Overview of the on-going development of a Highway Safety Manual

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Abstract

Better quantitative methods and a single authoritative document for estimating safety effects are needed to facilitate the incorporation of transportation safety of all road users into the decision-making process. The need for a highway safety manual was identified over a decade ago. Content development of the First Edition is currently underway.

The purpose of the Highway Safety Manual is "*To provide the best factual information and tools in a useful form to facilitate roadway planning, design, operations, and maintenance decisions based on explicit consideration of their safety consequences*." The Highway Safety Manual is intended to become a widely accepted resource within the transportation profession for quantitative safety analysis, just as the Highway Capacity Manual is generally accepted for quantitative operational analyses. Objectives of the Highway Safety Manual are to encourage: evidence-based decision making, more resources focused on safety research, and innovative approaches to improving safety.

New methodologies have been developed to enhance the quality of information included in the Highway Safety Manual. The First Edition will include concise summaries of validated highway research and analytical tools for predicting the impact of geometric and operational decisions on road safety.

This paper provides a brief history of the Highway Safety Manual, an overview of the outline and planned contents of the First Edition, the new methodologies developed and applied, an update on work completed to date, and a review of the next steps. Sample draft content related to geometric design and roadside elements will be presented as examples of Highway Safety Manual content. The Highway Safety Manual is planned for publication in 2008.

Introduction

The purpose of the Highway Safety Manual (HSM) is to provide the best factual safety information and safety tools in a useful form. The information contained in the HSM is intended to facilitate roadway planning, design, operations, and maintenance decisions based on explicit consideration of their safety consequences. The HSM will be an authoritative source of proven highway research that can be adapted and integrated into practice.

The vision for the HSM is to provide the best available information packaged into the most appropriate format that will be useful to transportation planners, highway designers, traffic engineers, and others. Information on the safety effects of treatments will be provided, whenever available, in the form of analytical tools for predicting the impact of various roadway elements on the safety of all road users.

The HSM will contain the latest quantitative "state-of-the-art" information; however, it is not intended to become simply another synthesis of safety literature and research. The HSM is intended to become a widely accepted resource within the transportation profession, much like the Highway Capacity Manual (HCM) is generally accepted to be the definitive source for quantitative operational analyses. Similar to the HCM, the HSM is not intended to be a standard, policy or legal document that mandates any particular decision. It is expected that the HSM will be used in conjunction with guidance from other documents such as the MUTCD, Geometric Design Guides, and state/provincial and local publications. It is also expected that the HSM will be updated regularly to reflect new sound findings from safety research studies.

This paper provides a brief history of the Highway Safety Manual, an overview of the outline and planned contents of the First Edition, the new methodologies developed and applied, an update on work completed to date, and a review of the next steps. Sample draft content related to geometric design and roadside elements is presented as examples of Highway Safety Manual content.

Brief History of the Highway Safety Manual

The Transportation Research Board (TRB) Task Force for the Development of a Highway Safety Manual is an international group of transportation professionals who are the driving force behind the HSM. The Task Force has its roots in TRB Committee A3A10 "Highway Capacity and Quality of Service". Several members of that committee shared an interest in exploring ways in which highway safety could be explicitly reflected within future editions of the Highway Capacity Manual (HCM). At the January 1999 TRB Annual Meeting a conference session explored alternative means for reflecting highway safety within the HCM. A key conclusion from that session was that one reason for a lack of safety emphasis in decision-making was the absence of a single authoritative document for estimating safety impacts. Thus, the need for a highway safety manual was identified.

Next, a workshop was held in December 1999 sponsored by eight TRB committees and funded by the FHWA. The purpose of the workshop was to determine the need for, nature of, and feasibility of producing a Highway Safety Manual. A group of about 25 researchers and practitioners participated in the workshop, and it was concluded that there was definitely a need for a manual, and that work should begin as soon as possible on the development of a Highway Safety Manual.

The HSM Joint Subcommittee held its first official, formative, meeting in January of 2000. The Joint Subcommittee became a TRB Task Force in 2003, and currently the group has grown to about 100 Members and Friends. The basic objective for the HSM Task Force is to provide the

direction and oversight of research, and the final preparation of material, for the first edition of the HSM.

Outline of planned Highway Safety Manual content

The HSM Task Force has developed an outline for the first edition of the Highway Safety Manual. This outline, summarized in Table 1, contains 5 Parts and 16 Chapters.

Table 1: Outline of Highway Safety Manual, First Edition

Part I – Introduction and Fundamentals	
Chapter 1	Introduction and Overview
Chapter 2	Fundamentals
Part II – Knowledge	
Chapter 3	Roadway Segments
Chapter 4	Intersections
Chapter 5	Interchanges
Chapter 6	Special Facilities and Geometric Situations
Chapter 7	Road Networks
Part III – Predictive Methods	
Chapter 8	Rural Two-lane Roads
Chapter 9	Rural Multi-lane Highways
Chapter 10	Urban and Suburban Arterials
Part IV – Roadway Safety Management	
Chapter 11	Roadway Safety Network Screening
Chapter 12	Diagnosis of the Nature of Safety Problems at Specific Sites
Chapter 13	Selection of Countermeasures to Reduce Crash Frequency and Severity at Specific Sites
Chapter 14	Economic Appraisal of All Sites Under Consideration
Chapter 15	Prioritize Rankings of Improvement Projects
Part V – Safety Evaluation	
Chapter 16	Safety Evaluation and Estimation of Accident Modification Factors (AMFs)

The content of these 16 Chapters is under development through several National Cooperative Highway Research Program (NCHRP) projects. The TRB HSM Task Force has developed Chapter 1, and is providing thorough technical reviews of each chapter developed through the NCHRP projects.

Development of Highway Safety Manual content

The following completed and on-going NCHRP projects are contributing to different parts of the first edition of the HSM:

NCHRP 17-18 (4) "Highway Safety Manual": This assignment developed the scope of the HSM in detail, and produced a prototype chapter for Part III of the HSM: Predictive Methods that incorporated the analytical procedure developed by the FHWA for safety estimation on rural two-lane highways. A product of this work is a draft Chapter 8 of the HSM. It was completed in October 2003.

NCHRP 17-26 “Methodology to Predict the Safety Performance of Urban and Suburban Arterials”: This assignment aims to develop a methodology that predicts the safety performance of the various elements (e.g., lane width, shoulder width, use of curbs) considered in planning, design, and operation of non-limited-access urban and suburban arterials. A product of this work is a draft Chapter 10 of the HSM. It was completed in February 2007.

NCHRP 17-27 “Parts I and II of the Highway Safety Manual”: This assignment aims to prepare Parts I (Chapter 2) and II (Chapters 3 to 7) of the Highway Safety Manual. This work is discussed in more detail below. At the time of writing, it is scheduled for completion in May 2007.

NCHRP 17-29 “Methodology to Predict the Safety Performance of Rural Multilane Highways”: This assignment aims to develop a methodology to predict the safety performance of rural multilane highways and to prepare a chapter on rural multilane highways for inclusion in the Highway Safety Manual. The methodology shall apply to both highway segments and at-grade intersections but will not include full access-control highways. A product of this work is a draft Chapter 9 of the HSM. At the time of writing, it is scheduled for completion in June 2007.

NCHRP 17-34 “Prepare Parts IV and V of the Highway Safety Manual”: This assignment aims to prepare Parts IV (Chapters 11 to 15) and V (Chapter 16) of the Highway Safety Manual. It was completed in January 2007.

NCHRP 17-36 “Production of the First Edition of the Highway Safety Manual”: The other NCHRP projects identified above will produce final drafts of most of the material needed for the first edition of the HSM; a key effort is needed to combine all of these materials into a comprehensive and consistent document and to provide complementary materials for other media, such as CD-ROM, DVD, or another electronic format. At the time of writing, it is scheduled for completion in June 2008.

NCHRP 17-25 “Crash Reduction Factors for Traffic Engineering and ITS Improvements”: This is a related research effort to establish existing knowledge and develop reliable Crash Reduction Factors for traffic engineering, operations, and ITS improvements. The results of this effort may become content for the Highway Safety Manual. It is scheduled for completion in June 2007.

Another major relevant effort by FHWA and co-sponsoring states and provinces is *SafetyAnalyst* (www.safetyanalyst.org), which will develop a suite of software tools for the identification of sites with promise, diagnosis and selection of countermeasures, the economic evaluation and project ranking, as well as a safety evaluation tool for before and after analyses. These tools will apply quantitative methodologies, as in the HSM. Interim tools are currently being tested, and the final *SafetyAnalyst* tools are planned for release in 2008.

NCHRP Project 17-27

This project is currently developing Parts I and II of the Highway Safety Manual, specifically Chapters 2 to 7.

The intent of Chapter 2 is to provide the fundamentals to the HSM user that will guide the application of all chapters of the HSM. Chapter 2 will include the material needed to understand and properly apply the methods and procedures in the HSM. This chapter will include topics such as the definition and measurement of safety, Safety Performance Functions, and Accident Modification Factors (AMFs).

An AMF is an estimate of the reduction (or increase) in the frequency and/or severity of crashes that occur after the implementation of a countermeasure or combination of countermeasures. AMFs are often calculated separately by crash severity (e.g., fatal, injury, PDO) or crash type (e.g., nighttime crashes, pedestrian crashes, etc.). AMFs are expressed as a decimal factor; if the AMF for a countermeasure is 0.86, the implementation of the countermeasure should reduce the number of crashes to 86% of the present number of crashes; that is, a crash reduction of 14%.

Chapter 2 will also examine crash causation, and the effect of traffic exposure, traffic mix, and speed on road safety. The fundamentals of evaluating the safety impact of different road elements will be provided, as well as the fundamentals of human factors related to traffic and road design.

With the goal of providing quantifiable measures of safety performance, Chapters 3 to 7 will provide known and reliable quantitative knowledge for the full range of transportation facilities (roadway segments, intersections, interchanges, work zones, railroad-highway grade crossings, and road networks). For each facility type, the safety effects of design, operations, pedestrians and cyclists, and other elements such as illumination are included.

New Approach to Develop HSM Content

In order to compile a comprehensive knowledge base, a thorough search for and review of safety literature was conducted, covering over 600 papers, reports and syntheses. The knowledge presented in Part II of this manual is based on an extensive literature review of published transportation safety research mostly dated from the 1960s to December 2004.

The objective was to establish what is currently known in terms of quantified safety impacts. The knowledge base relies on published Accident Modification Factors (AMFs). In some cases, the NCHRP 17-27 research team was able to use published data to estimate AMFs, if enough data were available in the publication.

A new approach was taken during the literature review and synthesis. A procedure was developed and consistently applied to quantify the reliability of Accident Modification Factors using an estimate of the standard error of the AMF. The procedure includes methods to calculate AMFs based on published data, estimate the standard error of published or calculated AMFs, and adjust the AMFs and standard errors to account for study quality and method. In summary, the steps followed in the literature review procedure are:

1. Determine the estimate of the safety effect or Accident Modification Factor or Function (AMF) of a treatment based on one published study: If AMFs were not published by the original authors, specific methods were applied based on published data to calculate an AMF

2. Adjust the AMF to account for potential bias from regression-to-mean and/or changes in traffic volume: The literature was critically reviewed to determine if confounding factors were accounted for, such as regression to the mean, or changes in traffic volume. If confounding factors were identified, the AMF was adjusted to reduce the potential for bias in the AMF value
3. Determine the ideal standard error of the AMF: Although the statistical distribution of AMFs is not known (i.e., it is generally accepted that AMFs do not follow a normal distribution), the estimate of standard error serves as an approximation of the reliability of the AMF. Standard errors can be equated to the concept of a statistical confidence interval, and can be estimated using the study sample size. For each published AMF, an estimate of the standard error of the AMF value was calculated (if not published by the original authors) based on sample size (number of accidents in the study) and the duration of the study. For example, an AMF of 0.86 (a 14% reduction in crashes) may have a standard error of 0.05
4. Apply a Method Correction Factor to ideal standard error, based on the study characteristics: Due to the variety of study methodologies that have been used to estimate AMFs, Method Correction Factors (MCFs) were developed by the project team for application to each estimate of standard error. The objective of the MCF is to adjust the standard error for different methodologies and levels of study quality. Method Correction Factors were developed for the range of safety evaluation study types, including empirical Bayes, simple before/after, before/after with likelihood functions, before/after with comparison group, expert panels, meta analysis, non-regression and regression cross-section studies. For example, the standard error of an AMF from a simple before-and-after study that did not account for regression to the mean and used accident frequencies or accident rates was adjusted using a factor of 2.2. The standard error of an AMF from a rigorous empirical Bayes methodology that properly accounted for potential sources of bias and used accident frequencies was adjusted using a factor of 1.2.
5. Adjust the corrected standard error to account for bias from regression-to-mean and/or changes in traffic volume: If confounding factors were identified in Step 2, the standard error was also adjusted to reduce the potential for bias
6. Combine AMFs for the same treatment under similar conditions: In a limited number of cases, multiple studies provided results for the same treatment in similar conditions. After careful consideration of the treatment and conditions of the studies, the results may be combined following the steps outlined in the literature review procedure. These steps are further detailed in Appendix A, and examples are provided.

The project team adjusted every standard error, as only a rigorous randomized trial evaluation would not require an inflation of the standard error value.

Inclusion Process

The result of the critical literature reviews, estimation of AMFs and process to quantify the reliability of those AMFs is a collection of over 350 AMFs with standard errors. In order to determine which AMFs to include in the First Edition of the HSM, an Inclusion Process was developed by the NCHRP 17-27 team and adopted by NCHRP Project Panel and TRB Task Force.

Each AMF was reviewed by the project team to assess if it is of sufficient quality (based on the estimate of standard error) for the First Edition of the HSM. Specifically, a standard error of 0.1 or less indicates an AMF value that is sufficiently accurate, precise, and stable to be included in the HSM and used with confidence. For treatments that have an AMF with a standard error of 0.1 or less, other related AMFs with standard errors of 0.2 to 0.3 are also included to indicate the potential safety effects of the treatment on other facilities, or other crash types and severities.

The Inclusion Process provides a level of confidence in the quality and accuracy of the AMFs included in the First Edition of the HSM.

This process also identifies "gaps in knowledge", that is, areas where there is limited quantified safety knowledge, or where safety knowledge is not known with the level of certainty that is desired for decision-making.

Similarities to the Medical Field

An examination of evidence-based reviews was conducted to determine if a similar process has been developed for the medical field. This review confirmed that the process developed for Part II of the HSM shares very similar aspects to the process commonly applied in the medical field for the evaluation and recommendation of various medical treatments. A rigorous review, supported by statistical evidence of the accuracy and validity of studies are advocated and applied in the medical field. Recommendations made to medical practitioners for the adoption of treatments are based on the studies graded highest.

Sample HSM Content

An example of a safety treatment with AMFs that are of sufficient quality to pass the Inclusion Process is centerline rumble strips (Table 2). These AMFs are based on centerline rumble strip application in seven states (California, Colorado, Delaware, Maryland, Minnesota, Oregon, and Washington). The AMFs for centerline rumble strips are applicable to horizontal curves and tangent sections, passing and no-passing zones.

Table 2: Safety effects of installing centerline rumble strips [1]

Treatment	Setting Road type	Traffic Volume	Accident type Severity	AMF	Std. Error
Install centerline rumble strips	Rural Two-lane	5,000 to 22,000 veh/day	All types All severities	0.86	0.05
			All types Injury	0.85	0.08
			Frontal and opposing-direction sideswipe All severities	0.79	0.1
			Frontal and opposing-direction sideswipe Injury	0.75	0.2#

NOTE:# Observed variability suggests less confidence than the AMF values in bold.

Next Steps

The HSM will be a comprehensive source for predicting the safety implications of transportation decisions, including design, operations, pedestrians and cyclists. The individual NCHRP projects will be completed by 2007, and the results of each will be compiled into one document through NCHRP 17-36. The First Edition of the Highway Safety Manual is scheduled for publication in 2008.

For more information, go to www.highwaysafetymanual.org.

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