Chapter 7—Economic Appraisal presents cost-effectiveness and benefit–cost analysis methods. Although costs are typically valued in monetary terms, agencies often incorporate nonmonetary considerations. Project comparisons can use common performance metrics and analysis techniques.

Chapter 8 outlines project prioritization, necessary when several candidate sites have been identified on the network, the economic evaluations have been performed, and the economically feasible candidate sites have been selected and are consistent with organizational policies. The process allows an agency to identify the projects with the greatest potential benefit across the system.

Evaluating the change to the system in terms of crash or injury reduction helps an organization to understand safety performance and to account for safety in decision making. This approach is more likely to succeed in improving system performance. Chapter 9 presents different evaluation methods and approaches, reviews the strengths and limitations of each, and supports the development of crash modification factors (CMFs). Evaluating safety effectiveness provides agencies with feedback for policies and decision making.

### *Assessing Safety Performance*

Part C—Predictive Methods applies to rural two-lane, two-way roads (Chapter 10), rural multilane highways (Chapter 11), and urban and suburban arterials (Chapter 12). The predictive method assesses anticipated safety performance—that is, the predicted average crash frequency—and the expected average crash frequency, where applicable.

The estimates can be used to assess a network, corridor, or site, for existing and future conditions, with or without proposed countermeasures, as well as the effectiveness of potential countermeasures under current and future conditions. Part C allows the assessment of the safety performance of new facilities under various traffic volumes.

### *Safety Treatments*

Part D—Crash Modification Factors presents the potential effects of safety treatments and of operational and other site-specific changes on crashes for roadway segments (Chapter 13), intersections (Chapter 14), interchanges (Chapter 15), special facilities and geometric situations (Chapter 16), and road networks (Chapter 17). Each chapter explores the potential safety impacts in terms of the quality and the statistical reliability of the research.

Part D presents a subset of the CMFs available in practice. All information in the HSM underwent thorough screening and expert review to assure reliability of the information and guidance. Part D is supplemented with information from the FHWA Crash Modification Clearinghouse[2] and the NCHRP Report 600 series.

The HSM is scalable; some organizations or

[2]www.cmfclearinghouse.org.

Photo: Wayan Vota

Raised medians were installed along New Hampshire Avenue in Washington, D.C., in 2009; safety treatments are examined in the HSM Part D—Crash Modification Factors.

agencies may choose to implement only a portion of the tools. For instance, an organization may decide to focus on the planning and scoping of projects covered in Part B and on the reliable approaches incorporated in Part C; others may focus on design and apply Part C and Chapter 2—Human Factors. AASHTO developed Figure 4 (right) to show potential links to the project development process.

## Software Tools

Several software tools were developed to ease application of the HSM and are an integral part of the package. Following are some of the noncommercial software applications.

Safety Analyst is a highway safety management software tool that performs functions outlined in Part B, Chapters 4 through 9, of the HSM. Safety Analyst was developed through a pooled-fund effort by states and is offered as part of AASHTOWare, AASHTO's suite of software for designing and managing transportation infrastructure projects.[3]

The Interactive Highway Safety Design Model (IHSDM), a software tool developed and made available at no cost by FHWA, is used to evaluate the safety and operational effects of design decisions and includes modules on crash prediction, design consistency, intersection review, policy review, traffic analysis, and driver–vehicle issues. The IHSDM–HSM Predictive Method 2011 (Version 7.0.0) is available online.[4] The crash prediction module incorporates Part C, Chapters 10 through 12, of the HSM.

Under NCHRP Project 17-38, *Highway Safety Manual* Implementation and Training Materials, Karen Dixon of Texas A&M Transportation Institute developed spreadsheets to assist in performing the Part C predictive methods. Alabama, Virginia, Illinois, and Washington State DOTs have applied and expanded the spreadsheets.

The FHWA Crash Modification Factors Clearinghouse is a web-based database that allows searches for CMFs and assists in selecting the most appropriate measure.[2] The site employs a five-star rating system and includes supporting research.

## Supporting Documents

To assist in the implementation of the HSM, documents have been created for a variety of levels within a state DOT, focusing on the HSM as part of the project development process. The documents are available on FHWA's HSM website[5] or AASHTO's Highway Safety Manual website.[6]

[3]www.aashtoware.org/Pages/default.aspx.

[4]www.ihsdm.org.

[5]http://safety.fhwa.dot.gov/hsm.

[6]www.highwaysafetymanual.org/Pages/default.aspx.

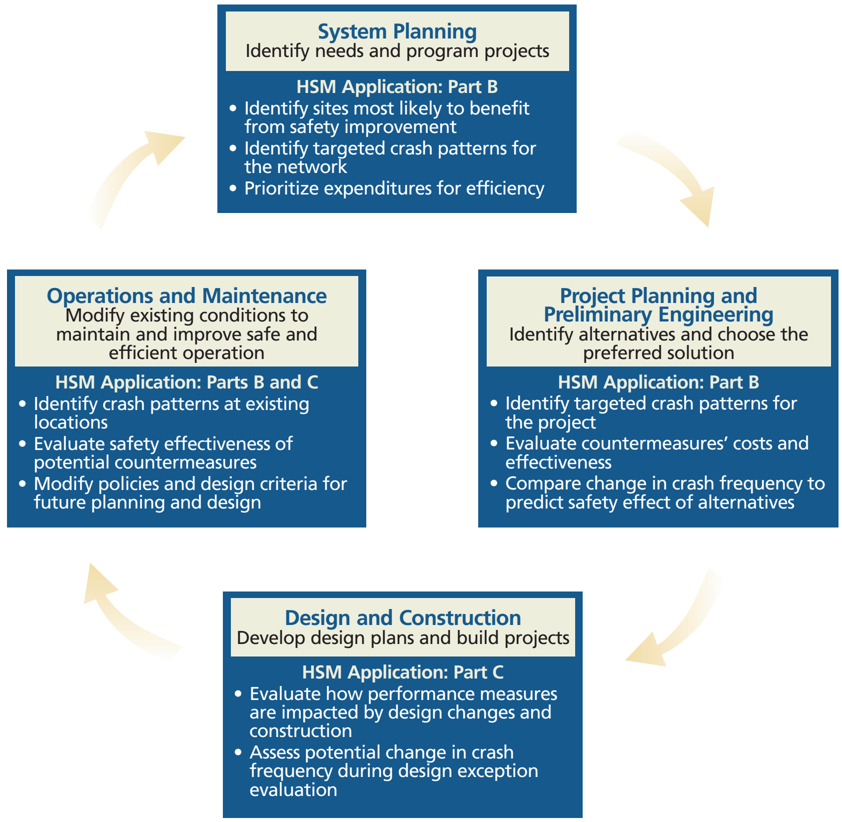



**FIGURE 4 HSM and the project development process.** (Source: AASHTO.)

The HSM outreach materials provide a quick point of reference and summary information to ease adoption of the HSM, including the *HSM Overview Brochure*, *HSM Overview Fact Sheet*, and *An Introduction to the Highway Safety Manual.*

FHWA has developed three HSM guides. The *HSM Managers Guide* (2011) provides information to state DOT managers charged with incorporating the HSM into the project development process. *Integrating the HSM into the Highway Project Development Process* (2012) helps transportation professionals apply the HSM in planning and scoping, environmental studies, predesign, final design, and day-to-day maintenance and operations activities. The *HSM Training Guide* (2011) was developed for state and local agencies considering implementation of the HSM; it documents training needs, sequences of training, delivery methods, and courses offered by FHWA's National Highway Institute and the Institute of Transportation Engineers.

Case studies complement the guides, demonstrating applications of the HSM, including the roadway safety management process, predictive methods, and the development of safety performance functions and implementation plans. FHWA also sponsors a user discussion forum on the AASHTO HSM website.[7]

[7]www.hsmforum.org.

# Safety Analyst

## *Software Tools for Safety Analysis of Specific Highway Sites*

DOUGLAS W. HARWOOD AND DARREN J. TORBIC

Safety Analyst consists of a set of software tools available from the American Association of State Highway and Transportation Officials (AASHTO) to help highway agencies analyze the safety effects of infrastructure improvements at specific sites on a highway and street network.[a] The tools were developed through a Federal Highway Administration (FHWA) pooled-fund study that ran from 2001 to 2009 with the participation of 27 state highway agencies and other stakeholders.

The software includes four modules that together address the six steps of the safety management process described in Part B of the *Highway Safety Manual* (HSM):

- **Module 1: Network Screening** reviews the entire highway network and identifies sites with the greatest potential for safety improvement.
- **Module 2: Diagnosis and Countermeasure Selection** diagnoses the safety concerns at particular sites and assists in selecting effective countermeasures to reduce the frequency and the severity of crashes.
- **Module 3: Economic Appraisal and Priority Ranking** performs cost-effectiveness and benefit–cost analyses for a specific countermeasure or for several alternative countermeasures at specific sites and ranks countermeasures and sites to assist highway agencies in setting investment priorities.
- **Module 4: Countermeasure Evaluation** performs before-and-after evaluations to document the effectiveness of implemented safety improvements.

The modular package allows for flexibility—users can apply Safety Analyst at any stage of the safety management process.

The Safety Analyst database consists of the highway agency's records of roadway segment, intersection, and ramp characteristics; traffic volumes; and crashes for its entire system. The software includes tools to import and manage data from the highway agency's databases. When Safety Analyst identifies a need, the project can be designed with supporting analyses from FHWA's Interactive Highway Safety Design Model (IHSDM; see article, page 11).

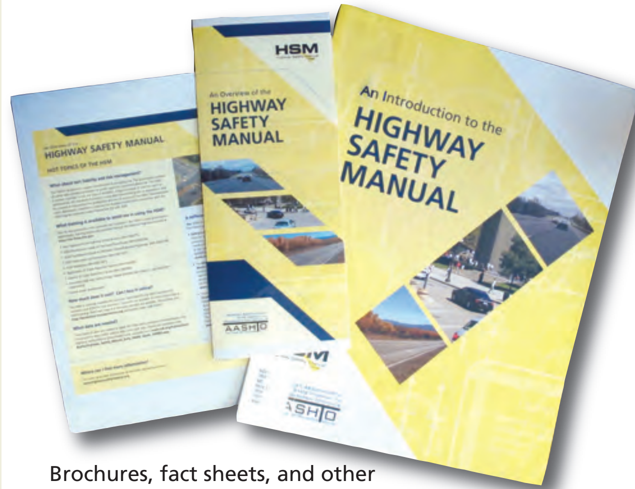
The data requirements for Safety Analyst are less extensive than for the predictive models in Part C of the HSM and in the IHSDM; project design requires more extensive data. Agencies that lack the detailed crash data to support Safety Analyst can apply the usRAP Tools software, available from the U.S. Road Assessment Program (see article, page 15), to perform the steps of network screening, countermeasure selection, and economic appraisal.

The Safety Analyst software can be licensed for use by highway agencies through the AASHTOWare program.[b] In addition to permitting use of the software, the license provides access to technical support, including engineering support from MRIGlobal and computer software and data management support from ITT Excelis.

*The authors are with MRIGlobal. Harwood is Transportation Research Center Director, Kansas City, Missouri; and Torbic is Principal Traffic Engineer, State College, Pennsylvania.*

[a]www.safetyanalyst.org.

[b]For licensing information, contact Vicki Schofield at AASHTOWare, VSchofield@aashto.org.




Brochures, fact sheets, and other outreach materials help states and localities assist in adopting the HSM.

## Research Supporting the HSM

TRB's Transportation Research Circular E-C142, *Methodology for the Development and Inclusion of Crash Modification Factors in the First Edition of the Highway Safety Manual* (2010), provides background on the development of Part D of the HSM and describes the CMF literature review and inclusion process.[8] This document offers a framework for the review of future safety publications, to determine statistical reliability, the characteristics of reliable CMF results, higher-quality methods to advance the science of safety, and improvements for later editions of the HSM.

During the development of the first edition, several professionals expressed concern about employing the monetary costs of crashes to justify programs and initiatives. In moving from a qualitative to a quantitative approach, however, economic appraisal is a key in decision making. Societal cost figures are often used to show the benefits of crash reduction and to prioritize projects. In 2011, NCHRP Project 20-24(068) developed a simple calculator to assist state DOTs in estimating the crash costs by state, using site and safety attributes such as posted speed limit, geometry, traffic control, signalization, crash type, and maximum severity of injury.[9]

CMFs are critical in quantifying the impacts on safety and directly affect the reliability of analyses. FHWA published *A Guide to Developing Quality Crash Modification Factors* (2010) to explain the process and the issues to consider in selecting evaluation methods; the document covers the background, definitions, purpose, use, and concerns in developing CMFs.[10]

In addition, FHWA sponsored research in support

[8]http://onlinepubs.trb.org/onlinepubs/circulars/ec142.pdf.

[9]http://usroadsafety.com/crash-cost-calculator.

[10]www.cmfclearinghouse.org/collateral/CMF_Guide.pdf.

# The Interactive Highway Safety Design Model

CLAYTON CHEN

The Interactive Highway Safety Design Model (IHSDM) is a suite of software tools that support project-level decisions about the geometric design of roadways. The model provides quantitative information on the expected safety and operational performance of a design. Produced by the Federal Highway Administration's Safety Research and Development Program, the IHSDM is a resource for the predictive method described in Part C of the American Association of State Highway and Transportation Officials' *Highway Safety Manual* (HSM).

IHSDM assists project developers in making decisions that improve the safety performance of designs. The software tools also help project planners, designers, and reviewers justify and defend decisions about geometric design.

The 2011 IHSDM comprises six evaluation modules: Crash Prediction, Policy Review, Design Consistency, Intersection Review, Traffic Analysis, and Driver–Vehicle. The Crash Prediction Module (CPM) is a software implementation of HSM Part C, which includes crash prediction methodologies for rural two-lane and multilane highways and for urban and suburban arterials.

The IHSDM includes a recently developed calibration utility to assist agencies in implementing the procedures described in the Part C Appendix. Agencies can enter their own safety performance functions and modify the default crash distributions. Efforts are under way to extend the CPM to include freeway, ramp, and interchange crash prediction capabilities from new HSM chapters developed under National Cooperative Highway Research Program Project 17-45, Enhanced Safety Prediction Methodology and Analysis Tool for Freeways and Interchanges.

Two recent case studies highlight the use of IHSDM to implement HSM Part C methods:

◆ The Louisiana Department of Transportation and Development (DOTD) conducted a safety analysis to quantify the benefits of constructing an alternative route from Interstate 12 to Bush. The CPM produced estimates of the crashes expected in 2035 for the study area network, for the no-build condition, and for four alternative scenarios. The total network crash performance was evaluated and compared for each scenario. An estimated cost per crash by severity was applied to the predicted number of crashes, and the alternatives were ranked by cost savings. Louisiana DOTD was able to identify the safest and most cost-effective solution.

◆ The Idaho Department of Transportation (DOT) conducted a comprehensive review of conditions on the State Highway 8 corridor to identify and prioritize operational improvements over a 10-year period. The IHSDM crash predictions were based on the existing traffic, roadway geometry, and recent crash history. The output indicated that for more than half of the 11-mile corridor, the calculated crash rate was higher than the statewide average. Potential locations were identified for improvement. "The advantage of employing IHSDM was the opportunity to perform a detailed and simultaneous review within the corridor on a variety of critical elements—for example, traffic operations, geometry, and safety—to isolate potential problem areas and allow the development of strategic mitigation strategies," the project manager noted.

PHOTO: WASHINGTON STATE DOT

*The Interactive Highway Safety Design Model's Crash Prediction Module presents methodologies for highways and arterials; efforts are under way to incorporate crash prediction capabilities for ramps, freeways, and interchanges as well.*

IHSDM training consists of a two-day course onsite or a web-based version led by experienced instructors. Participants learn about key IHSDM capabilities and limitations, evaluate highways using IHSDM, and recognize when and how the module can be used during the project development process.

## Resources

- For more information about the Idaho DOT case study, visit http://safety.fhwa.dot.gov/hsm/casestudies/id_cstd.cfm.
- For more information about training courses, see FHWA-NHI-380071 and -380100 in the National Highway Institute catalog, http://nhi.fhwa.dot.gov.
- Additional resources are available at http://www.fhwa.dot.gov/research/tfhrc/projects/safety/comprehensive/ihsdm/index.cfm and http://www.ihsdm.org.
- Contact: Clayton Chen, 202-493-3054; clayton.chen@dot.gov.

*The author is Highway Research Engineer, Federal Highway Administration, McLean, Virginia.*

Wikimedia Commons

A pedestrian refuge island in a roadway. Safety for nonmotorists also is part of the NCHRP research portfolio.

of the Highway Safety Improvement Program. *Investigation of Existing and Alternative Methods for Combining Multiple CMFs* (2010) presents issues in the application of multiple CMFs and offers guidance for estimating the effects of combined treatments.[11]

NCHRP Project 20-7(314), Recommended Protocol for Developing Crash Modification Factors, has outlined a process for developing CMFs. The findings describe the necessary documentation and how to address potential biases.

The NCHRP Report 600 series focuses on road user capabilities and on limitations in road design and operations.[12] The guidelines are useful for diagnosing the contributing factors in collisions and for the selection of countermeasures.

## Training and Implementation

Training is a critical component of the HSM. NCHRP Project 20-7(290), Highway Safety Training Synthesis, surveyed the safety training available and developed a roadmap and central database of the information. NCHRP Project 17-38, Development of Overview Training for the HSM, assisted FHWA and others in preparing to implement the HSM.

The first of many research publications supporting HSM implementation was NCHRP Research Results Digest 329, *Highway Safety Manual Data Needs Guide*.[13] The guide assists users in understanding the data needed for the Part C methodologies and explains the difference between available data and the data needed in the future.

NCHRP Project 17-50, Lead States Initiative for Implementing the HSM, started after the successful Safety Performance Function Summit hosted by Illinois DOT through the efforts of State Safety Engineer Priscilla Tobias; the summit focused on the use of quantitative tools in highway safety. The project has established a dialogue among states that have experience in quantifying safety, to inform other states,

[11]www.cmfclearinghouse.org/collateral/Combining_Multiple_CMFs_Final.pdf.

[12]http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_600A.pdf; http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_600B.pdf; and http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_600C.pdf.

[13]http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rrd_329.pdf.

# Roadside Safety Analysis Program, Version 3

## *Upgrading a Tool for Roadside Safety Design*

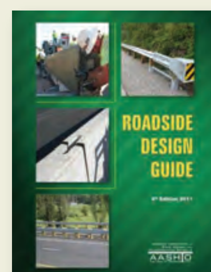
MALCOLM H. RAY, CHRISTINE E. CARRIGAN, AND CHUCK PLAXICO

The Roadside Safety Analysis Program (RSAP) was developed to update and enhance the cost-effectiveness analysis algorithms and procedures of the ROADSIDE software package included in the *Roadside Design Guide*, published by the American Association of State Highway and Transportation Officials (AASHTO). The program and its interface recently have undergone an extensive upgrade, incorporating new research results and enhancing the computing capabilities and ease of use.


*Version 3 of the Roadside Safety Analysis Program (RSAPv3) was developed as a tool for the 2011* Roadside Design

Version 3 of RSAP (RSAPv3) soon will be available electronically at no charge from AASHTO to purchasers of the *Roadside Design Guide*. The National Cooperative Highway Research Program is preparing to publish a final report that contains a user's manual with detailed, how-to explanations and an engineer's manual tracing the technical background behind the code, as well as the methodologies for the analyses. The software, manuals, and example problems are available on the website of the AASHTO Technical Committee for Roadside Safety.[a]

As the benefit–cost tool for the 2011 edition of the *Roadside Design Guide,* RSAPv3 assists in performing roadside safety economic analyses and serves as an alternative to the warranting approach also included in the guide. RSAPv3 incorporates substantive advances in roadside safety in the decade since the previous version; this required rewriting the code and developing new methods and techniques.




An encroachment-based approach, RSAPv3 divides collisions into three independent events:

1. The encroachment, when the vehicle first leaves the road;
2. The traversal of the roadside, where hazards may be located; and
3. The severity of the crash when a vehicle intersects a roadside hazard.

RSAP performs this series of calculations many times, simulating tens of thousands of encroachments for a typical roadway segment and estimating the crash costs of each possible encroachment. After generating all the encroachments and the estimated crash costs, the program produces an estimate of the total crash cost for the segment.

RSAPv3 can evaluate up to five design alternatives on up to

[a]http://design.transportation.org/Pages/RoadsideSafety.aspx.

and is developing a user guide for the HSM. The FHWA Pooled Fund Study for HSM Implementation is under way to advance the lead states initiative and to expand implementation to all states.[14]

## Toward Future Editions

NCHRP Project 20-7(279), Work Plan for the 2nd Edition of the HSM, is a comprehensive effort to assess future research needs for the manual. Surveys of safety professionals have helped the AASHTO Task Force on the HSM and the TRB Highway Safety Performance Committee prioritize research efforts.

The first edition of the HSM included only a few roadside countermeasures. NCHRP Project 17-54, Consideration of Roadside Features in the *Highway Safety Manual*, recognizes the role of roadside features in crashes and is exploring the differences between the HSM and the NCHRP-developed Roadside Safety Analysis Program (RSAP), including the comparative strengths and weaknesses of each and ways to address the differences. The project also is identifying ongoing roadside research, CMFs research, and needed CMFs and aims to develop CMFs.[15]

NCHRP Project 17-56, Development of Crash Reduction Factors for Uncontrolled Pedestrian Crossing Treatments, looks to quantify the relationship between pedestrian crashes and crossing treatments. The research will evaluate various crossing treatments and will develop CMFs for crash type and severity.[16]

The ability to assess crash injuries accurately is critical in the selection of appropriate countermeasures; however, police reports of crash injuries often lack accuracy. NCHRP Project 17-57, Development of a Comprehensive Approach for Serious Traffic Crash Injury Measurement and Reporting Systems, is developing a framework for moving to International Statistical Classification of Diseases and Related Health Problems codes and to provide a process for linking crash data with hospital discharge data. The findings may provide a new injury scale for the HSM.[17]

[14]Transportation Pooled Fund 255; www.pooledfund.org/Details/Study/484.

[15]http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2979.

[16]http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3178.

[17]http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3179.

20 highway segments and can compare the benefit–cost ratio of each alternative. The program identifies the alternative that makes best use of the funds.

The encroachment module in RSAPv3 takes into account the frequency of roadside encroachments by highway type and traffic volume. Adjustment factors are included for the effects of horizontal curvature, grade, number of lanes, lane width, access density, and posted speed limit.

RSAPv3 incorporates data on vehicle trajectories during an encroachment. The trajectories are superimposed on the user-entered data for roadside terrain, and the program assesses all possible interactions of trajectories with user-entered hazards.

RSAPv3 replaces the subjective severity index with an objective fatal crash cost ratio based on observed, police-reported crash data. RSAPv3 also accounts for unreported crashes—which can be considered roadside safety successes. The program includes a preloaded selection of crash severity models for many common roadside hazards, such as trees, utility poles, guardrails, and bridge piers.

The final report and its appendices document the methods and procedures in developing RSAPv3 and include a selection of case studies to illustrate use of the program. RSAPv3 provides roadside designers with an effective tool for making decisions about roadside safety designs.


PHOTO: MIKE LEE

*A median cable barrier on I-470 in Ohio prevented this tractor-trailer from reaching the opposite lanes of the highway in a crash. Roadside traversals are among the collision events analyzed by RSAPv3.*

### Resources


Mak, K. K., D. L. Sicking, and B. A. Coon. *NCHRP Report 665: Identification of Vehicular Impact Conditions Associated with Serious Ran-off-Road Crashes*. Transportation Research Board of the National Academies, Washington, D.C., 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_665.pdf.

NCHRP Project 17-43: Long-Term Roadside Crash Data Collection Program. http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=1637.

*Roadside Design Guide, 3rd Edition*. American Association of State Highway and Transportation Officials, Washington, D.C., 2006.



*The authors are with RoadSafe LLC, Canton, Maine.*

Several NCHRP projects are under way to inform future editions of the HSM; one is examining the relationship between pedestrian crashes and crossing treatments.

PHOTO: WASHINGTON STATE DOT

NCHRP Project 17-59, Safety Impacts of Intersection Sight Distance, is reviewing the relationship between safety and available intersection sight distance. Products include guidelines for various intersections and other factors and conditions, plus CMFs or other appropriate functions.[18]

[18]http://apps.trb.org/cmsfeed/trbnetprojectdisplay.asp?projectid=3181.

## Training Materials for Applying the *Highway Safety Manual*

Released by the American Association for State Highway and Transportation Officials in 2010, the *Highway Safety Manual* (HSM) presents tools to facilitate decisions on roadway planning, design, operations, and maintenance that focus on their safety consequences. Because a key component to the manual's success is wide dissemination and comprehensive understanding of its techniques, the National Cooperative Highway Research Program (NCHRP) initiated an outreach and training project, summarized in NCHRP Report 715, *Highway Safety Manual Training Materials*.

Training materials include basic introductory information, as well as specific content for advanced procedures. The report features 12 informational modules addressing the development of the HSM, safety fundamentals, network screening, predictive methods, human factors, economic appraisal and prioritization, specialized procedures, diagnosis and countermeasure selection, safety effectiveness evaluation methods, crash prediction procedures, candidate crash modification factors, and introductory information on safety assessment procedures. Training materials include presentation slides with speaker notes, participant handouts, interactive sample problems, and smart spreadsheets.

The report emphasizes the importance of clear, concise, and objective language in safety instruction and documentation. Phrases and terms used to describe transportation scenarios often have connotations beyond their intended meaning—the report also highlights phrases that can be perceived incorrectly.

*For more information on NCHRP Report 715 or to download the included CD-ROM, visit www.trb.org/Publications/Blurbs/167185.aspx.*

NCHRP Project 17-62, Improved Prediction Models for Crash Types and Crash Severities, is developing models to supplement or to replace those listed in the HSM. The research will produce new SPFs or distributions for predicting crash severity on a facility.[19]

NCHRP Project 17-63, Guidance for the Development and Application of Crash Modification Factors, is exploring procedures for formulating, calibrating, and using new CMFs for multiple-treatment applications.[20]

## Potential New Chapters

NCHRP Project 17-45, Enhanced Safety Prediction Methodology and Analysis Tool for Freeways and Interchanges, has produced two new chapters for the TRB Safety Performance Committee and AASHTO to consider for the HSM. The chapters will likely become part of the IHSDM predictive methods module. In addition, the research has enhanced the Interchange Safety Analysis Tool.[21]

NCHRP Project 17-58, Safety Prediction Models for Six-Lane and One-Way Urban and Suburban Arterials, is pursuing the continued development of the predictive methods chapters. The research will develop crash frequency and severity models for segments and intersections, as well as new chapters for the HSM.[22]

## An Evolving Science

The HSM was created to reduce fatal and serious crashes on the nation's highways. The manual has changed the field of highway safety by introducing the means to quantify the impacts of safety in common practice and to use this information throughout the program and project development process. The HSM cannot be a static document; changes will occur as new information develops and the science of safety evolves.

The development and implementation of the HSM has spurred many research efforts and partnerships. The dedication of AASHTO, FHWA, and TRB in the publication of the first edition is evident. Volunteers and staff have devoted and contributed countless hours to the development of the HSM and to the effort to improve the science of highway safety. The TRB Highway Safety Performance Committee encourages participation in HSM activities and in the nation's Toward Zero Deaths vision.[23]

[19]http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3420.

[20]http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3421.

[21]http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2512.

[22]http://apps.trb.org/cmsfeed/trbnetprojectdisplay.asp?projectid=2759.

[23]www.safetyperformance.org.

Blueprints to Improve HIGHWAY SAFETY

# Road Safety Management Tool Assists State and Local Engineers

PETER KISSINGER

The new highway bill signed in July increases funding for highway safety and emphasizes the value of state strategic highway safety plans for all public roads. This will generate demand for new and innovative safety management tools, such as usRAP—the U.S. Road Assessment Program.[a]

The AAA Foundation for Traffic Safety completed an eight-state pilot test in 2010 to explore the benefits of usRAP. Modeled on programs in Europe and Australia and in effect in more than 70 countries, usRAP uses crash history data or roadway inventory data to assess and benchmark the relative safety of roads. State and county engineers and other key stakeholders are represented on the technical advisory panel that has guided the program.

Implementation of usRAP is under way across the country. In Michigan and Illinois, the usRAP team is building on a successful project in Kane County, Illinois, and is working with the states' departments of transportation and several counties to assist in the development of county-level strategic highway safety plans. These efforts will demonstrate the utility and applicability of usRAP to county and local jurisdictions, which often do not have adequate crash data to deploy more traditional analytical tools, such as the American Association of State Highway and Transportation Officials' Safety Analyst.

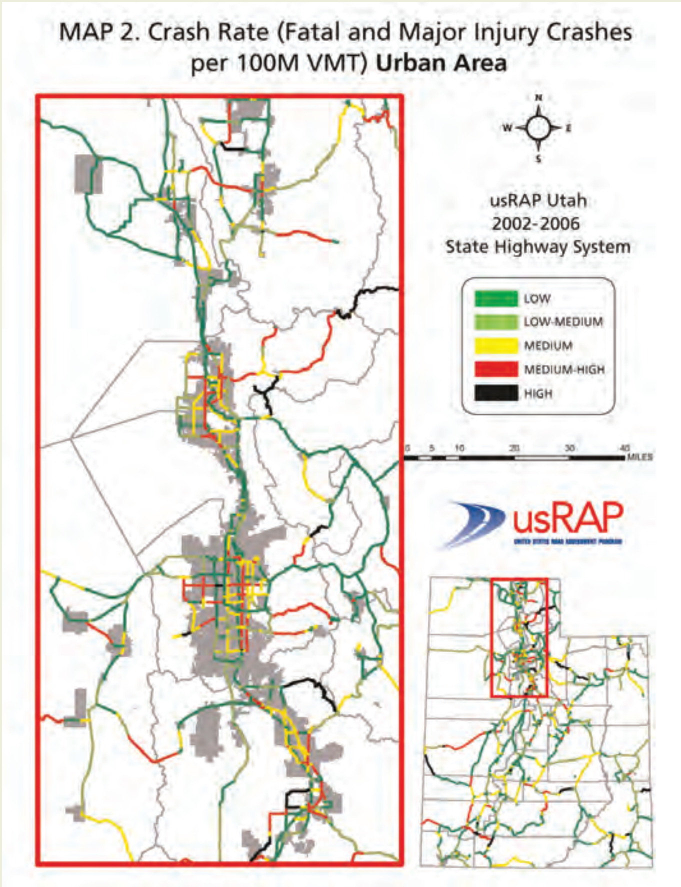
Through the Road Protection Score, usRAP identifies road segments with higher crash potential, analyzing road inventory data for the absence or presence of design features that correlate strongly with the risk of serious crashes. By generating a safety investment plan, usRAP offers cost-effective options—that is, road safety improvements—for engineers to consider for lowering the identified risks.

In Utah, the usRAP team has trained state safety engineers to perform analyses and produce color-coded risk maps from historical crash data. The team plans additional training sessions for state and county engineers, as well as for consultants interested in integrating the usRAP tools into their procedures.[b]

These efforts complement and supplement other highway safety management practices and help state and local jurisdictions respond to the new emphases on performance metrics and transparency, with the move nationwide to enhance traffic safety culture and to pursue the Toward Zero Deaths agenda.

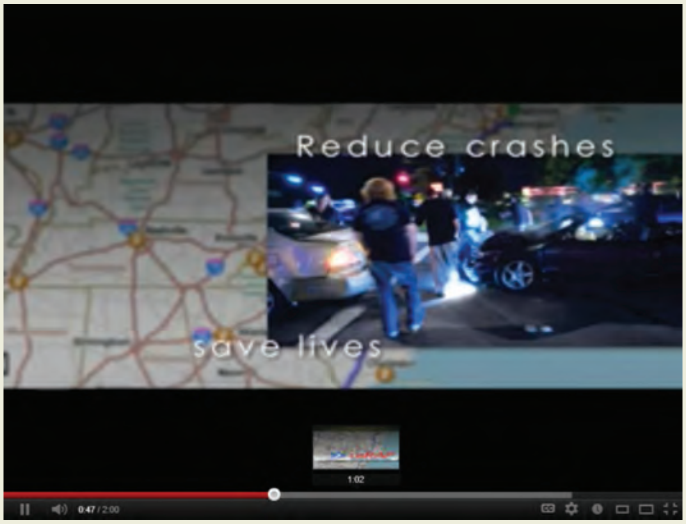
*The author is President and CEO, AAA Foundation for Traffic Safety, Washington, D.C.*

IMAGE: USRAP




*The usRAP risk map for Utah shows historical crash data in the state.*

IMAGE: USRAP




*An introductory video on the U.S. Road Assessment Program (usRAP) website provides an overview of the program. usRAP was pilot-tested in eight states and currently is being implemented across the country.*

[a] www.usrap.us.

[b] To collaborate with usRAP or to participate in the training, contact the AAA Foundation at usRAP@aaafoundation.org or 202-638-5944.