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Applying the Highway Safety Manual to Georgia

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Final Report

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GDOT Project Number 12-15

Final Report

APPLYING THE *HIGHWAY SAFETY MANUAL* TO GEORGIA

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This report examines the Highway Safety Manual (HSM) from the perspective of applying its methods and approaches within the state of Georgia. The work presented here focuses specifically on data requirements and methods that may be of particular focus in the implementation of HSM methods by Georgia Department of Transportation (GDOT).The report reviews the current status of implementation of HSM methods by other states, based on both extended interviews with selected states as well as a brief survey that targeted all states. Excluding Georgia, forty-three states provided either complete or partial responses to the survey. Selected reports regarding HSM implementation are also briefly reviewed. An example case study of an HSM application from Georgia (special freeway pavement markings) is provided to illustrate safety effectiveness evaluation and the application of crash modification factors. The report concludes with short- and intermediate term recommendations for Georgia DOT regarding implementation of HSM methods to improve road safety in Georgia.</td></tr>
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Table of Contents

List of Tables

List of Figures

Executive Summary

One of the overarching strategic goals of every state transportation agency is roadway safety. Many have attributed the significant decline in national fatalites over the past several decades to the cumulative efforts in design, enforcement, and driver behavior strategies that have targeted exactly this outcome. Despite this reduction in fatalities, too many lives are still lost on our roadway system. In recognition of the importance of roadway safety, the American Association of State Highway and Transportation Officials (AASHTO) has encouraged its member states to adopt a "toward zero death" policy that emphasizes incorporating safety into all aspects of planning and engineering. This report examines the recently-released (2010 and 2014) *Highway Safety Manual* (HSM), developed to assist this effort, from the perspective of applying its methods and approaches to the state of Georgia. It should be noted that the Georgia Department of Transportation (GDOT) already has significant efforts underway to implement various HSM analyses within the organization and this research effort is aimed to supplement rather than duplicate these ongoing activities.

The HSM offers state transportation agencies and other users a powerful set of tools to quantitatively predict crashes and the impact of various design and treatment options on the frequency and severity of these crashes. These predictions can, in turn, be incorporated into project development processes to ensure that the public receives the safest, and most effective transportation system possible within existing resources. However, as a relatively new tool, the safety performance function (SPF) that forms the basis of the *Predictive Method*, the flexible safety-related analytical framework that is the

basis of HSM safety analysis, has not yet reached a stage where it can be quickly and easily implemented across states. State departments of transportation are working towards refinement and execution of the complex statistical methodology required for implementation, in large part driven by the need to calibrate SPFs using Crash Modification Factors (CMFs) that allow for more nuanced and accurate predictions in the range of local conditions that exist across transportation systems.

To aid GDOT in determining how to best incorporate the HSM into Georgia practice, this study conducted two surveys with other states to determine their plans, experiences, benefits and reservations both with the HSM itself and with its integration into their systems. Between the two surveys and internal interviews with GDOT personnel, information was collected from forty-two of the fifty states. While states differed regarding many details regarding their implementations, several general conclusions may be drawn:

- Most (39 of 42) states, including Georgia, are in the process of implementing the HSM into at least some of the project development processes.
- Most states cited *data concerns* as either their primary concern regarding overall HSM implementation or why they were not implementing a particular type of analysis
- While most states were implementing the HSM in some way, only about half were currently using the Predictive Method or equivalent approaches.

To illustrate the use of the Predictive Method for Georgia-specific conditions, this report presents a case study for the development of a SPF for low-radius freeway loop ramps in the Metro-Atlanta area. The case study also included development of a *Crash Modification Factor* (CMF) and associated uncertainty for a safety treatment (special pavement markings) on these loop ramps employing an Empirical-Bayes (EB) approach.

Based on the results of the multi-state surveys, interviews with GDOT personnel and the case study, it was concluded that application of HSM methods in Georgia would be, like virtually all states, constrained by the limits of existing data sources. Based on these evaluations, the study makes the following recommendation regarding *Implementing the HSM in Georgia*:

Recommendation 1: Continue and expand current efforts at training GDOT personnel in the use of the HSM.

Recommendation 2: Continue to support efforts to improve the accuracy of the GDOT Crash Database especially in regards to location information.

Recommendation 3: Undertake development/calibration of Georgia-specific and regionally-specific safety performance functions for the major roadway facility types included in the HSM.

Recommendation 4: Improve the linkage between the GDOT Roadway Characteristics (RCLINK) and Crash Databases.

Recommendation 5: Develop a collection of specific roadway links and intersections as "HSM Control Sites" to aid in HSM analyses.

Recommendation 6: Evaluate additional factors that should be incorporated in the Georgia Roadway Characteristics database.

Recommendation 7: Provide a structured mechanism for user feedback regarding data issues.

Collectively these recommendations comprise a "Data Driven Strategy" that we believe will be an effective long-term approach for HSM implementation. However, there are several applications that are well suited for short and medium-term integration of the HSM into the GDOT Project Development Process. These are:

- The use of CMF-only analysis in the Design Exception/Variance Process
    - *Most of these projects are too small to use the full Predictive Method*
- Expanded use of Augmented (Research-Grade Empirical Bayes) Predictive analysis in developing Design Policy and Procedures.
    - *To further leverage existing and future GDOT research projects*
- Use of Georgia-specific SPFs in the project planning process.
    - *Calibrated for Georgia Specific conditions and GDOT Design Standards*
- Use of Predictive Method for safety audits and in planning of safety-related projects.
    - *Consistent with the objectives of the Highway Safety Manual*

Introduction

Project Overview

One of the overarching strategic goals of every state transportation agency is roadway safety. Many have attributed the significant decline in national fatalites over the past several decades to the cumulative efforts in design, enforcement, and driver behavior strategies that have targeted exactly this outcome. Despite this reduction in fatalities, too many lives are still lost on our roadway system. In recognition of the importance of roadway safety, the American Association of State Highway and Transportation Officials (AASHTO) has encouraged its member states to adopt a "toward zero death" policy that emphasizes incorporating safety into all aspects of planning and engineering.

This report examines the recently released (2010 and 2014) *Highway Safety Manual* (HSM) (AASHTO, *Highway Safety Manual*, 1st Edition Volumes 1-3 2010, AASHTO, *Highway Safety Manual*, 1st Edition, Supplement 2014) from the perspective of applying its methods and approaches to the state of Georgia. It should be noted that the Georgia Department of Transportation (GDOT) already has significant efforts underway to implement various HSM analyses within the organization, and as such, this research effort aims to supplement these ongoing activities rather than duplicating them. This report provides a detailed review of efforts undertaken by other states, as well as by providing recommendations for the evolution of data collection as would aid in the sustained long-term implementation of HSM methods.

Research Objectives

With the introduction of the HSM, all states, including Georgia, are facing a variety of challenges associated with implementation and incorporation of HSM-based methods. Some of these challenges are: 1) Providing personnel with the necessary tools and training to successfully identify and use the appropriate HSM methods; 2) Ensuring that existing data collection, archiving, and quality control activities can provide the data necessary to effectively implement these methods; and 3) Identifying procedures and policies that will produce the maximum benefit from incorporating these analyses. This research project was designed to assist GDOT in identifying effective answers to these challenges. Given the increasing availability of tools and training materials for implementation of HSM-based methods, personnel training is gradually becoming a less formidable barrier to implementation and thus, more emphasis has been given to evaluating data requirements and methods of particular concern to GDOT within this report.

This research project had three specific objectives as defined at the inception of the study:

1. Develop an overview of what other states are doing in implementing the *Highway Safety Manual*
2. Provide high-level decision-making support for Georgia-specific approaches/ analyses/studies that could be executed under the *Highway Safety Manual* guidelines

3. Develop a Georgia-specific case study that can be used to illustrate specific analysis and study processes as an aid to future implementation

While objectives 1 and 3 remained consistent over the course of the project, objective 2 evolved to have greater emphasis on data-related recommendations as it became apparent that successful application of the HSM within Georgia is largely constrained by data-related concerns. The following sections provide a description of the results for each of the objectives and provides specific recommendations for what additional short- and intermediate term actions should be taken by GDOT to further enhance the benefits from implementation of HSM methods.

The *Highway Safety Manual*

This section presents a brief discussion of the motivating factors that drove development of the *Highway Safety Manual* is first discussed here, and an overview of its methodologies.

Motivation for Development of the *Highway Safety Manual*

The benefits of using the HSM are all ultimately derived from, and dependent upon, the ability of its methods to predict the frequency and severity of crashes at a particular location, or class of facility, based upon specific conditions including roadway characteristics and safety treatments. If this can be done successfully, then analysts can determine the sensitivity of these crashes to changes in underlying conditions and determine how best to allocate limited resources.

Prior to the introduction of the HSM, the process of making relevant design decisions was based largely on adherence to design standards and policies (nominal safety) and good engineering practices. If subsequent experiences revealed that a particular location demonstrated the potential of a design or maintenance problem (e.g. a high number of crashes or fatalities) then corrective actions were taken based on engineering judgment as to the best method of correcting the problem. Based upon the frequency and success of these corrective actions, design standards and policies were updated to avoid similar problems in the future.

While this process has been effective in gradually improving roadway safety over many decades, it was relatively slow and inefficient. First, this process fails to fully inform

the design engineer as to the impacts that design decisions can have on actual safety performance (substantive safety) of a project rather than just on adherence to policies and procedures (nominal safety). Put another way, it is entirely possible that several design approaches could all meet relevant design standards yet differ significantly in their actual on-road safety performance, and thereby impact the selection of design alternatives.

More importantly, this traditional approach potentially exposes the public to additional risks until subsequent safety performance reveals the need for corrective action. Conversely, a 'spike' in crashes due to random fluctuations in crash rates at a particular location could result in expenditure of resources to correct a 'problem' in a substantively safe facility. The HSM attempts to place the analysis of safety throughout the lifecycle of facilities, from planning, design, construction, operations/maintenance, repair, and replacement, on a sound statistical footing to ensure that, at each stage of the process, available resources are allocated efficiently and effectively.

Overview

As a result of a series of workshops held in 1999 to examine issues surrounding the quantitative analysis of safety in highway design and operations, the Transportation Research Board (TRB) formed a joint-subcommittee to examine the feasibility of producing a single, authoritative national highway safety manual *(*AASHTO*, Highway Safety Manual*, 1st Edition Volumes 1-3 2010). This joint subcommittee ultimately became a TRB Task Force (AND25T) purposed with producing the document. In 2006,

AASHTO agreed to participate in the process and to publish and promote the use of the resulting document. The studies needed for the development of the HSM were largely conducted under the auspices of the National Construction Highway Research Program (NCHRP) with additional support from U.S. Department of Transportation, Federal Highway Administration (FHWA).

In 2010 the first three volumes of the HSM were published *(*AASHTO*, Highway Safety Manual*, 1st Edition Volumes 1-3 2010). Volume I presents background and introductory materials relating to Safety Fundamentals, Human Factors, and the Roadway Safety Management process. Volumes II and III introduced the analytical framework for HSM safety analysis, the Predictive Method and *Crash Modification Factors*, respectively. These methods are discussed later in the text.

The objective of the Predictive Method was to produce a flexible safety-related analytical framework that was useful for a variety of purposes, accessible to a range of analysts, and based on sound statistical foundations. The central approach was in the development of *Safety Performance Functions* (SPFs) that would quantitatively predict crashes, both in total and by severity, for specific types and functional classes of roadway under specified conditions. These SPFs could be adjusted based on local conditions (local calibration) or on changes in specific factors, including those related to the driver population (human factors), the vehicle fleet, and roadway or environmental conditions. These changes to predicted crash rates due to specific conditions, referred to as *Crash Modification Factors* (CMF)*,* are central to practical uses of the HSM methods under "real-world" conditions. For example, a CMF of 0.9 for a particular safety treatment indicates

that this treatment will reduce the predicted number of crashes, of the type being analyzed, by 10%. This knowledge allows planners, designers and operational personnel the ability to evaluate both the impact and cost-effectiveness of a particular action from a safety perspective along with whatever operational benefits the treatment may provide.

HSM Volume II, provided users with proposed SPFs for three different roadway facility types: 1) Rural Two-Lane, Two-way Roads; 2) Rural Multi-lane Highways; and 3) Urban and Suburban Arterials. The 2014 supplement (AASHTO, *Highway Safety Manual*, 1st Edition, Supplement 2014) subsequently provided SPFs for Freeways and Freeway Ramps. HSM Volume III, provided methods for determining CMFs for a limited range of conditions with the intention that the number of such CMFs would increase over the coming years as additional studies were conducted. Results from the other studies, including proposed CMFs are maintained in an online public archive (www.cmfclearinghouse.org).

To incorporate HSM-based methods into roadway safety management within state DOTs, AASHTO, TRB and others have produced a variety of tools (e.g. *SafetyAnalyst* and the *Interactive Highway Safety Design Module* (IHSDM) and a variety of third party spreadsheet-based tools) and training materials (see for example: Cambridge Systematics, Inc. (2010); AASHTO (2010); Oregon State University (2012); CH2M-Hill (2014)) to assist users with the use of the Predictive Method and other HSM-based approaches. Most notably, *SafetyAnalyst* and *IHSDM* allow users with fairly limited

training to perform structured safety evaluations using HSM methods, although more sophisticated analyses will still require more highly trained analysts.

Safety Performance Functions and Crash Modification Factors

At the heart of the HSM approach are the various predictive models that have been developed for various types of roadway facilities. The HSM approach is to develop a *Safety Performance Function* (SPF) that predicts the number and/or severity of crashes at either a particular location or over a class of facilities over a period of time based on the conditions associated with these crashes. These crash-related conditions include the characteristics of the roadway (e.g. horizontal curvature, shoulder width, etc.), vehicle fleet (e.g. heavy-duty truck fraction), driver population, environmental and other factors. Consequently, SPFs depend on prevailing conditions and a particular SPF appropriate to one type of facility or one region may not be applicable to another.

At first glance, these SPFs may appear very complex and difficult to understand. However, at their heart they are actually quite simple in concept. The HSM predictive models (SPF) belong to a class of models known as Risk/Exposure models. Such models are commonly used to predict a range of conditions ranging from prevalence of diseases to emissions of pollutants. In such models the number of predicted events is given by:

1) (Predicted Number of Events) = (Probability of Event per Unit of Activity)
x (Number of Unit of Activity Performed).

In principle, the unit of activity could be defined in many ways depending on what we are trying to model. For example, activity could be based on the number of events (e.g. pulling

out of a parking space or a vehicle entering an intersection), time (e.g. hours of operation) or distance traveled (e.g. vehicle-miles-traveled). In the HSM, the selected unit of activity is normally a vehicle-mile and the predicted event is either a crash (i.e. all crashes) or a particular type of crash (e.g. fatal crash or rear-end collision). Equation (2) gives a typical SPF function (e.g. for a rural highway) used in the HSM (eqn. 11-7):

2) $(\text{Predicted Crashes (number)}) = (AADT)^{\beta} \times 365 \times 10^{-6} \times L \times e^{(\alpha 0 + \alpha 1 + \alpha 2 + \alpha 3 + \dots)}$

where: AADT = Average Annual Daily Traffic on the facility being modeled

L = Length of the facility in miles

α, β = Coefficients to be determined by statistical analysis based on presence of specific features or conditions.

While at first glance equation (2) does not resemble equation (1), we can rearrange the terms of equation 2:

3) $(\text{Predicted Crashes}) = [(AADT) \times L] \times 365 \times 10^{-6} \times (AADT)^{\beta-1} \times e^{\alpha 0} \times e^{\alpha 1} \times e^{\alpha 2} \times e^{\alpha 3} \times \dots$

Noting that the number of vehicles multiplied by the facility length is just the number of vehicles miles travelled (VMT) per day on the facility and that the 365 and 10^{-6} factors convert the unit to "per year" and "per million" respectively we have:

4) $(\text{Predicted Crashes}) = [\text{Annual VMT (millions)}] \times (AADT)^{\beta-1} \times e^{\alpha 0} \times e^{\alpha 1} \times e^{\alpha 2} \times e^{\alpha 3} \times \dots$

If we take a set of "standard conditions" or "base conditions" to define our *α0* coefficient. Then all of the subsequent e^{α} terms modify this "base crash rate" depending on the presence, or absence, of a particular feature and/or condition. For the HSM, each of these

e^{α} terms is called a "crash modification factor" (CMF) and is expressed as a simple multiplicative term. We thus have:

5) (Predicted Crashes) = [Annual VMT (millions)] x [Estimated Crash Risk (per Million VMT)],

that is the form of equation (1) where [Annual VMT (millions)] is the number of activity units performed and the probability of event per unit of activity is given by:

6) [Estimated Crash Risk (per Million VMT)] = $(AADT)^{\beta-1}$x (Base Rate) x CMF_1 x CMF_2 x …

= (Activity Modifier) x (Base Rate) x CMF_1 x …

The activity modifier, $(AADT)^{\beta-1}$, corrects our estimates for certain classes of facilities and crash types to recognize that high traffic conditions, with many vehicles on the road, do not necessarily carry the same risks as the same total VMT spread out over longer periods. For lower traffic roads (e.g. rural two lane highways), the recommended value for β is one and this activity modifier disappears, leaving us with a constant base rate for our standard conditions.

From this discussion, we can draw some important conclusions. The usefulness of the SPFs, CMFs, and the HSM methods in general, for resource allocation and other purposes is largely dependent upon our ability to determine statistically valid estimates for base rates, activity modifiers, and CMFs that are applicable to the conditions that we need to evaluate. Since development of these estimates is based on empirical observations, they are thus highly dependent on the availability and accuracy of the data necessary to support these activities. The extent to which current GDOT and other state

DOT data sources can support various types of HSM analysis will be discussed in subsequent sections of this report.

Implementation of the HSM Outside of Georgia

This portion of the report will examine the experiences of other states in implementing the HSM within the needs and objectives of their respective state roadway systems. This material will provide relevant case studies to learn from as GDOT continues its prioritization of HSM analyses of roadway safety in Georgia.

Literature Review

As discussed earlier, the HSM was published by AASHTO in 2010 and since then has been adopted by many states. The purpose of this portion of the study was to explore how various states have implemented the HSM, as well as details as to how these implementations were executed. This involves looking at how states are using CMFs, how they are calibrating SPFs that apply to their state specifically, how they are going about the data collection process, and what safety management tools are being used. It is useful to note that State DOTs are not the only ones adopting the HSM; some international regions and cities are also considering the adoption of the HSM into their roadway policies.

CMFs are given in the HSM to provide states with a method to quantify the effects of different safety treatments. Because states are very different in their roadway conditions, driver behaviors, and reporting methods, some states have found a need to develop their own state-specific CMFs. Florida, as well as states in the Midwest (Brown

2014), have developed their own state-specific CMFs (Abdel-Aty 2014). The Midwest has even set up the *Midwest Smart Work Zone Deployment Initiative* made up of the DOTs from the states of Iowa, Kansas, Missouri, Nebraska and Wisconsin. With the development of CMFs by state agencies and universities, comes the need to ensure the quality of the research used to generate these CMFs. This may necessitate the use of protocols in generating CMFs to ensure a certain standard of quality and reliability (Carter 2011). Studies have also been conducted to look at how CMFs vary over time after the implementation of different treatments and the tendency for there to be a delayed effect of treatments on safety performance (Wang 2015).

Safety Performance Functions are described in Part C (Volume II) of the HSM; this section provides predictive methods for states to use in crash frequency estimation. The SPFs provided in Part C are equations capable of estimating the expected average crash frequency using information regarding traffic volume and roadway characteristics. Utah, Florida, Alabama, Illinois, and Oregon have all calibrated the SPFs given in the HSM for specific roadway and driver conditions found in their state (Brimley, Lu, Mehta, Williamson, and Xie 2012). The calibration factors that were developed are not only state specific, but were also developed for different roadway facilities found in the states. Tools for developing SPFs without using *SafetyAnalyst* as a tool for statistical analysis also exist (Tegge 2010). A study was conducted to compare the performance of jurisdiction-specific calibrated SPFs to un-calibrated SPFs. This work was performed in Canada and found that the jurisdiction specific SPFs performed best at predicting collisions (Young 2013).

Many states have encountered problems collecting the data necessary to use the methods prescribed by the HSM. The HSM is very data intensive and states are struggling to fill the gaps in their data in order to use the HSM. Some states also struggle with linking their existing databases with those used by the HSM. Use of the *Highway Inventory Data Collection* methods has also been applied by some states in an effort to assist with efficient data collection to help them make use of the HSM (Jalayer 2015). In one report, Dibakar Saha of Florida International University suggests the use of a new data mining approach called boosted regression trees as another way to help with the data collection hurdle many states are facing. An approach that can be implemented before any actual data collection is the projection of necessary samples to ensure that enough data is collected to reach a target precision (Sando 2015). This pre-collection step can help prevent states from having to re-collect data which is inefficient and costly. On the other side of data mining is the possibility of integrating existing databases to collect data and generate SPFs instead of starting over with a completely new technology (Parisien 2012). While the approaches to data collection previously mentioned are not state-specific, they are relevant to the challenges many states face when adopting the HSM. Many alternatives are available to help states overcome these obstacles or handle them in a more effective manner.

Many states have begun implementing certain sections of the HSM in their design and review processes and have published reports describing their current status. California is considering two different safety management tools that have been developed and tested by Caltrans safety engineers (Chung 2013). Alabama is examining

cost-effective ways to implement the HSM by first comparing existing software to their current software, then assessing data needs and by looking into developing SPFs specific to Alabama's roads (Turner 2012).

A Louisiana study focused on the application of safety prediction models and methodologies, as well as different observed implementation issues on two-lane rural roads (Sun, X.D. 2006). Similarly, a report published for Kansas DOT also focused on two-lane rural highways, like Louisiana, but specifically studied the accuracy and practicality of using the predictive methods on this facility type (Lubliner 2012). The University of Missouri published a report discussing the data collection and calibration process and its challenges during the implementation of the HSM there (Sun, Carlos 2013). The Maryland State Highway Administration focused on developing local calibration factors used to apply the HSM and provided justification for their jurisdiction-specific local calibration factor generation as described in a report by Hyeon-Shic Shin and his colleagues (Shin 2015). Virginia DOT published a report that acts as a guide for helping transportation agencies determine how they can best customize the HSM for their state based on the procedures Virginia used to customize the HSM in their own state (Kweon 2014). The scope of state implementation of the HSM is broad and many states have made great strides in overcoming some of the challenges to adopting the HSM.

As previously noted, many other agencies around the world have looked at the methods prescribed by the HSM. Fortaleza City, Brazil is considering using the HSM due to recent increases in the frequency of crashes in its urban areas (Cunto 2015). Specifically, they looked at the applicability of the SPFs presented in the HSM to Brazil's

urban areas. The HSM is also being considered in the Italian province of Arezzo (Martinelli 2009). The main concerns for application of the HSM in this region are the different environment, road characteristics, driver behavior, and crash reporting system. These differences could lead to problems related to data requirements and model calibration. The regions of Valencia and Western Castile in Spain were studied when developing models to predict accident rates on Spanish two-lane rural roads (Mayora 2003). The roads in these two regions were studied to find variables that showed the strongest relation to accident rates. This report does not necessarily relate to the HSM but shows various analytical techniques that can be used to improve roadway safety.More complete information regarding the reports mentioned above can be found in the *Annotated Bibliography* presented as Appendix A to this report.

State-Specific Surveys

To obtain specific information regarding implementation, and plans for implementation of the HSM by state DOTs, two surveys were undertaken. The first survey was undertaken early in the project (Fall 2012 and Spring 2013) and was designed to identify areas of interest for the various states, their plans for upcoming implementation and to identify barriers/issues being encountered. The second survey was conducted near the end of the project (Spring 2015) to provide the most up-to-date results for inclusion in this report, with the intent of providing a contemporary “snapshot” of the status of HSM implementation among the states.

Initial (Phase 1) Survey

The initial project survey targeted twenty-three states (not including Georgia) for telephone interviews between project staff and state DOT safety personnel to discuss their plans for implementation of the HSM within their jurisdictions. These targeted states were selected to include a diverse set of regions and large/small states. Of the twenty-three states contacted, fourteen (Alabama, Alaska, California, Florida, Hawaii, Idaho, Indiana, Louisiana, Michigan, Minnesota, Missouri, Montana, New Hampshire, and South Carolina) agreed to participate. The geographic distribution of states participating in the Phase 1 surveys is presented in Figure 1. These interviews were initiated in late October 2012 and the last interview was completed in March 2013. Outside of basic questions concerning HSM use, the researchers asked participants about their agency's use of the *Roadway Safety Management Process*, the Predictive Method, as well as usage of the *Crash Modification Factors* outlined in the HSM. The researcher also inquired about the use of the online CMF Clearinghouse and the various issues that the agency had encountered in implementing the HSM methods. A summary of the results from each of the participating states is provided in Appendix B. Separate interviews were conducted with GDOT personnel between January and April 2013.

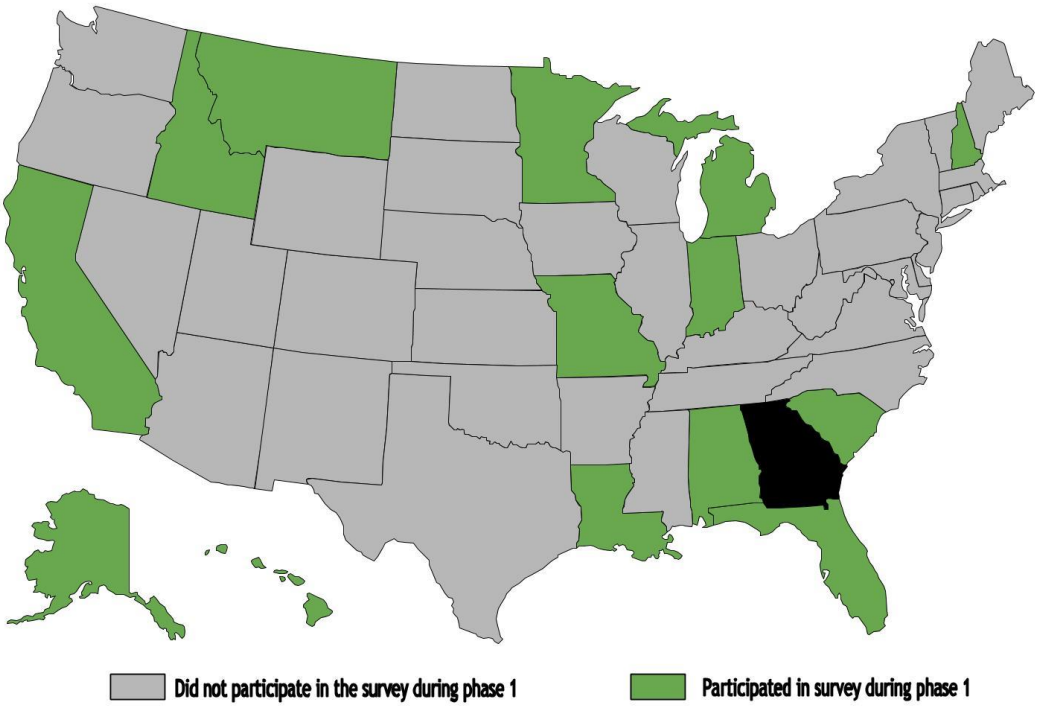

Figure 1: States Participating in Phase 1 HSM interviews

From these discussions, a number of general trends in state implementation could be discerned. First, was that use of CMFs from the HSM for safety analysis purposes greatly exceeded the uses of the Predictive Method. This was especially true in the most common applications for HSM related analysis: design exceptions. For its part, GDOT was undergoing a major revamp of its own design exception process, including the development of a monitoring program, and had initiated a research project toward that objective.

In terms of concerns, two observations stood out. The first was associated with the difficulty and lack of guidance provided for selection of CMFs to use in analysis and concern regarding the applicability to CMFs to their local conditions. Several states (e.g.

California, Minnesota, Idaho and South Carolina) either had, or were in the process of modifying, CMFs to fit local conditions. The second, a concern shared by almost all of the participants, was that of availability and quality of the data available to conduct HSM-type analyses. These concerns were especially noted by states that were deferring large-scale implementation of the HSM. Based on these results, analysis of data availability and quality was identified as the leading consideration for subsequent analysis and development of implementation guidance for this project.

Final (Phase 2) Survey

A second telephone survey was conducted near the end of the project (Spring 2015) to provide the most up-to-date results for inclusion in this report to provide a contemporary "snapshot" of the status of HSM-implementation among the states. Unlike the Phase 1 interviews, this survey used a defined script to provide a consistent framework with which to compare results from different states and targeted all fifty state DOTs. As for the Phase 1 survey, participants were asked questions regarding their organizations usage of the HSM and HSM-related safety analyses as well as issues that they may, or may not, have experienced with implementation of the HSM.

In order to maximize participation, the experimental protocol called for extensive follow up activity. As a result, usable responses were ultimately obtained from forty state DOTs. Figure 2 illustrates the participating states. Appendix C provides additional experimental details and both a summary of results by question and state and detailed responses for each participating state DOT.

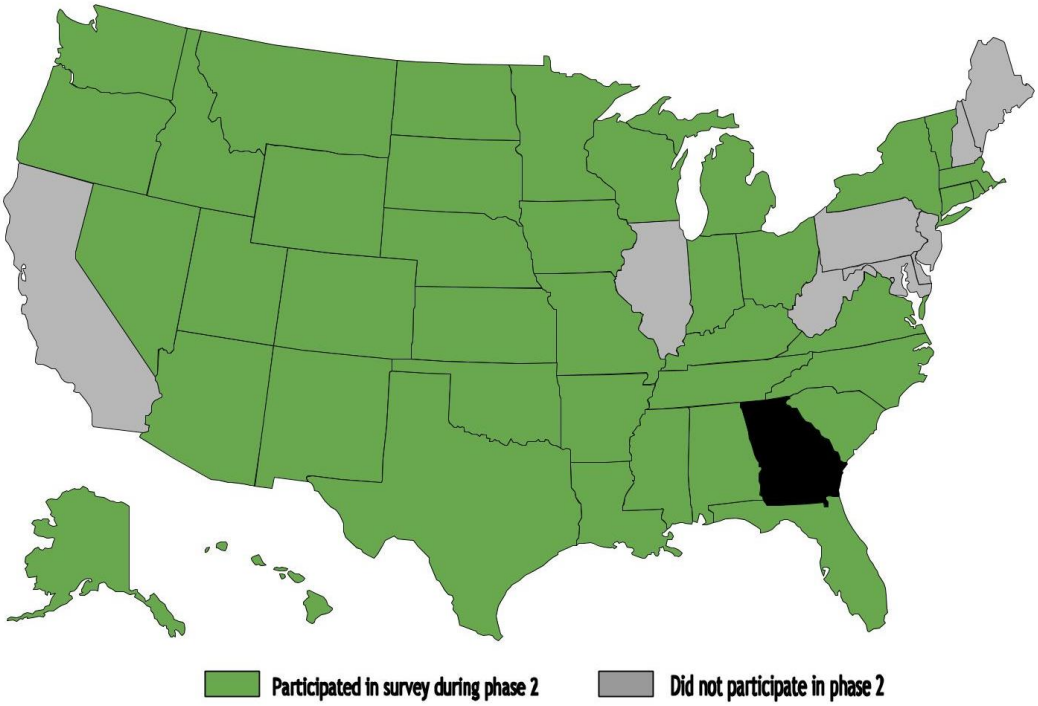

Figure 2: States Participating the Phase 2 HSM Survey

Of the 41 states interviewed, many are using the HSM in similar ways and have found deficiencies in the existing version of the HSM. Many states related that they are hoping to make changes to their use of the HSM, and want to further incorporate the manual in their department's design and review processes. Figure 3 shows the number of states that fully use the HSM compared to those that only use the HSM in a limited capacity, and those that don't use the HSM at all. As shown in the figure, there was a relatively even split between states that fully use the HSM and states that only partially use the HSM. Many states indicated that they are working towards full implementation but have not yet had enough time or resources to reach that goal.

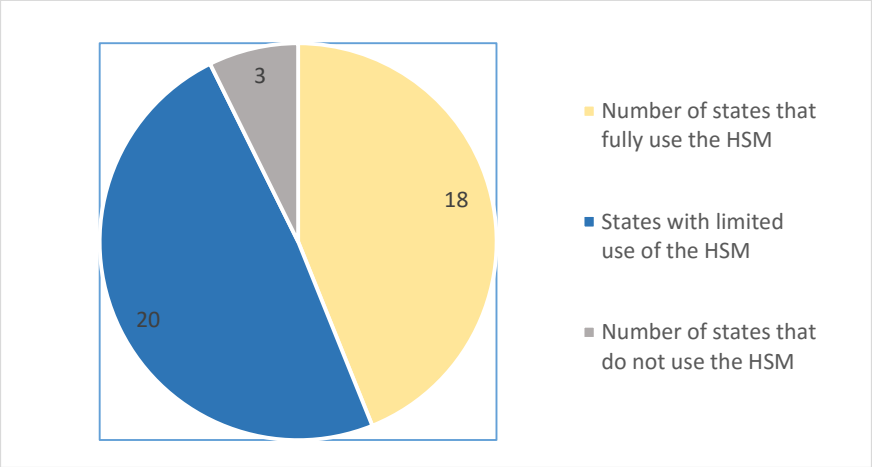

Figure 3: State reported level of usage of HSM

Of the 38 states that reported using the HSM in some form, there were several specific uses that states reported finding for the HSM. Figure 4 shows the different uses that states in the surveys reported. It is likely that other states are also using the HSM for some of these purposes, but did not report their usage in the survey. The most common reported use for the HSM is in assessing safety and safety benefits. Project prioritization and project review were also common uses for the HSM.

States were also asked about their use of the Roadway Safety Management Process detailed in the HSM. Five states reported that they use the process as it is detailed in the HSM, and 16 states reported using parts of the process or a semblance of the process in their Roadway Safety Management program. Many states reported using aspects of the Predictive Methods section in the HSM. Twelve states responded that their employees are trained to use the predictive methods and 23 states said their employees had received some form of training or have had the opportunity to be trained. However,

many reported that the trainings occurred a while ago and that they would like to have another opportunity for training.

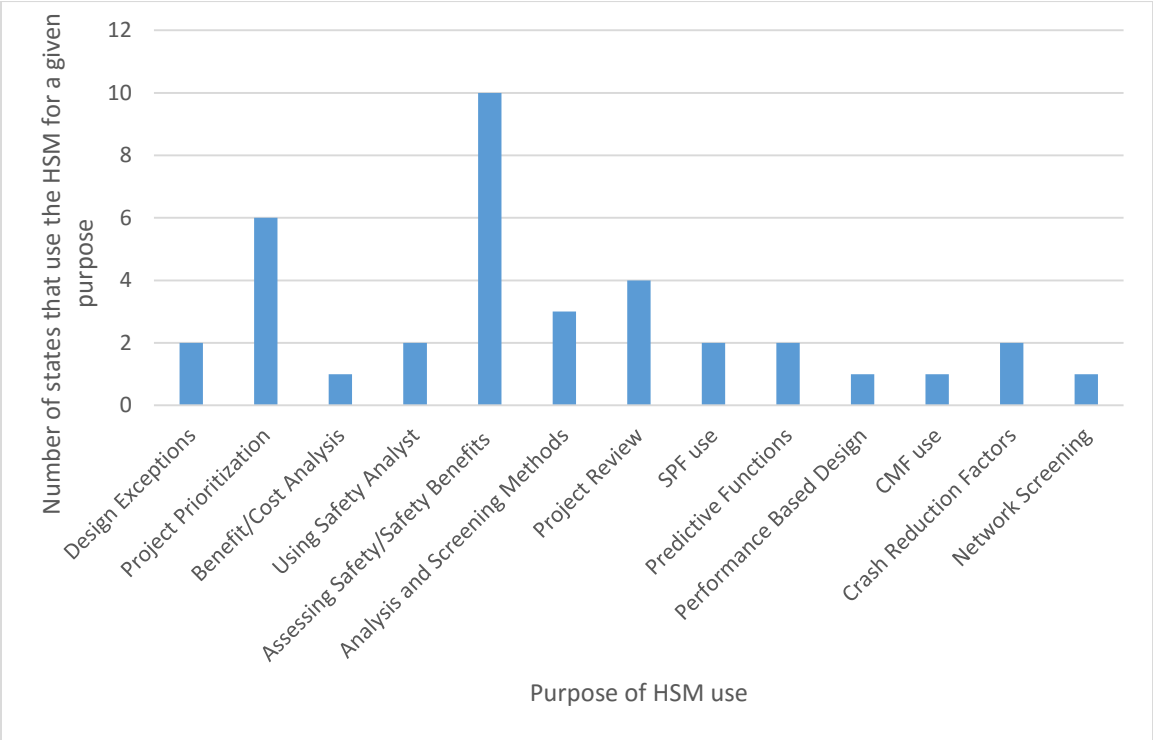

Figure 4: State reported uses of the HSM

Figure 5 shows the ratio of states that have planned changes to their use of the HSM compared to those that are not planning any changes. A majority of states are planning on making changes in their policies and HSM usage.

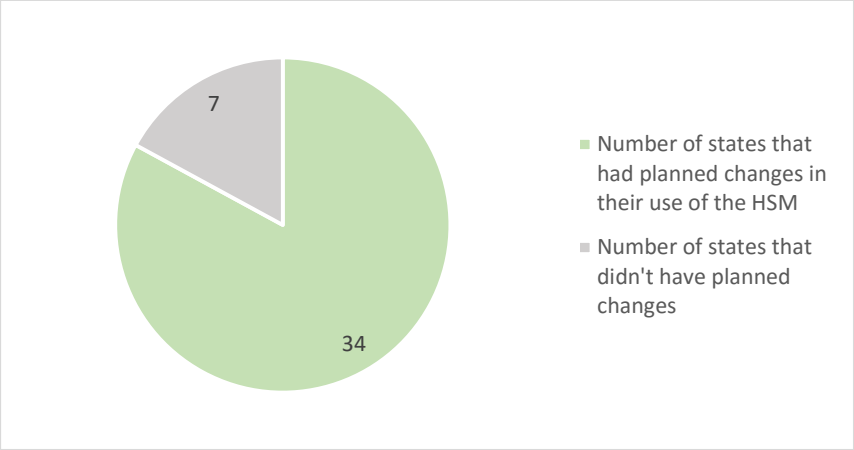

Figure 5: Number of states reporting planned changes relative to entire sample (n=41 states)

Of the states that reported that they are planning on changing their implementation of the HSM or policies regarding its implementation, a majority are planning on further integrating the HSM or starting to use the HSM. Figure 6 shows different changes states are considering making to their HSM policy. Further integration into their design process was the most frequently reported change that states considered, while some states reported that they were still in the research process, or were determining where to implement the HSM into their design and review process.

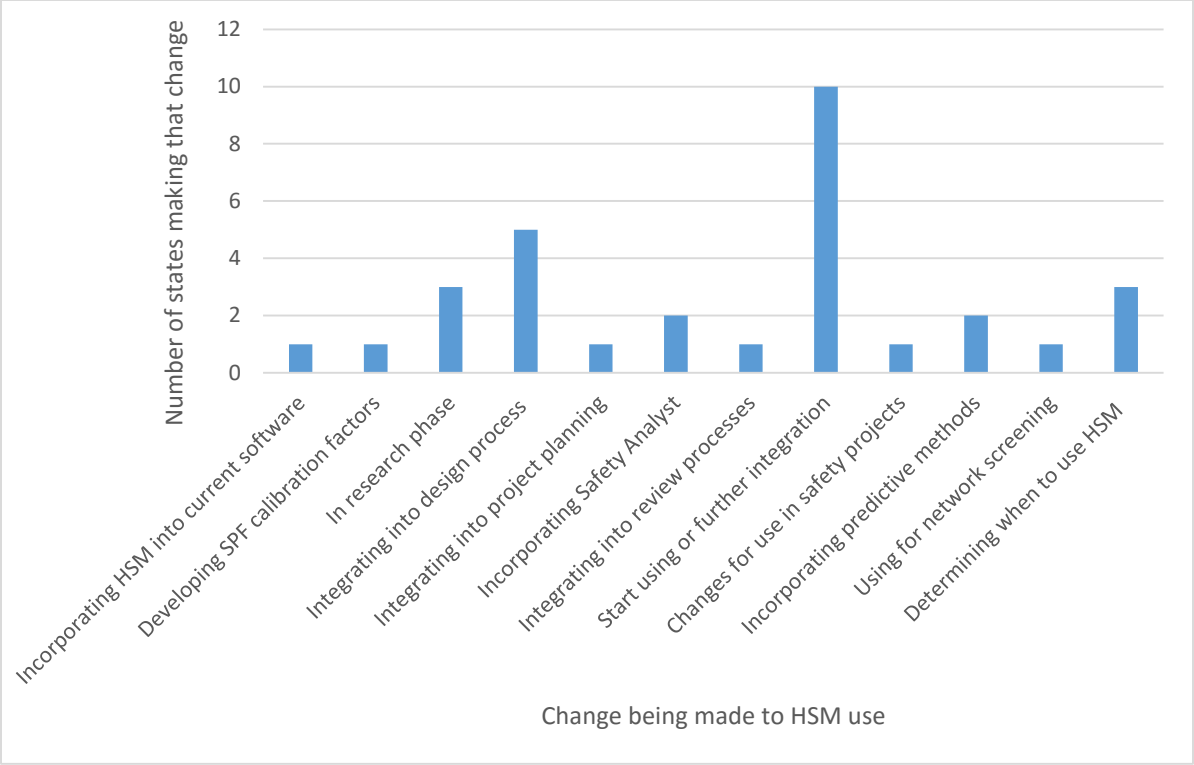

Figure 6: HSM implementation plans at the state level

Figure 7 shows the difference between the numbers of states that found deficiencies in the HSM compared to those that did not. Many states that reported finding no deficiencies in the HSM said that they were new to using the HSM or did not have enough experience to report deficiencies. States also reported that as more parts of the HSM have been published, some of their initial complaints have been resolved. Other states said they are aware of ongoing research that is aimed at correcting a deficiency they have noticed.

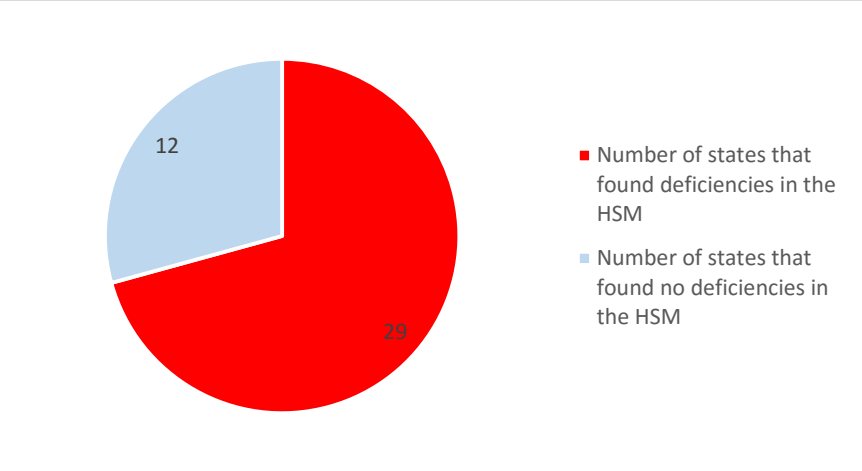

Figure 7: Number of states reporting deficiencies relative to entire sample (n=41 states)

Figure 8 shows the range of deficiencies reported by states and the frequency of states that reported the same deficiency. The most common deficiency reported is a lack of different roadway types included in the manual. Specifically, states said they would like for the HSM to include local roads, 6-lane divided arterials, roundabouts, and a section for bridge roadways. Some states mentioned that the manual can be difficult to follow and difficult to navigate the way it is currently organized. Many states also reported that they have been slow to incorporate the HSM because they are still calibrating their own state specific SPFs and that the calibration process recommended by the manual is long and difficult to follow. Another delay in state implementation of the HSM is the large volume of data required that is unavailable to many states.

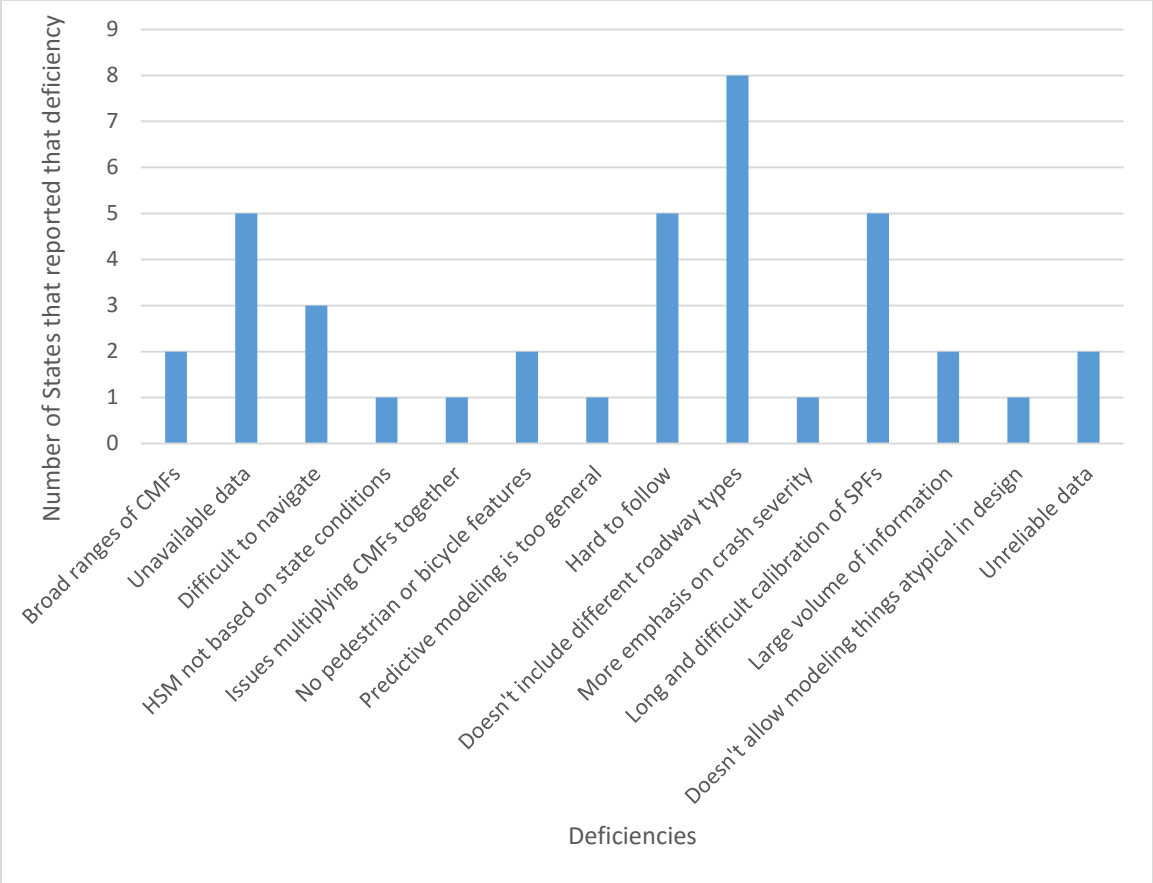

Figure 8: HSM deficiencies reported by states

Applying the *Highway Safety Manual* in Georgia

Uses of the *Highway Safety Manual* in a DOT context

As mentioned in the project overview, one of the overarching strategic goals of state transportation agencies, including GDOT, is roadway safety. The HSM was designed to allow quantitative measures of safety to be incorporated throughout the lifecycle of a roadway project from planning to design to construction to operations and maintenance. Figure 9 illustrates potential applications of the HSM within the project development process:

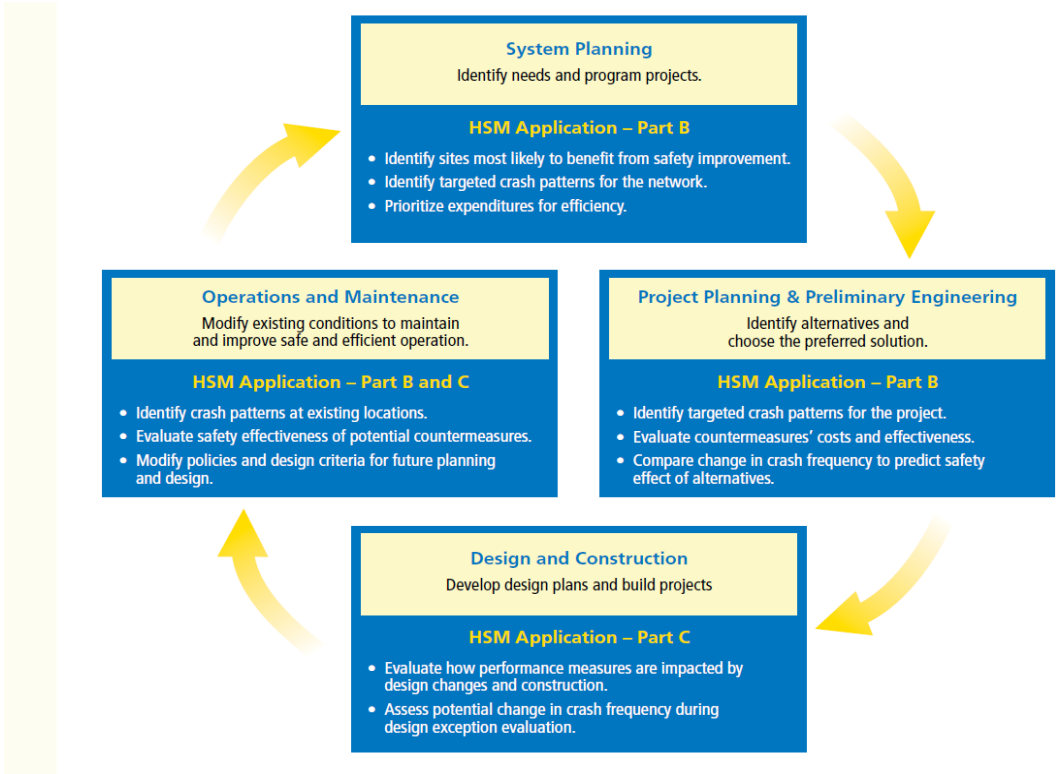

Figure 9: Application of the HSM in the Project Development Process (AASHTO (2010a))

Importantly, proper application of HSM methods produces quantitative and verifiable estimates of the frequency, type and severity of crashes that would be expected to arise from various design and treatment options. This allows decision makers to directly weigh safety concerns against other quantifiable project parameters such as operational performance and cost to produce the greatest overall societal benefit from available resources.

Given these potential benefits, it is not surprising that GDOT (and a majority of other states as seen from the above surveys) is seeking to incorporate HSM methods into its processes. Like any other similar system, the degree to which HSM methods can be successfully implanted is dependent on five major factors:

- *Policies & Procedures:* GDOT will need to establish a policy to recommend or require the use of HSM methods for selected applications. Fortunately, significant guidance has been developed by AASHTO, FHWA and others to help guide this process.
- *Supporting Tools:* HSM analyses are complex and often difficult and/or tedious to implement manually, even for experts. Thus for practical application of these methods, supporting analytical tools is highly desirable. In the years since the introduction of the HSM, a variety of tools have been developed to support various HSM analyses. These include *SafetyAnalyst,* the IHSDM and a variety of third party spreadsheet-based tools. Many of these tools also have available technical support assistance.

- *Trained Personnel:* No tool is useful without personnel who know how to operate it. Similar to that of supporting tools, both training materials and instruction in HSM related analysis are available from a variety of sources. Most of the training materials are available at no cost, and the costs for HSM training courses are in line with that for other types of training.
- *Supporting Data:* As discussed earlier, HSM-based methods are highly data-driven and most of the available data sources were originally developed for other purposes. As such, these data sources are rarely optimal for incorporation into HSM analyses. In some cases, the necessary data may be either unavailable or require significant additional effort to produce.
- *Decision Support Tools:* While the HSM may produce results that are quantitative, there is still the need to provide information necessary to weigh these results against other considerations in selecting the best alternatives.

While the availability of Decision Support Tools is of some concern, we believe that the availability and/or costs of obtaining the necessary (high-quality) data essential for conducting HSM-type analyses will constrain every state DOT's ability to implement a full range of HSM analyses. The following sections describe these data needs and present a plan for cost-effectively increasing GDOT's ability to implement a variety of HSM-based analyses on both a short and intermediate term basis.

Supplying the Need for Data

This section discusses the specific types of data needed for the successful implementation of HSM methods. It begins with a general overview, and then moves into a case study analysis that was executed within Georgia. Experience from other research projects is also integrated to provide a more general perspective of the data needs of the HSM. This section lays the foundation for the Georgia-specific recommendations that will conclude this report.

General Data Requirements

As illustrated in the previous sections, the HSM requires a significant amount of data for implementation of its quantitative approach to safety. These data needs can be classified into three main categories: crash data, traffic volume data and roadway characteristics data. The HSM requires several specific attributes for crash data, these are: year, location, type, severity level, relationship to intersection, and distance from intersection. Traffic volume data requires AADT data, as well as minor and major street AADT for safety evaluations occurring at intersections.

The roadway characteristics data requirements are detailed, and the needs differ depending on facility type. Table 1 provides a sample of the roadway characteristics needed for rural two-lane two-way roads, rural multilane highways, and urban and suburban arterials. The roadway characteristics requirements differ for intersections, and include variables such as presence of lighting, presence of red light cameras, intersection sight distance, and presence of right/left turn lanes (AASHTO (2010a)).

Table 1: Roadway characteristics variables required across facility types (AASHTO (2010a)).

Variables	Chapter 10 Rural Two-Lane, Two-Way Roads	Chapter 11 Rural Multilane Highways	Chapter 12 Urban and Suburban Arterials
Roadway Segments			
Area type (rural/suburban/urban)	✓	✓	✓
Annual average daily traffic volume	✓	✓	✓
Length of roadway segment	✓	✓	✓
Number of through lanes	✓	✓	✓
Lane width	✓	✓	
Shoulder width	✓	✓	
Shoulder type	✓	✓	
Presence of median (divided/undivided)		✓	✓
Median width		✓	
Presence of concrete median barrier		✓	
Presence of passing lane	✓		
Presence of short four-lane section	✓		
Presence of two-way left-turn lane	✓		✓
Driveway density	✓		
Number of major commercial driveways			✓
Number of minor commercial driveways			✓
Number of major residential driveways			✓
Number of minor residential driveways			✓
Number of major industrial/institutional driveways			✓
Number of minor industrial/institutional driveways			✓
Number of other driveways	✓		
Horizontal curve length	✓		
Horizontal curve radius	✓		
Horizontal curve superelevation	✓		
Presence of spiral transition	✓		
Grade	✓		
Roadside hazard rating	✓		
Roadside slope		✓	
Roadside fixed-object density			✓
Roadside fixed-object offset			✓
Percent of length with on-street parking			✓
Type of on-street parking			✓
Presence of lighting			✓

GDOT Data Resources Supporting HSM Analysis

As discussed above, HSM analyses for a roadway segment or intersection require data for:

- *AADT:* In Georgia, as in other states, traffic counts are collected to meet federal reporting requirements as part of the Highway Performance Monitoring System (HPMS) as well as additional counts conducted for state-specific purposes. Although annual sampling directly measures only a small subset of roadway links, these data are applied through a series of assignment procedures and extrapolations to provide AADT estimates for every link of the State highway system.
- *Roadway Conditions:* In Georgia, roadway data (e.g. lane width, length of the segment, presence and type of shoulders, etc.) for each homogeneous link in the network are archived in the RCLINK database. The AADT described above is also linked to these data.
- *Crash Data:* To meet federal reporting requirements, GDOT maintains a crash information database containing basic information (e.g. time, location, number of vehicles, type of crash, injuries, etc.) regarding Georgia crashes and also maintains an archive with images of the police reports from which these data were drawn. Maintenance and operation of these databases is executed through an independent third party that provides GDOT access to these records. The third-party database provider also makes annual payments in exchange for the right to sell copies of the police reports to the public.

To demonstrate the use of these databases to conduct HSM type analyses, a case study that was implemented in Georgia is described in the following section.

Case Study: Determination of SPF and CMF (Special Pavement Markings on Freeway Ramps)

This case study involved evaluation of the effectiveness of the use of special pavement markings (converging chevrons) as a safety treatment to warn drivers of their approach to a low-radius (< 850 feet) loop-type freeway ramp. The treatment was aimed at reducing roadway departure (and potentially side-swipe) type crashes by either increasing driver awareness of the ramp or inducing a decrease in approach speed.

The treatments were installed on two ramps in metro-Atlanta, I-285 eastbound to I-75 northbound in Cobb County and I-75 south to I-85 north in Fulton County. The objective was to develop a SPF for low radius loop ramps using data derived from the GDOT data sources described in the previous section. Additionally, the team sought to evaluate the CMF, and the uncertainty associated with this CMF, based on crash data before and after the treatment was applied, using the EB method presented in the HSM. The discussion here will describe how the databases were used in developing the SPF and CMF. Details concerning the actual calculation procedures and final results are presented in Appendix D.

To determine the SPF, it was first necessary to establish the physical, traffic and safety performance of the ramps that were to undergo treatment. These data were obtained from the RCLINK and Crash Databases. However, additional “control” ramps

(i.e. ramps with similar parameters for which the treatment would not be applied) were also selected. Search of the RCLINK database allowed us to identify seven additional ramps with low radii (< 850 feet) and similar AADT.

Crash data were needed for these nine ramps (2 treatment + 7 control) in order to develop the "Georgia low radii loop ramp" SPF. Obtaining these data was a very labor-intensive process. First, since we were dealing with a ramp associated with a nearby mainline, simple location data was insufficient to determine whether the accident occurred on the mainline or on the ramp. Second, even if the accident occurred on the ramp, it was important to know on what section of the ramp the accident occurred (e.g. we would not wish to consider merge accidents occurring on the exiting taper of the ramp). Both of these criteria, as well as others, required a manual examination of all police reports for these ramp accidents. Similarly, the process of developing data for the post-treatment (CMF) analysis required detailed mining of the police reports as well.

While this approach produces good quality data and excellent results (see Appendix D), as noted previously, it is highly labor-intensive. This experience is not specific to this case. For example, another ongoing GDOT study is developing a CMF for application of centerline rumble strips (CLRS). However, developing this CMF requires that one successfully separate crashes occurring on the roadway links (where CLRS are installed) from intersections along the roadway (where they are not) and separating single vehicle crashes with centerline crossover from those that did not. As for the pavement markings, this analysis requires manual examination of police reports to produce the necessary filtered crash data for analysis. An additional complication in the

CLRS case is that the RCLINK database does not include the presence or absence of CLRS as an attribute.

This does not mean that the GDOT RCLINK or Crash databases are insufficient databases; in fact, the authors believe that these databases fulfill their original purposes well. It is important to note that these databases were developed and put into place long before the original meetings to organize the development of the HSM. In a sense these databases are being asked to support uses that were not contemplated when they were first developed. It is therefore reasonable to ask, "If data are the prime determinant of success in implementing the HSM, can GDOT develop an effective low-cost data strategy that will substantially improve its ability to conduct HSM-derived analyses?" In the coming section, we evaluate and present a possible data strategy.

A Data-Driven Strategy

Given that data is crucial to support the intensive HSM quantitative methods, this section focuses on data related strategies to improving HSM implementation.

Levels of HSM Implementation

In considering implementation of the HSM, it is important to recognize that such an implementation is not a binary "yes/no" type decision, but rather is a range of discrete choices where an agency can choose to implement certain elements while deferring or declining to implement others. As an aid in guiding subsequent discussions, it is useful to define a framework that illustrates these implementation levels. One such framework is

given in Table *2* below. This is the framework that will be used in subsequent discussions and recommendations.

Table 2: HSM Implementation Levels for Particular Analyses

Level Number	Label	Description
0	None	Does not use HSM results or methods
1	Basic	Uses HSM-derived results (e.g. recommended CMFs) for screening or analysis purposes without use of localized predictive methods.
2	Localized	Uses State-specific (calibrated) Safety Performance Functions (SPF) and/or Crash Modification Factors (CMF) rather than national defaults. Uses predictive methods for screening (e.g. hot spot analysis) or similar purposes.
3	Full	Uses HSM-based predictive methods, including Empirical Bayes (EB), with standard data quality assurance to determine expected crash rates and uncertainties for particular locations and treatment effects.
4	Augmented Full	Uses complete Empirical Bayes (EB) or similar methods with full data filtering and enhanced data quality assurance to produce project or treatment-specific results including development of specialized CMFs and SPFs for use in other analyses.

While these are only general guidelines, they are illustrative of the types of analyses that can be performed. Costs and data requirements rise with each increase in analysis level, and assignment of a particular level of analysis to each task is constrained by financial, personnel and data resources available. Example applications of each level of analysis are given below:

- *Level 0 (None):* It may be determined that many current policies and procedures have proven effective and HSM-based methods offer little opportunity for cost-savings and/or performance improvements over existing approaches.
- *Level 1 (Basic):* Crashes are a rare event and it can take many years of observations, if ever, to develop a sufficient large number of crashes to determine the impact of either a very small scale project (e.g. a single low volume roadway segment) or a treatment that would be expected to have very small impact on overall crash rates (e.g. narrowing a five-foot wide shoulder to four feet). In these cases, the most effective analyses are likely to arise from the use of CMFs to estimate impacts rather than any direct analysis of field data. Most design exceptions and design variances fit into this category due to their small scale. While an individual design exception evaluation may entail only the use of a CMF, these CMF's are likely to be derived from a higher level of analysis (typically Level 4).
- *Level 2 (Localized):* Environmental conditions (e.g. frequency of fog or heavy snow) vary enormously from state-to-state as does topography, vegetation and a host of other safety related parameters, including an individual state's standard construction procedures and design policies. Therefore, it is not surprising that base crash rates associated with certain roadway types (e.g. rural multilane highways) would vary significantly across the United States. For example, Minnesota found that their base crash rate on rural roads was only about one-third that predicted by the national SPF included in the HSM. Therefore,

development of state-specific (or regionally-specific) SPFs for the most important roadway types and functional classes may be required to effectively use HSM-based approaches for screening of particular locations for potential safety treatments or to effectively evaluate the cost-effectiveness of alternatives in the design and planning process.

- *Level 3 (Full):* This is the level of application in which data and personnel concerns become paramount. Personnel need to be fully trained in the use of HSM methods and equipped with the proper analytical tools and have access to reliable, quality-assured crash and roadway characteristic data both at the location of interest and at control sites. At present, supplementary data quality assurance/quality control activities are required to accurately perform these analyses in Georgia.
- *Level 4 (Augmented):* Analyses at this level are generally not designed to evaluate project alternatives but rather to produce highly accurate CMFs and/or SPFs for particular treatments or conditions for use in analyses conducted at lower levels. The case study presented in this report provides an example. These analyses are currently very resource intensive and are likely to remain so in the near future. As such, studies at this level are generally aimed at development of design policies and procedures or at understanding the effectiveness of new or modified treatments (e.g. the case study) or conditions.

As described above, HSM analyses are currently constrained by data limitations. The following sections describe a strategy designed to cost-effectively support higher-level

HSM analyses without "wholesale" changes to existing data collection and archival procedures.

Matching Needs with Data in the Present

For GDOT to continue to move forward with implementation and execution of HSM methods, it is important to develop a targeted approach towards maintaining and acquiring the data needed to achieve the various implementation levels presented above in Table *2*. At present, the highest priority for GDOT in HSM implementation should be to continue and expand ongoing efforts to improve existing databases. GDOT has a current initiative to improve location data within the crash database, and these efforts need continued support. Likewise, efforts to streamline and improve the roadway characteristics information in the RCLINK database are a high priority. This will ensure the continued availability of high quality data to serve the original purposes for which these databases were developed, as well as in the application of these data to HSM purposes.

Expanding Horizons in the Near Future

This section presents a three-pronged strategy toward improving GDOT's ability to conduct more sophisticated HSM analyses. The first element in this strategy is in producing locally calibrated SPFs for the most important roadway types in Georgia. The existence of these SPFs will allow a much wider range of potential GDOT HSM users to implement analyses up to Level 2, as previously presented. Analyses at Level 2 offer significant opportunities for inclusion of HSM results in the planning and project development process and introduces important HSM concepts across the organization.

Development of Georgia-specific SPFs and CMFs will require identification of representation sites across the states. Once these sites have been identified and analyzed, these locations provide an ongoing opportunity for developing enhanced data collection at representative locations from across the state. The second element of the three-pronged approach is to develop a collection of enhanced monitoring sites that can serve as the basis for future analyses. A subset of the sites used to develop the Georgia-specific SPFs should be retained as "HSM control sites," with enhanced data collection continuing into the future. This enhanced data collection would include more frequent traffic counts (annual/semi-annual), as well as, documenting a large set of roadway characteristics. These sites can serve a vital role as control sites for a variety of HSM analyses, as well as helping to identify critical roadway characteristics for future inclusion in the RCLINK database.

Lastly, the final element of this strategy is to develop policies for enhanced data collection at sites being considered for future roadway or safety projects. This is to ensure that subsequent analyses will have access to adequate before/after data, to make maximum use of the Predictive Method or similar approaches. This general strategy is converted into specific recommendations in the following section.

Conclusions and Recommendations

As discussed above, the HSM offers state transportation agencies, including GDOT, a powerful set of tools with which to quantitatively predict crashes and the impacts that various design and treatment options have on the frequency and severity of crashes.

These predictions can, in turn, be incorporated into the project development process to ensure that the public receives the safest, and most effective transportation system possible within existing resources.

To aid GDOT in determining how to incorporate the HSM into Georgia practice, this study conducted two surveys with other states to determine their plans, experiences, benefits and reservations both with the HSM itself and with its integration into their systems. Between the two surveys and internal interviews with GDOT personnel, information was collected from forty-two of the fifty states. While states differed regarding many details related to their implementations, several general conclusions may be drawn:

- Most (39 of 42) states, including Georgia, are in the process of implementing HSM into at least some of their project development processes.
- Most states cited *data concerns* as either their primary concern regarding HSM implementation or the reason that they were not implementing particular types of analysis.
- While most states were implementing the HSM in some way, only about half were currently using the Predictive Method or equivalent approaches.

To illustrate the use of the Predictive Method for Georgia-specific conditions, this report presented a case study for the development of a SPF for low-radius freeway loop ramps in the Metro-Atlanta area. The case study also included development of a CMF and

associated uncertainty for a safety treatment (special pavement markings) on these loop ramps employing the Empirical-Bayes (EB) approach.

Based on the results of the multi-state surveys, interviews with GDOT personnel and the case study, it was concluded that application of HSM methods in Georgia would be, like virtually all states, constrained by the limits of existing data resources. Based on these evaluations, the study makes the following recommendations regarding *Applying the HSM to Georgia*:

Recommendation 1: *Continue and expand current efforts at training GDOT personnel in the use of the HSM.*

Rationale: As GDOT expands its implementation of the HSM, increasing numbers of GDOT personnel will need to be familiar with its methods, approaches and nomenclature. GDOT should continue, and expand to the extent practical, training its staff in use of the HSM.

Recommendation 2: *Continue to support efforts to improve the accuracy of the Georgia Crash Database especially in regards to location information.*

Rationale: Accurate crash records are at the heart of all HSM-derived methods. Existing crash databases were primarily designed to support other uses and need to be continually upgraded to improve their ability to serve HSM-based analyses. This is particularly important in regards to location data as this is key to project or area specific studies. GDOT has several ongoing efforts in this area. These efforts

should be continued and a long-range plan for database maintenance and upgrades put into place.

Recommendation 3: *Undertake development of Georgia-specific and regionally-specific safety performance functions for major roadway types included in the HSM.*

Rationale: Like many other states, Georgia roadway conditions are likely to depart significantly from the national average conditions presented in the HSM. While statewide factors could be considered, we recommend development of separate SPFs for the major physiographic divisions (North Georgia Mountains, Piedmont (including Atlanta) and the Upper/Lower Coastal Plain) of the state and for each of the major roadway types considered in the HSM (rural two-lane roads, rural multilane roads, urban and suburban arterials, freeways and ramps). In the case of freeways and ramps, separate factors for Atlanta and the rest of the state may be required. In the case of rural roads, the upcoming results of a similar calibration currently being conducted in South Carolina should be examined to identify any additional analyses that should be conducted. Development of these factors should both greatly simplify and enhance virtually all GDOT analyses conducted using the HSM at levels 2 and higher.

Recommendation 4: *Improve the linkage between the Georgia Roadway Characteristics (RCLINK) and Crash Databases.*

Rationale: All analyses using HSM-based methods require coupling of data from these two data sources. At present, the primary index for data in the roadway

characteristics database is route and mile-marker while the crash data is indexed by latitude/longitude and road name. While these can be cross-referenced to link the two databases, the process is inefficient and should be streamlined to simplify the use of the HSM.

Recommendation 5: *Develop a collection of specific roadway links and intersections as "HSM Control Sites" to aid in HSM analyses*

Rationale: Any determination of changes in crash rates based on Bayesian procedures, including the EB procedure used in the HSM, requires the availability of data from control sites as well as treatment sites. While close proximity is ideal, data availability and quality is also essential and thus it is important to have high quality data available regardless of its location. One of the most difficult aspects of long-term implementation of an HSM program is predicting the types of analysis that will be needed in the future and planning accordingly. While we can certainly anticipate the need for certain analyses, future social and technological developments are likely to produce unanticipated needs. To plan for this uncertain future, we recommend that a portion of the sites selected to create the Georgia-specific SPFs representing the major roadway types, functional classes and physiographic/political regions across the states be designated "HSM Control Sites" to aid in future analyses. Since these sites will have undergone a "level 4" analysis (described in the previous section) significant additional roadway characteristic data is likely to be available for these sites. The "HSM Control Sites" would be designated for special data treatment including more frequent traffic

counts (e.g. semi-annual or annual) and more complete documentation regarding changes to roadway characteristics. The existence of the augmented data from these sites would both provide a more stable control of analyses over time as well as increasing the likelihood of available data to meet unanticipated future needs.

Recommendation 6: *Evaluate additional factors that should be incorporated in the Georgia Roadway Characteristics database.*

Rationale: As mentioned earlier, the Roadway Characteristics database was developed long before the existence of the HSM. There is a need to examine if additional characteristics need to be incorporated into this database to avoid "hidden variable" effects. While the HSM control sites partially address this issue, available CMFs need to be examined to determine if additional parameters should be gradually incorporated statewide. As an example, a recent GDOT study on the impact of illumination on crash rates showed that a simple binary (yes/no) classification was inadequate to fully characterize nighttime crash risk and that some type of scale was required. While we would not recommend inclusion of any particular parameter at this point, the issue should be examined.

Recommendation 7: *Provide a structured mechanism for user feedback regarding data issues.*

Rationale: An essential element in any effective quality improvement process is the incorporation of feedback regarding issues that were encountered. This will be especially true as HSM analyses become more widespread in GDOT, and HSM

users will need an effective mechanism to provide feedback to those responsible for data collection and quality assurance. This mechanism will ensure that the data are both available and meet data quality objectives in a non-confrontational and collaborative sense. Based on this feedback, decision makers can choose to allocate resources to provide the users with the data resources necessary to ensure overall success.

Collectively these recommendations comprise what we refer to as a *Data Driven Strategy* that we believe will be over the long term a more effective approach for implementation than that based on pre-selection of particular applications of the HSM. That being said there are some particular applications that appear to be good initial applications for the HSM within the GDOT Project Development Process. These are:

- **The use of Level 1 (CMF) analysis in the design exception/variance process.** A number of states are already doing this and there is an ongoing GDOT project on updating the GDOT design exception process.
- **Expanded use of Level 4 (Augmented) analysis in developing design policy and procedures:** Several of these analyses have already been completed as part of research or operational projects and more are underway. Over time this should become GDOT standard practice.
- **Use of Level 2 (Localized) analysis in the project planning process:** This approach has great potential for achieving significant results. These efforts should be undertaken as soon as the Georgia-specific SPFs are available.

- **Use of Level 3 (Full) analysis for safety audits and in planning safety related projects:** This effort is already well underway in GDOT (Office of Traffic Operations) and should become standard practice over time. Implementation will be both simplified and significantly enhanced by the development of the control sites described earlier.

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Cambridge Systematics, Inc. *NCHRP Report 667: Model Curriculum for Highway Safety Core Competencies.* Washington, DC: Transportation Research Board of the National Academies, 2010.

CH2M-Hill. *NCHRP Report 17-50: Highway Safety Manual User Guide.* Washington, DC: Transportation Research Board of the National Academies, 2014.

Oregon State University. *NCHRP Report 715: Highway Safety Manual Training Materials.* Washington : Transportation Research Board of the National Academies, 2012.

Appendices

Appendix A: Annotated Bibliography

Abdel-Aty, Mohamed A, et al. "Validation and Application of Highway Safety Manual (Part D) in Florida." Ed. DOT, Florida 2014. 199. Print.

This report discusses the use of the crash modification factors (CMFs) given in the HSM as well as the effects of safety treatments outlined in Part D of the HSM. CMFs are a way to quantify the effects of different safety treatments, but some states have found a need to look into developing CMFs specific to their state. Florida has employed different methods of observational study to develop these Florida-specific CMFs. The Florida-specific CMFs developed and the CMFs given in the HSM were compared and it was found that the state-specific CMFs were usually statistically significant. Florida also generated CMFs for safety treatments that were not listed in the HSM and found that these treatments generally showed a positive impact in reducing crash occurrences. This report was organized by the Center for Advanced Transportation and Systems Simulation at the University of Central Florida and funded by the Florida DOT.

Brimley, B. K., M. Saito, and G. G. Schultz. "Calibration of Highway Safety Manual Safety Performance Function Development of New Models for Rural Two-Lane Two-Way Highways." *Transportation Research Record*.2279 (2012): 82-89. Print.

This report details the calibration of SPFs for rural two-lane two-way road segments in Utah as well as how the state developed new SPFs using a negative binomial regression. The calibration and model development were based on three years' worth of crash data from 157 study segments in Utah. The models used four variables to develop SPFs: annual average daily traffic (AADT), segment length, speed limit, and the percentage of AADT composed of multiple-unit trucks. This report was published by Bradford K. Brimley of Texas A&M University, and Mitsuru Saito and Grant G. Schultz of Brigham Young University. This report is useful because it discusses both the calibration of SPFs given in the HSM and the process of creating new state-specific SPFs. It also discusses what variables were found to be most important to include in calculating SPFs. This report could also be helpful during the data collection phase since it describes what data is essential which could cut down on expensive, non-essential data collection.

Brown, Henry, Praveen Edara, and Carlos Sun. "Calibration of Highway Safety Manual Work Zone Crash Modification Factors," TPF-5(081), 2014. Natural Resources, Department of

The CMFs presented in the HSM correlate to work zone characteristics such as work zone duration and length. Because many of these CMFs were based on high-impact work zones in California, studies have been done to evaluate CMFs specific to the Midwest. Work zone and safety data was taken from 162 work zones in Missouri that were picked as representative from 11,000 different work zones. The dataset was then used to model and test CMFs specific to the Midwest. This report was written by a team of professors and

researchers from the University of Missouri-Columbia's Department of Civil and Environmental Engineering. This report was sponsored by the Midwest Smart Work Zone Deployment Initiative, which is made up of five states including Iowa, Kansas, Missouri, Nebraska and Wisconsin.

Carter, Daniel. "Research for AASHTO Standing Committee on Highways. Task 314. Recommended Protocol for Developing Crash Modification Factors." 2011. Print.

This report is focused on the development of CMFs and the documentation and research involved with that development. Specifically this report discusses the need to ensure the quality of the research used to generate CMFs used in the HSM. Because CMFs can be generated in a variety of ways and using different calibers of data, the CMFs generated can also have variety in their quality and reliability. This report recommends protocols to be used in generating CMFs to ensure the same standard of quality and reliability of the CMFs and how to address potential biases in this process. This report was prepared by Daniel Carter and Raghavan Srinivasan of the UNC Highway Safety Research Center and Frank Gross and Forrest Council of Vanasse Hangen Brustlin, Inc. Because this report is less focused on state implementation of the HSM it might be less relevant to the topic; however it may still be relevant for the state of Georgia to consider, as many states have found a need to generate their own state-specific CMFs. If Georgia finds a need for that, this report may give more insight into what makes a CMF more reliable for use in roadway design.

Chung, K., et al. "Developing Safety Management Tools for State Departments of Transportation." *Transportation Research Record*. 2364 (2013): 36-43. Print.

This report discusses two safety management tools that have been developed and are being considered for use in California. One is the California Safety Analyst (CASA) which is a web-based application that assists safety engineers use with their safety investigations and the documentation associated with these investigations. The other is the Continuous Risk Profile (CRP) approach, which is a network-screening tool. This report also discusses some room for improvement in these two management tools based on feedback from a survey of Caltran safety engineers as well as an empirical analysis. This report also discusses the misunderstandings that still exist regarding the relationship between different safety management tools. This report was written by Koohong Chung of the California DOT and Offer Grembek and Jinwoo Lee of the University of California, Berkley's Safe Transportation Research and Education Center. This report is relevant because it discusses different options in safety management tools and the ways these tools are inter-related. This report also covers a topic that many reports listed have yet to cover, given that the majority of reports tend to focus on SPFs and calibration factors.

Cunto, Flavio, Lucas Sobreira, and Sara Ferreira. "Assessing the Transferability of the Highway Safety Manual Predictive Method for Urban Roads in Fortaleza City, Brazil." Journal of Transportation Engineering 141.1 (2015): 04014072. Print.

This report discusses the transferability of the HSM to Fortaleza City, Brazil. This study was motivated by recent increases in the frequency of crashes in urban areas of Brazil. The focus of this study is specifically to analyze the applicability of the SPFs presented in the HSM to Brazil's urban areas; and this analysis was executed in two steps. The first step involved the estimation of the calibration factors using the steps detailed in the HSM and models to validate these estimations with collected data. The second step involved analyzing the over-dispersion parameter k. The results indicate that the SPFs given in the HSM can be applied in Fortaleza City, Brazil with caution. The authors of the paper are Flavio Cunto (Assistant Professor III, Brazil Departamento de Engenharia de Transportes, Universidade Federal do Ceara), Lucas Sobreira (Research Assistant, Brazil Departamento de Engenharia de Transportes, Universidade Federal do Ceara) and Sara Ferreira (Assistant Professor, Civil Engineering Department, School of Engineering, Porto University).

Jalayer, Mohammad, et al. "Comprehensive Assessment of Highway Inventory Data Collection Methods for Implementing Highway Safety Manual", Transportation Research Board 94th Annual Meeting, 2015. Print.

The purpose of this report is to address the difficulty some states have in obtaining costly highway inventory data and the resources that are required for states to utilize the HSM. This report examines existing methods of collecting highway inventory data to assess their capability to efficiently collect the required data in a cost-effective manner. This report looks at existing inventory methods through a nationwide survey and a trial of the Highway Inventory Data Collection (HIDC) methods. Different HIDC methods were also compared analytically to determine which method is the most suitable for a given purpose, taking into account weights provided by state DOT stakeholders. While this report does not look at a specific states' implementation of the HSM, it does discuss the process states use when implementing the HSM. Specifically it discusses the hurdles many states encounter when trying to collect all the data required by the HSM and how to work through this obstacle. Many of the other references have discussed generating state-specific data, but few have gone into how to efficiently collect this data, thus this report may prove to be useful in that regard.

Kweon, Young-Jun, et al. "Guidance on Customization of Highway Safety Manual for Virginia: Development and Application." (2014). Print.

This report provides details about the steps the Virginia DOT used to customize the HSM procedures to their state. Some states may develop calibration factors that are then applied to the SPFs given in the HSM, but other methods can also be used, as was the case in Virginia. This report also acts as a guide for helping transportation agencies determine how they can best customize the HSM for their state. The analysis performed for Virginia was limited to four-leg signalized intersections and divided segments of rural multilane highways. The report recommends using their guide in conjunction with expert opinion and data analysis. This report was written by Young-Jun Kweon of the Virginia Center for Transportation Innovation and Research and by In-Kyu Lim, Tracy L. Turpin, and Stephen W. Read of the Traffic Engineering Division of the Virginia DOT. This report is helpful in

providing a process for implementing the HSM in a manner that can be customized to a particular state, particularly when the option to develop calibration factors is not available. Specific data requirements of this method were not closely examined, so this method may or may not be viable depending on data requirements and the associated costs.

Lu, Jinyan et al. (2012). "Comparing Locally Calibrated and SafetyAnalyst- Default Safety Performance Functions for Florida's Urban Freeways." *Transportation Research Board 91st Annual Meeting.* Washington DC, United States.

Freeway interchanges and basic freeway segments are characterized by different crash and traffic flow occurrences yet are treated as the same in many safety analyses. Part of the problem is the lack of framework in place that dictates how to separate interchanges and basic freeway segments. This paper discuses a method to do just this using GIS and spatial manipulation techniques. With the development of safety analyst tools, Florida was able to generate state specific SPFs for both sections of the freeway network using four years of crash data. These SPFs generated specifically for the Florida freeway network were found to create a better-fitted model than the calibrated SPFs given in the HSM. This report may be helpful for the state of Georgia's implementation of the HSM when considering the interconnection and heavy use of Georgia's freeway network. This report could help Georgia generate a model that best predicts the safety performance of different alternative actions.

Lubliner, Howard, and Steven D Schrock. "Calibration of the Highway Safety Manual Prediction Method for Rural Kansas Highways." (2012). Print.

Some states are hesitant to implement the predictive methods given in Part C of the HSM because of the lack of research validating the accuracy of these methods. This report is a study done by the Kansas DOT that looks into the accuracy and practicality of using the predictive methods on rural two-lane highways in Kansas. This involved testing all of the calibration methods for two-lane segment SPFs given in the HSM for accuracy. The calibrated predictions proved to be very accurate when analyzed on an aggregate level. Alternative calibration techniques were also analyzed including looking at linear calibration methods. These linear calibration methods showed improvement on the project level but not on the aggregate level. This report was written by Howard Lubliner and Steven D. Schrock of the Transportation Research Board. This report may not be helpful in determining the accuracy of predictive methods in Georgia specifically, but may be helpful in describing a process to determine the accuracy of predictive methods. It also describes other predictive methods that can be used as possible replacements for the methods provided in the HSM.

Martinelli, Filippo, Francesca La Torre, and Paolo Vadi. "Calibration of the Highway Safety Manual's Accident Prediction Model for Italian Secondary Road Network." 2009. Print.

The potential application of the HSM worldwide has been explored in some nations, with the main concern being the transferability of the predictive methods to networks different from those in America. This has specifically been examined in the Italian Province of Arezzo. This region has a different environment, road characteristics, driver behavior, and crash reporting system than those for which the HSM model is developed. The transferability problems identified so far are related to segmentation and overestimation of curvature effects. This report discusses four approaches to determining calibration factors. It also details problems related to data requirements of the HSM and necessary adjustments for HSM model calibration and application. This report was written by Filippo Martinelli and Francesca La Torre of the University of Florence and Paolo Vadi of the Province of Arezzo Road Administration Service. This report may prove to be irrelevant to this study as it deals with transportation systems very different from those in Georgia. However, it may give insight into what all factors need to be considered when calibrating the HSM for a particular state or region.

Mayora, J., and R. Rubio. Relevant Variables for Crash-Rate Prediction on Spain's Two-Lane Rural Roads. Presented at 82nd Annual Meeting of the Transportation Research Board, Washington, D.C., 2003.

This report discusses the variables that were found to be the most relevant to consider when developing models to predict accident rates on Spanish two lane rural roads. The roads that were considered were part of the Spanish National Network, specifically in the regions of Valencia and Western Castile. The variables that were found to show the strongest relation to accident rates were access density, average sight distance, average speed limit and the proportion of no-passing zones. The study also found that a combination of multiple characteristics and the gradients of design speed between consecutive alignment elements were more effective at predicting accident rates than considering single variables alone. These results were published by a partnership between Madrid Polytechnic University and the National Road Directorate. This report may be less relevant to this study as it does not relate to the HSM or Spain's implementation of the HSM. However, it does discuss variables that were found to be important and should be focused on during the data collection phase of Georgia's implementation of the HSM.

Mehta, Gaurav, and Yingyan Lou. "Calibration and Development of Safety Performance Functions for Alabama: Two-Lane, Two-Way Rural Roads and Four-Lane Divided Highways." (2013). Print.

This project, performed by the University of Alabama, analyzes the applicability of the HSM predictive methods to the state of Alabama. This project considers data collected in Alabama and develops statistical models specific to the state for two-lane, two-way rural roads and four-lane divided highways. The SPFs in the HSM are calibrated using the method prescribed in the HSM and an approach that treats calibration factor estimation as a case of negative binomial regression. State specific SPFs and their new forms are also investigated using Poisson-gamma regression techniques. The model used is evaluated by five performance measures. The result of their efforts is the identification of a state-specific SPF that best fits Alabama's data and outperforms the other models. The results

showed that the method with the best performance described the mean crash frequency as a function of annual average daily traffic, segment length, lane width, year and speed limit. This study found that the HSM predictive methods also performed well. This report may be relevant to Georgia due to Alabama's proximity to Georgia and the similarity in the terrain between the two states. Some of those similarities may break down when considering the difference in population densities in certain regions in the two states.

Parisien, J., Park, P.Y., Coziahr, C., Eguakun, G., and Gardiner, A. Using a GIS to Integrate Multiple Databases for Developing Urban Safety Performance Functions. The 91st Annual Meeting of Transportation Research Board, TRB, Washington, D.C., US, January, 2012, Manuscript No. TRB12-1465.

SPFs were developed using collision records, traffic volume data, and roadway geometric data. Pulling all of this information from multiple databases can be time consuming and meticulous. This report discusses using the ArcGIS spatial database to collect this data to aid with the generation of SPFs. The three topics discussed in this paper are: using GIS to create one spatial database by integrating three different databases, addressing differences in detail and quantity in the different databases, and providing jurisdictions that are knowledgeable about challenges associated with developing SPFs. This report was written by Parisien Jordan and his colleagues at the University of Saskatchewan, Cozihar Chad of Canada North Environmental Services and Angela Gardiner of the City of Saskatoon. This report may be useful in that it provides a faster way to collect data needed to generate the SPFs used in the HSM and it may save Georgia time and manpower in their initial implementation stages.

Saha, D., et al. (2015). "Prioritizing Highway Safety Manual's crash prediction variables using boosted regression trees." Accident Analysis & Prevention 79(0): 133-144.

While this report does not give specific information about one state's process of implementing the Highway Safety Manual into their design processes, it does give recommendations about how states should go about this process. Specifically it discusses shortcomings of the manual and how those shortcomings can be accounted for and overcome. The HSM encourages derivation of local calibration factors using the Empirical Bayes (EB) method; however, this method requires significant data resources that are unavailable in many states' databases and detailed information about roadway characteristics. This report encourages the use of a new data mining approach called boosted regression trees (BRT). A BRT can help explore the relationship between variables and crash predictions to help determine the most influential variables. Data for these influential variables would be collected and maintained instead of collecting data for all the required variables, which is cost-inhibitive. This report was co-written by Dibakar Saha, Priyanka Lluri and Albert Gan all of the Department of Civil and Environmental Engineering at Florida International University.

Sando, T., and D. Mohr. "Planning Sample Sizes for before-after Accident Comparisons." *Accident Analysis and Prevention* 45 (2012): 826-27. Print.

This report discusses the projection of necessary sample sizes when conducting safety studies and gathering data. The data collected can then be used for before-and-after studies used to generate CMFs. The projections are done in order to ensure that a target precision is reached or power when the effect is shown as a proportional change in a Poisson rate. This report was written by Thobias Sando and Donna Mohr of the University of North Florida. This report may be more applicable to the data collection phase of implementing the HSM rather than simply providing general guidelines for how other states are implementing the HSM. Data collection is a major part of implementing the HSM though, and represents an aspect that many states are struggling to manage as many have found large gaps in the existing data.

Shin, H.-S., et al. (2015). "Results and Lessons from the Local Calibration Process of the Highway Safety Manual for the State of Maryland." *Transportation Research Board 94th Annual Meeting.* Washington DC, United States.

This paper gives details about the process used by the state of Maryland to develop local calibration factors (LCFs) as part of applying the Highway Safety Manual (HSM). The paper discusses how data collected over two years was used to calculate LCFs for 18 facility types. The paper also discusses the values Maryland used in their calculations that deviate from those suggested by the HSM and the justification for their jurisdiction-specific LCF generation. This paper was co-written by Hyeon-Shic Shin (Ph.D.), Seyedehsan Dadvar (Ph.D. Student), and Young-Jae Lee (Ph.D.). Hyeon-Shic Shin is the corresponding author and is in the Department of City and Regional Planning at Morgan State University and is the Acting Director of the National Transportation Center. Seyedehsan Dadvar is a Ph.D. Student from the Department of Transportation and Urban Infrastructure Studies at Morgan State University. Young-Jae Lee is an Associate Professor in the Department of Transportation and Urban Infrastructure Studies at Morgan State University.

Sun, Carlos, et al. "Calibration of the Highway Safety Manual for Missouri." (2013). Print.

This report discusses the data collection and calibration process and its challenges during the implementation of the HSM in Missouri. The HSM does not detail the techniques states should use for acquiring data as states do not all use the same data-system. This leaves states to make decisions about sampling approaches and what should be included or excluded. The models calibrated for this study included eight intersection and five segment site types, in addition to three freeway segment types. They applied a random sampling technique in their efforts and used an assortment of data processing methods, using CAD to attain geometric data. During the calibration process they had problems with: data availability, having sufficient sample sizes for site types, balancing segment homogeneity and minimum segment length, and disregarding inconsistent crash data. From their study they found that there are a few site types that Missouri may want to develop its own SPFs for, but otherwise the HSM predictive methods worked well in Missouri. This report was written by Carlos Sun and his colleagues at the University of Missouri's Department of Civil and Environmental Engineering. This report's relevance will be somewhat dependent on

the database and data collection practices Georgia already has in place and how closely those line up with the data needed to implement the HSM.

Sun, X. D., et al. "Application of Highway Safety Manual Draft Chapter - Louisiana Experience." Statistical Methods and Crash Prediction Modeling. Transportation Research Record. Washington: Transportation Research Board Natl Research Council, 2006. 55-64. Print.

With the publication of the HSM, comes a need to further study its applicability to states with crash data that were not included in the original development of the model. This is a crucial step in HSM application because states have different crash data recording practices and driving conditions. This paper focuses on segments of two-lane rural roads for the application of the safety prediction models and methodology. The results of this study showed that the predictions models do an acceptable job with small variations in observed and predicted crash frequencies on rural two-lane highways in Louisiana. The report also discusses different observed implementation issues like the level of effort versus degree of accuracy, simplification of the calibration process, and the potential need for reliability measurements. This report was a collaboration between faculty at the University of Louisiana and the Louisiana Department of Transportation and development. This report may be important to consider when determining the extent to which the HSM will be implemented in Georgia. This may be affected by whether or not crash data from Georgia was included in the original model prescribed by the HSM. Huge variations in crash data recording practices and driving conditions may make parts of the HSM less directly applicable to Georgia.

Turner, D. S., et al. (2012). "Implementation of the AASHTO Highway Safety Manual." (UTCA Report Number 10404).

This report published by the Alabama Department of Transportation details a cost-effective way to implement the Highway Safety Manual (HSM) in the state of Alabama. This process involved: researching the implementation of existing software compared to the capabilities of Alabama's currently used safety software, assessing data needs, and looking into developing Safety Performance Functions specific to Alabama's roads. This research was conducted by Dr. Daniel Turner, Dr. Steven Jones Jr. and Yingyan Lou of the University Transportation Center for Alabama and Dr. David B. Brown and Dr. Randy K. Smith of the Center for Advanced Public Safety. The implementation plan was broken into three different time phases based on this research: short term, mid-term and long term. The plan can be described by three methods: activities of ALDOT Office of Safety Operations, implementation actions by Bureaus, and by implementation task or activity.

Tegge, R., Jo, J., and Ouyang, Y. 2010. Development and Application of Safety Performance Functions for Illinois, Research Report for Illinois Center for Transportation.

This report was written before the FHWA released SafetyAnalyst as a tool provided to states for statistical analysis of safety conditions on their roadways. This report discusses

the development of SPFs in Illinois that were developed for later use with SafetyAnalyst. These SPFs were also generated to be used in calculations of a location's Potential Safety Improvement (PSI), which was used to determine what sites have the most opportunity for safety improvements. This report also discusses the usage of Visual Basic for Applications, which can be used for updating SPFs and PSI screening in the future. This report was written by Robert A. Tegge and his colleagues at the University of Illinois at Urbana-Champaign. This report also discusses the generation of state SPFs. While many other reports cited have also detailed this process, this report describes this process before the use of SafetyAnalyst and the HSM. This may be helpful to look at while researchers in Georgia are still familiarizing themselves with SafetyAnalyst or want to compare different ways of generating SPFs.

Wang, J.-H., et al. (2015). "Estimating safety performance trends over time for treatments at intersections in Florida." Accident Analysis & Prevention **80**(0): 37-47.

This report studies the use of CMFs to predict the safety effectiveness over time of converting a stop sign controlled intersection to a signal controlled intersection and adding Red Light Running Cameras. This study was done based on previous study's indications that CMFs varied over time after the implementation of these two treatments. The trends for the results of both kind of safety modification signified a delayed effect of the treatments on safety performance. This report was written by Jung-Han Wang of the University of Central Florida, Mohamed A. Abdel-Aty of the University of Windsor, and Chris Lee of Central Police University. While this report was informative for specific applications of the Highway Safety Manual, it did not give very much detail about Florida's implementation of the HSM. As the purpose of the report being written is more focused on state application of the HSM as a whole and not specific scenarios in which it may be used, this source may be less relevant for the report.

Williamson, M. and H. Zhou (2012). "Develop Calibration Factors for Crash Prediction Models for Rural Two-Lane Roadways in Illinois." 8th International Conference on Traffic and Transportation Studies. Changsha, China, August 1-3, 2012, pp. 330-338.

This report details the development of two calibration factors for two different SPFs to be used on rural two-lane roadways in Illinois. This report was written by Michael Williamson and Huaguo Zhou of Southern Illinois University Edwardsville Department of Civil Engineering. This report may be less relevant because of the different geographic and weather conditions found in Illinois compared to Georgia. The report also does not detail the implementation of the HSM in the state of Illinois as much as describing the development of calibration factors for use in the implementation of the HSM.

Xie, F., Gladhill, K., Dixon, D.K. and Monsere, C. Calibration of Highways Safety Manual Predictive Models for Oregon State Highways Transportation Research Record: Journal of the Transportation Research Board, No. 2241, Transportation Research Board of the National Academies, Washington, D.C., 2011, pp. 19–28.

This report focuses on the state of Oregon's calibration of SPFs for the weather conditions, driver populations, animal populations and crash reporting procedures specific to Oregon. Oregon calibrated SPFs for rural two-lane two-way roads, rural multilane roads and urban and suburban arterial roads based on historic safety performance in Oregon. These calibrated HSM predictive methods can now be used by Oregon's transportation agencies to analyze expected facility safety performance and facility alternatives based on conditions there. This report may be useful as it discusses specifically how the predictive methods outlined in the HSM were used and how Oregon broke down the process of generating SPFs based on the three different facility types. This report was written by Karen Dixon and Fei Xie of Oregon State University in collaboration with Chris Monsere and Kristie Gladhill of Portland State University.

Young, J., and P. Y. Park. "Benefits of Small Municipalities Using Jurisdiction-Specific Safety Performance Functions Rather Than the Highway Safety Manual's Calibrated or Uncalibrated Safety Performance Functions." *Canadian Journal of Civil Engineering* 40.6 (2013): 517-27. Print.

This report compares the performance of SPFs that are jurisdiction-specific, calibrated using the HSM's methods and uncalibrated. This study was done using data from the city of Regina in Saskatchewan, Canada. The SPFs were generated using negative binomial regression and five years of collision data at three different intersection types: 3-leg unsignalized, 4-leg unsignalized and 3- and 4-leg signalized. The three sets of SPFs generated from this study were compared using goodness-of-fit tests and cumulative residual plots. The conclusion was that jurisdiction-specific SPFs performed the best at predicting collisions. This report was written by Jason Young of the City of Saskatoon Infrastructure Department and Peter Y. Park of the University of Saskatchewan. This report makes a case for the development of jurisdiction-specific SPFs for more accurate collision prediction. GDOT might want to consider generating these SPFs for use instead of only generating calibration factors depending on the costs and accuracy associated with generating these values.

Appendix B: Results from Initial (Phase 1) HSM Surveys

Background:

The initial project survey targeted twenty-three states (not including Georgia, which was handled separately) for telephone interviews between project staff and state DOT safety personnel to discuss their plans for implementation of the HSM within their jurisdictions. These targeted states were designed to include a diverse set of regions and large/small states. The fourteen states described below agreed to participate. These interviews were initiated in late October 2012 and the last interview was completed in March 2013. Outside of basic questions concerning HSM use, the researchers asked participants about their department's use of the *Roadway Safety Management Process*, the Predictive Method, as well as use of the *Crash Modification Factors* outlined in the HSM. The researcher also inquired about the use of the online CMF Clearinghouse and the various issues that the respective state DOT had encountered in implementing the HSM methods.

Implementation:

To make a list of contacts, the researcher's primary source of information was the individual state DOT websites. Searches on the sites were made for personnel with job titles that would indicate familiarity with HSM policy. The researcher would first search for titles containing or similar to "Safety Engineer." In the absence of this particular title being present on the site, a title containing something concerning "Safety" would be located. In these instances, it was preferred that the person's title either contained the word "Engineer" or they were designated as a registered P.E. This helped assure that even if the initial contact was not the correct one, they would at least be familiar enough with the subject matter of the study as to direct the researcher to the appropriate person. When this failed, the researcher would attempt to find a contact for someone within the design department with titles similar to "Traffic Engineer" or "Highway Engineer." As a result of this selection process, each contact that was successfully reached was able to either answer the survey themselves or direct the researcher to someone who could.

Results:

The results from the 14 successful surveys reflect conditions as of the **March 2013** and are not necessarily indicative of current conditions. More recent results are presented in Appendix C.

Alabama: Alabama DOT used the HSM in their design exception analysis but did not use the *Roadway Safety Management Process* from the HSM. Although they had approximately 200 people trained in the use of the predictive method, they were in the process of developing their own method based on modifications to the one described in

the HSM. They used CMFs, including those from the CMF Clearinghouse after an approval process based upon a review of the original report, though they could not give specifics on any strict guidelines. If no report was available, they did not use the CMF. Alabama was one of the lead states in HSM implementation and they were planning to conduct an extensive evaluation of their processes concerning the HSM later in 2013. The largest deficiency they have found in the HSM is that they have not found it to be user friendly. To assist their employees, Alabama partnered with Virginia and Illinois to produce a set of spreadsheets employees could use during their evaluations. There was no documentation on their HSM policy available since it was still in draft form at the time of the interview.

Alaska: Alaska does not currently use the HSM in their design or review processes. They are considering implementing it as a part of their Highway Safety Improvement Program (HSIP). At this point (Early 2013), they did not anticipate these changes would take place for at least another two years.

California: In 2013, California was introducing the HSM-related program *SafetyAnalyst* as a method of analyzing their data. They did not use the HSM's Roadway Safety Management Process, but their own process instead. Their employees had received training in the Predictive Method. California has their own "Crash Reduction Factors" that they use, but they do use the CMFs from the HSM and the CMF Clearinghouse on occasions, sometimes modifying them for their own, unique purposes. They select the online CMFs by comparing them to their existing practices and choosing those that most closely match. They are currently trying to further incorporate *SafetyAnalyst* by encouraging their highway design teams to use it as well. The biggest deficiency in the HSM for California was the lack of discussion on pedestrian and bicycle features. They were also waiting to see chapters concerning freeways included (N.B. Included in 2014 supplement). The only documents concerning California's HSM policy and implementation were only being shared internally at the time the survey was conducted.

Florida: Florida did not currently use the HSM. However, they were beginning the implementation process and planned to use it in their design exception process. They hoped to have these changes in place within 6-12 months.

Hawaii: Hawaii DOT did not currently utilize the HSM, and they had no plans to implement it in the future unless they are required to. The reasons they quoted for this were their lack of familiarity with the manual and the amount of research and training that would be required to implement it.

Idaho: Idaho had begun implementing the HSM into their design exception analysis, but they were still in the very early stages. They did not use the Roadway Safety Management Process, but hoped to be using it in the near future. Training for the Predictive Method was currently taking place. They did use the CMFs from the HSM, but they were modifying

them to better fit their state's conditions. They also use the CMF Clearinghouse, but they were still formulating a selection process. They had found no major deficiencies to speak of with the HSM.

Indiana: Indiana was currently developing their HSM policy, and they had begun to use it, primarily in their design exception analyses. They used the Roadway Safety Management Process with a few minor revisions. They did not use the Predictive Method, but had done a few test projects with it and hoped to eventually implement it. They used HSM CMFs as well as the CMF Clearinghouse. They preferred to use online CMFs that reduced all types of crashes, unless they have a very specific problem at a site and had a specific countermeasure in mind. They also instructed their employees to only use CMFs with three or more stars, though preferably no less than four stars. For the immediate future, their main goal was to continue further implementation. There are certain chapters that they feel were missing from the current (2010) edition of the HSM, particularly interchanges and interchange ramps. They were currently in the policy development process and had no formal documentation to share.

Louisiana: Louisiana used the HSM in their design exception analysis as a way to justify design exceptions. They have also begun to utilize it in feasibility studies for new projects. They did not use the Roadway Safety Management Process, but were then developing their own similar process. Louisiana's employees were trained to use the Predictive Method. They used CMFs from both the HSM and the CMF Clearinghouse. They currently lacked a formalized process for selecting CMFs, but their website presented some general guidelines for selection. They were looking to continue integrating the HSM into their policy over time, including writing it into their project development manual. They found that the HSM was difficult to incorporate into policy since it is not yet integrated as a standard policy, and thus, each state must determine the best way to incorporate it with their own standards. They also noted that they would like to see more guidance on how to best train employees in HSM practices, particularly who needed to be trained in what areas based on their position. They were currently looking for solutions to these issues.

Michigan: Michigan had only recently integrated the HSM into their review process. They had also been encouraging more use on local levels as well. They did not currently use the Roadway Safety Management Process, but their employees were trained to use the Predictive Method. They used the CMFs provided by the HSM as well as the CMF Clearinghouse. While Michigan lacked its own formalized selection process for CMFs, their employees had received training from AASHTO that covered CMF selection. As they were integrating the HSM on multiple levels, Michigan's biggest complaint concerning the HSM was the lack of consistency with the language between the manual itself and the programs based off of it. They had also found that the language within the manual is often not very intuitive, which causes problems for employees at lower levels. They were

dealing with this with continued training as well as further use of the more intuitive spreadsheets. No documentation was available at that time.

Minnesota: Minnesota had not fully integrated the HSM in early 2013, but they had been using and testing it on certain applications. One thing they had been focusing on was using it on projects in the environmental documentation stage to evaluate alternatives. They did not use the Roadway Safety Management Process, but rather they used their own process. Only one or two people in the department were trained to use the Predictive Method. They used the CMFs from the HSM and the CMF Clearinghouse. Their selection process was very general and was based on the ratings of each CMF. They hoped to further integrate HSM use in their environmental documentation as well as their intersection code evaluation reports. One major deficiency that Minnesota had found in the HSM is that rural, multi-lane, traffic controlled intersections tended to generate unusually high numbers. When this occurred, they went into their own crash database and pulled a number that they considered to be more realistic. This number was usually only about one-third of the original HSM number. There was no official HSM policy documentation available at that time.

Missouri: Missouri used the HSM for design exceptions. They were currently attempting to integrate the Roadway Safety Management Process, in particular *SafetyAnalyst*, into their own process. Many of their employees had been trained to use the Predictive Method. They used the CMFs from the HSM and the CMF Clearinghouse. They instructed their employees to choose CMFs with higher star ratings, and they were currently in the process of training their employees to be better able to recognize which CMFs were preferred. Missouri wanted the HSM to become common practice as their analysis tool. They had trouble incorporating the *SafetyAnalyst* program. Like many other states, they wanted to see modules on freeways and interchanges in future editions of the HSM. For documentation on HSM policy, we were directed towards Missouri's online Engineering Policy Guide.

Montana: Montana had not incorporated the HSM into their policy to date. They were applying its principles on a very limited basis as test projects. They did hope to one day integrate the HSM into their policy. Before that could happen, they feel they needed to modify their crash database with an updated safety information management system. There was currently no timeline for these changes/updates.

New Hampshire: New Hampshire was in the early stages of implementing the HSM. They did use *Safety Analyst* to identify problem areas, but they had not yet begun to use the HSM for design exception analysis. They did use the Roadway Safety Management Process, and their employees were trained to use the Predictive Method. New Hampshire did use the CMFs from both the HSM and the CMF Clearinghouse. They attempted to be conservative in their selection of CMFs by choosing those with the most conservative estimates and the highest number of stars. They hoped to integrate the HSM into their

design exception analysis in the near future. At that point, New Hampshire had found no major deficiencies with the HSM. For policy documentation, we were directed to an online copy of their HSM implementation plan.

South Carolina: South Carolina had not integrated the HSM into their design and review processes. Their safety office was familiar with its contents and often referred to it. They had held a class on the HSM for many of their employees in the design office. They hoped to begin using the manual soon. Currently, Clemson University was helping them calibrate the CMFs. The results of this study were due to be completed in June 2013. They were also reviewing North Carolina's results from HSM implementation.

Appendix C: Results from Final (Phase 2) HSM Surveys

Introduction

This appendix to the report details the *Highway Safety Manual* (HSM) research survey design and results from the Final (Phase 2) HSM survey conducted by researchers from the School of Civil and Environmental Engineering at Georgia Institute of Technology during Spring 2015. Information pertaining to various states' HSM implementation process was obtained by surveying state departments of transportation (DOT) and Offices of Traffic Safety and Traffic Engineering.

Survey Approach

The HSM research survey was designed and administered to collect information about different states' HSM implementation process and progress. The survey was also designed to identify which parts of the HSM states have already adopted and are using and which parts are seeing less application.

The HSM survey approach employed a phone interview process in which a researcher called representatives from each state and administered the survey over the phone. These state representatives were identified from a number of sources including state DOT websites and GDOT who were able to provide information for the appropriate contact person in various states. The Federal Highway Administration (FHWA) Tribal Transportation Program Team also published a list of transportation safety contacts that provided contact information for the FHWA State Division Safety Specialist, State Highway Safety Improvement Office, and Governor's Representative for Highway Safety that was also used.

Once the correct contact information was obtained, the representatives were called and the researcher left a message either on their answering machine or with an office receptionist. Some contacts were called multiple times and multiple messages were left over the three month survey period. Through this extensive follow up activity, ultimately 40 different states completed the survey either by telephone or by email. A few states requested to have the survey sent to them through email instead of administering the survey via telephone.

The responses to the survey questions were recorded and tabulated on a state-by-state basis into a single document for each state. The responses were not recorded word-for-word but were paraphrased in a way that best captured the speaker's response. This was done to help the reader understand what the speaker was discussing in the case of run-on sentences and other transcription issues.

Survey Questionnaire

The questionnaire consisted of four parts; the sections were created to account for the most likely responses to the opening question and to provide a conclusion section. Section A was focused on states that use the HSM in their design or review processes. Section B was for those people who didn't have time to answer the survey questions or believed they were not the right person to contact for the survey. Section C was for states who do not use the HSM in their design or review processes. Section D was in regards to future contact for follow up questions and for concluding the phone interview. A script of the survey including all four sections of the survey can be found along with each states' responses are provided following Table 3.

Survey Results

In total, 41 states participated in the Phase 2 survey. These results are summarized in Table 3. Individual state survey results are presented following the table and are organized in alphabetical order by state and then by question. The state, contact person and job title are shown at the top of each survey followed by the individual questions and their responses. The italicized text represents the response given for each question.

Table 3: Summary of results from state surveys regarding implementation of the *Highway Safety Manual*

State	Department uses HSM in design or review processes?	Description of scope of HSM use.	Use of the Roadway Safety Management Process detailed in the HSM?	Employees are trained in the predictive methods?	Use the Crash Modification Factors (CMFs) in the HSM?	Planned changes in department's HSM use?	Found major deficiencies in the HSM?
Alabama	Yes	HSM used for design exceptions	Incorporating processes into a road safety assessment manual that will detail project procedures	Yes, but a while ago	Yes	Have projects underway to incorporate the HSM into their crash analysis software	Ranges of CMFs recommended for same application; unavailable data; gaps in how things tie together
Alaska	Not using the HSM in their design processes	HSM is used by consultants on state projects, but not actively used by DOT designers	No; but their process lines up with some steps of Roadway Safety Management Process	Not from a design point	Yes from a HSIP perspective; no from a general design standpoint	Currently researching and analyzing development of state calibration factors for SPFs	No; have noticed differences in Alaska data compared to states the HSM was based on

Arizona	Use parts of the HSM	Use the predictive methods for prioritizing locations, and benefit cost analysis. Use of the HSM is not in their written policy	Are using Safety Analyst which includes components of this process	Some are trained but have had many staff changes	Only use CMFs from the clearinghouse with a 4 or 5 star rating	Currently using the HSM on an experimental basis, but with further research they may use it more	Major hurdle is availability of accurate data required to implement the HSM
Arkansas	Not much at this moment	Using the HSM for project planning purposes	Don't follow the process exactly; use it more as a guide	3 out of four of their engineers know about the predictive methods; one engineer is new.	Yes; have used CMFs to come up with their rumble strip policies	Working to integrate into their design process and project planning	Have had issues multiplying CMFs together because of assumption of independence; leads to over-predictions
California	Yes	Introducing HSM-related program Safety Analyst for data analysis	No; they have their own process	Yes	Yes, they use CMFs from the HSM and from the CMF clearinghouse	Trying to further incorporate Safety Analyst	Biggest deficiency is the lack of discussion on pedestrian and bicycle features

Colorado	Yes, use the HSM in program level planning	Use the HSM in assessing safety and safety benefit of a project using CMFs	No; consistent with the process though	Yes, but training was a while ago	Sometimes	No; still use the HSM in the same capacity as when it was first produced	Predictive modeling is too general
Connecticut	Starting to incorporate the HSM	Using the HSM for analysis and screening methods	Using the process mainly for network screening	Yes; have spreadsheets for using the predictive methods	They refer to the CMF clearinghouse	Slowly incorporating the HSM into their review process	Would like clarification on what to use for some of the analysis
Delaware	Did not participate						
Florida	Yes	Use the HSM for projects review and statewide implementation efforts	Using Safety Analyst	Yes	Yes, looking at effectiveness of changes in design	Yes, changes to use of HSM being considered	6-lane divided arterials are not included in the HSM
Hawaii	NO	N/A	N/A	N/A	N/A	N/A	N/A

Idaho	Yes; unsure how designers specifically use the HSM	For research analysts, the HSM is used for comparing different safety features for improvements on roadways or intersections	Not clear on what this means; use some of processes to determine what locations to further look into doing safety enhancements	Not officially	Mostly uses the CMF clearinghouse	Yes, going forward HSM will be factored into any changes to methodology for safety evaluation	The HSM doesn't incorporate different types of roadways
Illinois	Did not participate						
Indiana	Yes; to an extent	Use the SPFs and predictive functions in the HSM	No; they have a separate asset management process	Yes; have had training in IHSDM software	Use CMFs from clearinghouse	No; waiting for next version of manual	Not enough emphasis placed on severity of crash; long calibration process
Iowa	Yes	Trying to use the HSM for performance based practical design	Unsure	Yes	Yes; unsure if they are using CMFs from the HSM or those developed for Iowa	Yes, planning on implementing the HSM in design exceptions	No; haven't used the HSM enough to find any

Kansas	Yes	The HSM is used to consider alternatives and their effect on safety	not sure* not a designer	Have had opportunities to receive training, but not required	CMFs are used by traffic engineers in scoping safety projects	No	Has not used the HSM enough to answer
Kentucky	Yes	Use the HSM for initial project prioritization and screening	Their process is not exactly how the manual says, but is close to following the process	Have had training in what they use the HSM for	Sometimes; use CMFs in the HSM with CMFs from the CMF clearinghouse	Looking to do additional integration of the HSM	No
Louisiana	Yes	Use the HSM to evaluate design conception and alternatives for safety	Process is similar but they don't use SPFs for network screening	Yes	Use CMFs from the clearinghouse	Under consideration to start using the HSM	Deficiencies in SPFs, CMFs recommended don’t consider bikes and pedestrians
Maine	Did not participate						
Maryland	Did not participate						
Massachusetts	Tried to use the HSM	Finishing developing state SPFs before use	Use a semblance of the process	Yes	Still in the research process	Working to use the HSM	Nothing in the HSM for local roads

Michigan	Yes	Use the HSM for network safety and have it outlined in the scoping process	Yes, if referring to network surveillance	Have developed their own spreadsheet to do predicted and expected processes	Yes, use CMFs for those applicable to total crashes	Working to make the HSM more applicable to their business	Difficulty applying a large volume of information to their entire process
Minnesota	Infrequent use	Use the HSM for specific projects to evaluate potential benefits	No	Very few	Yes	Plan to start using the HSM more	Doesn't allow you to model or look at things atypical in design
Mississippi	Use the HSM for Highway Safety Improvement Program projects	Use for comparing nominal safety versus substantive safety	Vaguely	Safety engineers are trained but unsure about designers	Always	Changes in use of HSM for safety projects	Crash reduction factors don't fit all scenarios and its range is too high
Missouri	Yes	Require use of the HSM for design exceptions	Not to the point of using that process	Yes; have trainings once a year in their district locations	Yes; use CMFs in the HSM and in the CMF clearinghouse	Working on using Safety Analyst to do network screening; incorporating predictive methods	Unreliable data; need to provide state specific SPFs

Montana	Yes	Recently had SPFs completed for state; using for network screening also	Yes if referring to network surveillance	Only the HQ safety engineering section is trained	Yes	Using the HSM methodology for network screening	Technical and difficult to navigate
Nebraska	Yes	Don't use the HSM for every project; just on things like resurfacing projects	Not typically	Have had some webinars and have training by Nebraska Federal Highway	Don't use CMFs from the HSM for policy, but for design they do	Right now in review process of how to better their process in Nebraska	No; have not used the HSM as thoroughly yet
Nevada	Yes and no	Used the HSM some in their traffic safety office and by their design team	Not completely	Yes, all of their scoping teams and design staff are trained	Yes	Pushing for further implementation of the HSM	Cumbersome to use; problematic link up with Safety Analyst software and databases
New Hampshire	Yes	In the early stages of implementation	Yes	Yes	Yes; get CMFs from the HSM and CMF clearinghouse	Want to integrate the HSM into design exception analysis	No
New Jersey	Did not participate						

New Mexico	Sparing use	Use the HSM in alignment studies in roadway safety audits	No; currently perfecting data gathering tools	Have had a couple of trainings, but not efficient with the predictive methods yet	Use CMFs from the clearinghouse in some studies	Yes, considering making changes	Doesn't cover a lot of scenarios they face; concepts can be hard to grasp
New York	Sometimes	Using the HSM to calculate crash reduction factors from data collected and use the CMFs in the HSM	Not exactly	Yes, but could benefit from more training	Use CMFs from the clearinghouse to go through PIL location studies	Doing gap-analysis between current process and process in the HSM	Struggling to determine where their process is better and where the HSM process is better
North Carolina	Yes	Using the HSM for alternative analysis and comparison	No	Have had some training but are mostly self-taught	They have their own list in North Carolina; reference the HSM CMFs though	Want to implement the HSM on more projects	Hard to follow; lay out can make the HSM hard to navigate
North Dakota	No	N/A	N/A	N/A	N/A	N/A	N/A

Ohio	Yes	Use the HSM for safety funded projects	Yes, do priority lists for Safety Analyst	Yes, have 5 to 6 trainings a year	Use the HSM CMFs and CMFs from clearinghouse	Working on defining when to use the HSM and when not to	HSM is missing things current research is trying to address
Oklahoma	To an extent	Use the HSM for network screening, site selection and systemic projects	No	No	Use the CMF clearinghouse	Currently modifying database interface with help from local university	SPFs have too simplistic a fit to ADT
Oregon	Not formally	Use some for network screening, project development, and planning processes	No	Some staff are trained	Yes	Considering incorporating the HSM into their design exception process	Lack of civil facilities and one-way couplets
Pennsylvania	Did not participate						
Rhode Island	Yes; just began using it	Use the HSM to run SPFs they are developing	No	Yes	Yes, HSM is where they get their benefit-cost ratios	Yes, trying to go to predictive method	Not enough data points in certain circumstances

South Carolina	To a limited extent	Developing calibration factors with Clemson University	No	Semi-trained	Yes	No	No
South Dakota	To a limited extent	Use the HSM in the scoping process	No	The designers are not, but the safety engineers are trained	Yes	Moving towards using the HSM for consultant review on interstate interchange configuration alternatives	Not major
Tennessee	No	N/A	N/A	N/A	N/A	N/A	N/A
Texas	Yes	Use for determining crash reduction factors and design exceptions	No	In the process of exploring the predictive methods	Yes, get their CMFs from the clearinghouse	Looking to move towards empirical based methods	New at using the HSM, so no complaints except difficult to read

Utah	Yes, but not on every project	Use the HSM for corridor studies and to run relative expected crash scenarios	Yes, but the process is not used on all projects	No, they use consultants for HSM analysis	Yes, mostly use CMFs for design and limited use on policy decisions	No; established in how they use the HSM now	Inconsistencies in value of crashes; calibration data labor intensive; limited background information given in CMF clearinghouse
Vermont	Limited use	Used predictive equations from the HSM and used for comparison of design alternatives	Unsure, but doesn't think so	Not many are trained	Use CMFs from the HSM for the HSIP process	Being encouraged to go into data driven highway safety plans	No
Virginia	Use the HSM on some designs, but not in their policy	Have fully implemented Part B for network screening	Yes; have fully implemented network screening and economic assessment	Have had training, but need a refresher	Yes, but mainly use CMFs from the clearinghouse	Wanting to write more of the HSM into their policies	Yes; waiting for roundabout sections and on increasing lane numbers for arterials

Washington	Yes	Use the HSM for project prioritization and design	Yes; use the process for project prioritization	Not everyone is trained, but every region has someone who has been trained	Yes; also have a short list of approved CMFs	Changing to do performance based practical design	No; expect HSM to improve over time though, so watching
West Virginia	Did not participate						
Wisconsin	To a limited extent	Have used the HSM in safety effectiveness evaluations	No	Have had limited training	Yes	Discussing where in their process it would be best to implement the HSM	No roundabout SPFs
Wyoming	Just starting to use the HSM	Use the HSM for reviewing a projects' safety benefit	No	No; looking at doing a NHI training course	Yes, they modify the CMFs from the HSM	Progressing in adopting the concepts in the HSM	Data required to utilize the HSM is not readily available

Alabama

Contact Person: Tim Barnett

State Safety Operations Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Yes

A2. Can you briefly describe the scope of your HSM use?

Use it for design exceptions and working on other methods to use it.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

To a certain extent. Currently incorporating a lot of those processes into a road safety assessment manual they are putting together that will detail the procedures for a project from the planning stage to post construction operations stage.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Have been trained, but it's been a while back. They are moving probably to the point that the predictive methods will be housed within their office of safety. Working to build tools and utilize existing tools like AAHSTM and others for the designers to use because they have realized that for example if you are looking at a five mile stretch of interstate you will spend weeks plugging in all the potential combinations of projects, ramps, lanes and curves, etc. so they need a way to simplify that process.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Not sure how to answer; Alabama is one of the focus states for the use of the HSM so they are doing everything they can to implement it at various steps. They have several projects underway to incorporate it in their crash analysis software, utilize it in the design process, and use it in the operations process. Trying to incorporate it in all of their processes but it is a pretty big hurdle to get everyone to use it and incorporate it in all of the different process because of its complexity

A7. Have you found any major deficiencies in the HSM?

**He is on the panel for writing the third edition. But yes, there are a lot. Gaps in the knowledge of how certain things tie together. There is a gray area between a rural, suburban, and urban area and some of the research being done is to determine what makes a crash rural or urban in the transition zones. One of the biggest gaps is due to the fact that so much of the data is not even available to them yet. Ranges of CMFs recommended for the exact same application is astronomical; making sure research is consistent from one site to the next is a big hurdle.*

Alaska

Contact Person: Jeff Jeffers

State Traffic and Safety Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Not really using HSM in their design process

A2. Can you briefly describe the scope of your HSM use?

They don't have a robust enough road inventory to make it feasible from an HSIP program standpoint to compare projects. It is theoretically usable and some consultants have used it on state projects but at this point the DOT designers aren't actively using it but it is something that may be adopted in the future

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

No; but said the steps prescribed in the Roadway safety management process line up with an AASHTO tool called Safety Analyst. At this point they have a screening process that they use for their highway safety improvement program for determining which projects they should deal with in a fiscal year but it doesn't include that. This is partly because they don't have the information available in the databases. They are developing a more robust and modern database system and an inventory and asset management database.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Not from a design point, no; but, people are becoming aware of it. It is something of a management decision not to pursue it because there are plenty of processes already required from the federal-aid highway program and their own preconstruction manual and this would be another layer of requirements put on the design group. The effort is to minimize that. One possibility in the next five years is that HSIP related people will be looking at using the HSM particularly when they get an electronic roadway inventory so they can access different characteristics on a variety of roadways around the state. This is currently not automated. It is also possible that in the future people other than the HSIP

people would be trained. Most likely they will have an expert on the HSM for each region so every project could ask the expert to analyze their project.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

From a HSIP perspective they do, from a general design standpoint they don't. They don't refer directly to the HSM as much as they have their own HSIP program list of countermeasures and crash reduction factors. Their system comes from the early 2000s and it uses the crash reduction factor process. They can go through the CMF clearinghouse or go to the HSM and pick out a CMF and convert that to a crash reduction factor.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Yes, they are actively doing a research project/analysis where they are developing a state calibration for SPFs listed in the HSM. Focusing on signalized intersections, stop-controlled intersections, rural two-lane highways and they are going to have regional and possibly state-wide calibrations for those. They have a professor at one of their universities, who for his own research did a comparison of a four-legged, signalized intersection and found that the SPFs listed in the HSM understates the number of crashes they would normally experience in Alaska. There is a calibration associated with aligning the crashes per given volume and they are doing that.

A7. Have you found any major deficiencies in the HSM?

No; they haven't had enough experience with it to say that they have found something wrong with it. The data that was the basis for the SPFs was drawn from states very different from Alaska (they have a lot of low volume, rural 2-lane highways, some urban sections), so it is not directly applicable to Alaska in its origin. The originating data is inconsistent with what they find there so as a result they find not only a vertical shift in the y-axis (as they try to calibrate for their state) but also that it moves left and right.

Arizona

Contact Person: Kohinoor Kar

Transportation Safety Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Currently we don't have a written policy to use HSM predictive methods in highway projects; however, we have used HSM predictive methods and tools such as NCHRP 17-38 spreadsheets and Interactive Highway Safety Design Model (IHSDM) software to evaluate a few "pilot" safety improvement projects.

A2. Can you briefly describe the scope of your HSM use?

As a part of safety evaluation, we identify locations based on crash data, analyze and then prioritize them for further evaluations. We currently do the screening using observed crash data that is collected from all public roads and maintained in a central repository called Accident Location Identification Surveillance System (ALISS). Then we identify countermeasures that have established Crash Modification Factors (CMFs) in the CMF Clearinghouse. The projects include issues such as lane departure, intersections, pedestrians/bicyclists safety. After identifying locations (e.g. segments or intersections) for additional evaluation, we do a site visit and try to find patterns in crash types. We also review crash reports to gather additional details. Once we identify safety countermeasures, typically we perform a Benefit/Cost analysis and calculate the B/C Ratio. Cost includes safety improvement cost, benefit includes reduction in crashes. Typically, CMFs provide the effectiveness that is converted to safety benefit; however, in some cases (e.g. new construction/improvement without any historic crash data), we use either NCHRP 17-38 spreadsheets or IHSDM software to calculate predicted crashes and compare that to existing crashes. The difference between the two is the benefit in terms of reduction in crashes. They have a set dollar value for crashes by various severities (e.g. fatal crash = $5,800,000) that they receive from FHWA Headquarters.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

Arizona DOT has the license for AASHTO's Safety Analyst, which includes essential components of the roadway safety management process contained in the Part B of HSM. We are looking into data needs and data gaps and how to address them to run Safety

Analyst. We will use Safety Analyst initially to do network screening of the state highway system.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Some Employees are trained in the HSM as well as available tools (NCHRP 17-38 spreadsheets, IHSDM), but due to changes in staff (e.g. retirement, change in position or division), we are considering offering additional training for the staff.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

We use CMFs available in the CMF Clearinghouse only and recently developed a guideline to select most suitable CMFs with 4- and 5-star ratings. If a CMF is not available (e.g. roadside tree removal), we are considering conducting research to develop one.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

HSM predictive methods are currently being used as an experimental basis. Once we have adequate training, gather critical data and experience in using the tools, we may review the current policies and try to incorporate HSM methods as far as practicable.

A7. Have you found any major deficiencies in the HSM?

HSM does not contain everything perfectly. Further research is being undertaken and will be needed to make certain improvements in the methods and tools.

The major hurdle is the availability of accurate data to fully implement HSM. Part B of the HSM is the roadway safety management process which is being handled by Safety Analyst but it requires a lot of data. We are almost done with a research project that is looking into data needs, data gaps, and the availability of data. Once we are successful in running Safety Analyst for the state highway system, we plan to utilize the tool initially for network screening. On the other hand, IHSDM software and NCHRP 17-38 spreadsheets have project level applications. We have been successful in using them both on pilot projects.

Arkansas

Contact Person: Kenneth Banga

Transportation Programming Specialist

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Not at this moment no. They have played around with IHSDM, but it has not been fully accepted or integrated in their design.

A2. Can you briefly describe the scope of your HSM use?

They are currently using it for project planning purposes.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

Sort of, they don't follow it exactly but use it more as a guide or a tool. They do have a process but they don't exactly follow the Roadway Safety Management Process.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Not all of the engineers in Traffic Safety are trained in the predictive methods. They have four engineers currently and only three of them know about the predictive methods because one of the engineers is new.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes, they have used CMFs to come up with policies like their rumble strip policies. They also use the CMF clearinghouse to justify that those policies are helping save lives.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

They are currently working to integrate the HSM into their design process as well as project planning.

A7. Have you found any major deficiencies in the HSM?

Yes, they have had issues with multiplying CMFs together because the HSM multiplies them and assumes independence between those CMFs. In their experience, that can cause over-predictions.

Colorado

Contact Person: David Swenka

Transportation Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

His department isn't responsible for design but is responsible for program level planning, but yes they do use the HSM.

A2. Can you briefly describe the scope of your HSM use?

They use the methodologies in the HSM in assessing the safety of a project and also in assessing the safety benefit of a project using the CMFs.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

They are consistent with the process but they may not follow all of the steps precisely.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Yes

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Sometimes

A6. Do you know if changes to how your department utilizes the HSM are being considered?

They aren't really considering any changes; they still use it in the same capacity as when it was first produced. They use it as a reference document and keep up with the updates made to it and additional documents associated with it.

A7. Have you found any major deficiencies in the HSM?

Some of the predictive modeling is very general. They have more specific models developed for their state, which helps them stay consistent in their methods and apply them the same way.

Connecticut

Contact Person: Ryan Pothering

Transportation Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes? (If YES, continue to A2; If NO, skip ahead to Section C)

They are starting to incorporate the HSM.

A2. Can you briefly describe the scope of your HSM use?

They are mainly using it for their analysis and screening methods. They aren't incorporating it into their project priority or anything like that yet.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

They are still in the preliminary steps of trying to incorporate it. Right now they have been using it more for the network screening process to see where the locations are and selecting the best countermeasure for it. They are still trying to incorporate things like the economic appraisal parts of it. Once they get through incorporating that they can do a much better evaluation. They should be incorporating more of the HSM into their project development process in the near future.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Yes, they have some spreadsheets to use for using the predictive methods for the analysis.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

They are starting to refer to the CMF clearinghouse website to pick the correct one.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

They are still in the beginning parts of it so they are still figuring out how to incorporate it into their review process. They are making progress, especially with screening and selecting the correct countermeasure. It is also slowly being incorporated into how they do their benefit-cost analysis.

A7. Have you found any major deficiencies in the HSM?

Haven't found many deficiencies in looking through it. The only thing is clarification on what to use for some of the analysis, because it looks like in some examples it uses crashes and in other examples it uses the actual number of injuries and fatalities in the analyses. Some clarification on how to do the analysis would be a lot better.

Florida

Contact Person: Joe Santos

State Safety Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Yes

A2. Can you briefly describe the scope of your HSM use?

HSM has primarily been with providing training on the use of the HSM and involvement with projects review and statewide implementation efforts.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

We will be using Safety Analyst as our Roadway Safety Management Process

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Yes, FDOT employees and consultants have received HSM training that covered the predictive Method.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes, FDOT would look into the use of a CMF when evaluating the potential effectiveness of a change in design or policy.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Yes, changes to how FDOT utilizes the HSM is being considered.

A7. Have you found any major deficiencies in the HSM?

Six-lane divided arterials were not included.

Hawaii

Contact Person: Julius Fronda

State Highway Design Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

No

C1. Would your department consider using the HSM in the future?

Probably yes if it is required by the Federal Highway Administration. They will adopt it and use it once it is mandatory.

Idaho

Contact Person: Kelly Campbell

Principal Research Analyst

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Yes, but doesn't know how designers specifically use it.

A2. Can you briefly describe the scope of your HSM use?

She is a research analyst not a roadway designer. She uses the HSM to look at situations where a section of roadway or intersection could see improvement by adding different safety features. Not specifically in the design process though.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

Wanted more definition of what is meant by Roadway Safety Management Process in HSM. If I'm asking if they go in and look at sections of roadway and do a corridor analysis to break it down based on different features, then yes. They have two processes where they use similar processes to determine areas where they want to look at enhancing safety features or doing safety projects on roadways. In other words, they use some of the processes to determine what locations they want to look into doing enhancements on, but not sure if that is answering the question about the roadway safety management process because not remembering off the top of her head what that section is.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

There are a few people that she has shown the worksheets and predictive methods, but that was not an official training.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes and no, some of them they do use out of the HSM but most people, she recommends to go to the clearinghouse to look at the more updated CMFs. So yes if the CMFs in the

manual are the same ones still in the clearinghouse and those are the best ones. But because the HSM is somewhat outdated at this point and doesn't include all of the research that she has, when people ask her about it she recommends that people go to the clearinghouse to find the best and most recent modification factors that may be more directly related to their type of roadway system. Idaho is more rural and a lot of the CMFs were developed for more urban states.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Yes, anything they do anymore at this point in time, the HSM is factored into any changes that they look towards for the future when it comes to methodology for safety evaluation.

A7. Have you found any major deficiencies in the HSM?

Yes, it is only rural two-lane and some of the restrictions are that it doesn't incorporate all of the different types of roadways.

Indiana

Contact Person: Mike Holowaty

Traffic Safety Manager

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

They do to an extent. They don't use Safety Analyst; they have another software that they use that was developed prior to that and is an analog of it.

A2. Can you briefly describe the scope of your HSM use?

They use the safety performance functions and the predictive functions.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

No; they have a separate asset management process.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Yes, their engineers and their design division are interested in developing that and have training in IHSDM software.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

They use the CMFs in the clearinghouse; don't necessarily go to the manual to get their CMFs.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

At present, no; they are waiting for the next version of the manual and will then assess whether or not it is a better fit for what they do than what they have now. They don't have any active plans for changes at the moment.

A7. Have you found any major deficiencies in the HSM?

Yes; manual doesn't place enough emphasis on the severity of the crash. They break their crashes up by severity characteristics and do their analysis that way. The calibration process in the manual is long and difficult, which is part of the reason they limit their use of it. They currently have software tools that utilize the same theory but are calibrated for Indiana. Some elements of the manual are limited on certain areas and need to be developed and agreed to; particularly with interstates and on-ramps.

Iowa

Contact Person: Jan Laaser-Webb

Supervisor- Transportation Safety, Utilities, and Access Management

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Yes

A2. Can you briefly describe the scope of your HSM use?

Uses HSM on a very limited capacity. She is in Traffic and Safety and they are a small group so their office of design has begun to use it. They are trying to start doing performance based practical design and they are using the HSM to analyze the safety issues on the corridor. Other than that, they haven't implemented its use.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

Not sure because not involved in the day to day.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Yes

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes, but not sure if they use the CMFs developed by Iowa State University or those given in the HSM.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Yes, they have been talking about implementing the HSM in more instances. For example using it in design exceptions, and other things the districts have asked about whether projects were safety initiated or capacity initiated.

A7. Have you found any major deficiencies in the HSM?

Haven't used it enough to find any. Deficiencies she did see have been improved since its first publication.

Kansas

Contact Person: Steven Buckley

State Safety Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Yes; not a designer but going to refer me to someone else for design specific questions

A2. Can you briefly describe the scope of your HSM use?

Using it for practical improvement projects where they are designing a project within a budget and using the HSM to consider alternative scopes to measure their effect on safety

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

Does not know

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Wanted to clarify that this is referring to part B of the HSM? Two software tools associated with the HSM: IHSDM and SafetyAnalyst. They have had opportunities to receive training on the HSM, but he is not aware of it being a requirement. Opportunity is there for traffic engineers and roadway designers though.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Not sure how designers use CMFs, but he knows that traffic engineers in scoping their safety projects are trying to integrate that into their processes but this is a slow process. As far as road design though he is not certain how they use the CMFs

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Not that he is aware of

A7. Have you found any major deficiencies in the HSM?

He has not found any, but he has not used it enough to answer that honestly.

Kentucky

Contact Person: Jason Siwula

Innovative Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Yes

A2. Can you briefly describe the scope of your HSM use?

They primarily use Part B of the HSM. Use it for initial project prioritization and screening and to determine sites of promise that they can then go out and do a field review on to program projects.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

If they don't do it exactly how the manual says they are very close to following the process.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

A lot of their HSM work is done by a university partner. They have had training on the HSM though for what they use it for.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Sometimes. They use them in concert with CMFs found in the CMF clearinghouse as well.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

They are constantly evaluating their processes and they are looking to do additional integration but are currently unsure what that will look like.

A7. Have you found any major deficiencies in the HSM?

No

Louisiana

Contact Person: April Renard

Highway Safety Manager

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Yes

A2. Can you briefly describe the scope of your HSM use?

They use the HSM to evaluate design conception; they do not have a policy requiring it. They also use it to evaluate alternatives for safety. She is a big campaigner for using it, but is not in charge of making that decision for the department

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

Process is similar but don't use SPFs for network screening

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Yes

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes, they use the clearinghouse.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

She is involved in policy decisions, but they don't have policies on using the HSM currently in place; it is under consideration to start using the HSM though.

A7. Have you found any major deficiencies in the HSM?

The use most parts of it, but the network screening SPFs are not a good fit to data so limited use in network screening. They are developing specific state SPFs to overcome deficiencies in SPFs recommended in the HSM. Also, the CMFs recommended in the HSM don't consider bikes and pedestrians.

Massachusetts

Contact Person: Bonnie Polin

Chief Safety Analyst, Traffic and Safety Engineering Section

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

They have tried to use the HSM.

A2. Can you briefly describe the scope of your HSM use?

It is difficult for them to use because Part C (related to SPFs) didn't line up with their state information at all. Have to develop their own SPFs before they can use the HSM. Currently finishing up developing intersection SPFs and they are hoping to use the HSM for design exceptions and design alternatives.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

They use a semblance of it that is their own.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Yes, they have had training.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Still in the research process.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Yes, they are working to use the HSM.

A7. Have you found any major deficiencies in the HSM?

There is nothing in the HSM for collective roads and local roads (referring to intersections only), it's all for arterial roads. Their state is urban so intersections are more critical and they have very little rural segments. The intersections dealt with in the HSM are only for arterials, so they would like to see analysis for local roads and collective roads.

Michigan

Contact Person: Dean Kanitz

Traffic Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Yes

A2. Can you briefly describe the scope of your HSM use?

They use it from a networking safety standpoint and have it outlined in scoping process.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

If referring to Network surveillance, then yes.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

They have developed their own spreadsheet to do predicted and expected processes.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

They have those applicable in the HSM that apply to total crashes built into spreadsheet to be selected by users.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Constantly working to make it more applicable to their business as a whole

A7. Have you found any major deficiencies in the HSM?

Difficulty in application because of content and applying large volume of information to entire process; They have been in data analysis for a long time so it is helpful to incorporate the HSM into existing efforts and advertise for the benefits of the HSM.

Minnesota

Contact Person: Derek Leuer

Assistant State Traffic Safety Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

They use it infrequently.

A2. Can you briefly describe the scope of your HSM use?

The main thing they use it for is to either to look at specific projects to see what the benefits to be gained are. They have used it on new projects for alternative analysis. Also have started using it for intersection design.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

No

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Very few

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Right now the plan is to just start using it more, which is the main thing they are focused on.

A7. Have you found any major deficiencies in the HSM?

Not so much a deficiency in the HSM, but certain people/certain positions want you to model or look at things that are unusual or not typical in typical design and you can't really do that with the HSM but that is also kind of the point; the point is to be able to look at what is commonly out there and has been highly used and highly deployed.

Mississippi

Contact Person: Jim Willis

Safety Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Not in design so he said that he may not be able to say exactly how the designers are using it, but can share how their Highway Safety Departments are using it. Asked if I am talking about typical roadway projects or highway safety improvement program projects; said he can talk about the highway safety improvement program projects. Said they use the HSM for design for HSIP projects.

A2. Can you briefly describe the scope of your HSM use?

They use the SPFs as far as looking at nominal safety versus substantive safety and then will use that to apply certain content and concepts to see what expected crash frequencies are in certain facility types. They incorporate that into their recommendations for countermeasures for locations.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

Vaguely

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Highway safety engineers are trained but he isn't sure if their designers have been trained or not.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Always

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Other than safety projects, no.

A7. Have you found any major deficiencies in the HSM?

The biggest issue they have is that some of the crash reduction factors don't fit all of the scenarios and the range/standard deviation on a lot of the crash reduction factors is way too high.

Missouri

Contact Person: Drew Williford

Traffic Safety Engineer*

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Yes

A2. Can you briefly describe the scope of your HSM use?

They generally require it for design exceptions. If there is anything that gets changed out in the field related to safety has to go through that. Their designers also use it to weigh two different options as far as alternatives go but that is not mandatory.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

They have not quite gotten to the point of using that. They focus more on the predictive method. They are hoping to incorporate more of that as they go forward. They are currently working on using Safety Analyst and they are hoping to get that up and going soon, but linking it to their database has proved very challenging since it is so data intensive.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Yes, they do trainings every now and then. They generally try to do training about once a year in their district locations. The idea is that out of the districts you have personnel that are familiar with the regions and then you have the central office (where he works) that coordinates among all of the districts.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes, they use it a lot when they are looking at different design alternatives or doing a design exception. They generally try to focus on the CMFs found in the HSM but they are also using the CMF clearinghouse for most of the analysis.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Yes, they are currently working on using Safety Analyst to do network screening. They are also trying to incorporate the predictive methods. They now recommend to their personnel that any project that uses federal money should have an HSM analysis done on it to get a Benefit-Cost ratio to submit to the DOT.

A7. Have you found any major deficiencies in the HSM?

The data is tricky to use when working with non-state specific values. So, providing state specific SPFs or calibrating the SPFs given may be an important step in the HSM process. In other words, unreliable data.

Montana

Contact Person: Roy Peterson

Chief of the Bureau of Traffic & Safety

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Yes

A2. Can you briefly describe the scope of your HSM use?

They recently had SPF's completed for our state. They have LOS graphs for all rural two lane highways as well as freeways both for roadway departure crashes and total crashes.

This is the first year they are using these new tools to screen the network for potential safety improvement projects. Their safety office recently visited the district offices to educate (high level) those on what tools have been developed for Montana and how HQ Traffic Safety will be using them in the future.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

Yes

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

The only employees that are trained to use this method are in HQ Safety Engineering Section. Quite a few folks have been made aware that this tool exists but are not comfortable in performing the calculation. For the most part, the request to use this method comes to the Safety Engineering Section as the experts in the area.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes

A6. Do you know if changes to how your department utilizes the HSM are being considered?

They are not only being considered; they are being put into practice. They are using the HSM methodology (LOS method; page 4-12 of the HSM) to screen our network. Also they are encouraging the districts on when they pick projects for overlay or rehabilitation work; to use the LOS graphs that have been developed to help them select projects that have a greater safety need.

A7. Have you found any major deficiencies in the HSM?

The biggest complaint he has heard is that it is quite technical and can be difficult to navigate through if you are not very familiar with the 'language' of safety.

Nebraska

Contact Person: Allen Swanson

Traffic Analysis Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Yes, but it is not every project.

A2. Can you briefly describe the scope of your HSM use?

Sometimes they have just resurfacing projects or things like that where because of time and other factors they don't use the HSM for every project.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

No, typically they don't.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Yes, most of his staff has been through some kind of training. They have done some webinars and Nebraska Federal Highway had training a few years ago.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Not so much for policy purposes, but for design yes.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Right now they are in a review process looking at how to better their process in Nebraska. Their local Federal Highway representatives are really pushing the HSM on them though but there is a lot of push back from people reluctant to change how things have been done

for the last 20 years. Anticipates that in the next year or so they will have some more documented changes in their process and how they deal with the HSM.

A7. Have you found any major deficiencies in the HSM?

No, they haven't used it as thoroughly as other states probably have so they haven't found anything they would call a deficiency.

Nevada

Contact Person: Ken Mammen

Chief Traffic Safety Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Yes and no.

A2. Can you briefly describe the scope of your HSM use?

The traffic safety office uses it and their scoping team uses it probably the most of anybody; some of their design teams have played with it but they haven't fully adopted it yet.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

Not completely, they aren't doing network screening yet because they are still trying to get Safety Analyst up and running. They currently do their own screening in house using sliding mile analysis and do their own benefit-cost ratios and such.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Yes; all of their scoping teams and some of the design staff have also been trained. They have had several iterations of training and have had the IHSDM come in as well. They have several projects that have used it on that will soon be up on their website.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes

A6. Do you know if changes to how your department utilizes the HSM are being considered?

They are trying to push it out for further implementation; however, they are getting some push back from their design staff who want the Safety Engineers to be the only ones who have to deal with it.

A7. Have you found any major deficiencies in the HSM?

Staff sometimes complains that it is cumbersome to use. They would have liked to have a guide on how to use it that is more concise. Also complaints about linking up Safety Analyst software with their databases. They have hired university students to go out and collect the data to populate the database for them.

New Mexico

Contact Person: Afshin Jian

State Traffic Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Sparingly.

A2. Can you briefly describe the scope of your HSM use?

They use it in alignment studies in roadway safety audits, use it on phase AD study if it is part of the scope.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

No, currently are trying to perfect their data gathering tools and working on crash data and infrastructure data that is necessary for Safety Analyst; at this point they are lagging a little behind.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

They have had a couple of training sessions (3-4 days), so they have been exposed to it but he is not sure how efficient they are at it right now. In the past they have used consultants to provide those analyses.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Have used the CMFs from the clearinghouse in some of their studies as a tool.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Yes, they are considering making changes- didn't specify how specifically

A7. Have you found any major deficiencies in the HSM?

Still hard to grasp the concepts for a lot of people. It doesn't cover a lot of the scenarios they are facing.

New York

Contact Person: Robert Limoges

Safety Program Management & Coordination Bureau Director

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Sometimes.

A2. Can you briefly describe the scope of your HSM use?

They have their own methodology in New York including a network screening process, which is fairly sound. Each year they calculate the average crash rate for various types of highways. Once they know the rates for all different facilities they will do a sliding window analysis and determine high crash locations based on a threshold and a comparison of that individual 3/10 of a mile window and compare that to the expected average rate for that same type of a facility. Don't use the HSM in that process though. Once they have identified sites, they have a program to investigate them and come up with a Priority Investigation List (PIL). Study 20% of locations on PIL per year (~350-400 sites). At each site they will do an in-depth investigation and look for potential countermeasures, do a benefit-cost analysis and will either program a capital project or low cost maintenance treatment. Part of studies also includes calculating crash reduction factors based on their project data and the Highway Safety Manuals CMFs.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

Not exactly. They do their network screening process, safety investigations and then have a system for evaluation. They record where the studies have been done, any safety capital projects, and what maintenance work has been done in their evaluation system. They also look at how much HSIP funding has been spent and what the overall impact of the safety project was.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Yes, but there is probably more training they could benefit from. Not all have been trained.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

They use CMFs from HSM and clearinghouse to go through PIL location studies when determining what potential countermeasures should be considered.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Right now they are doing a gap-analysis between their current safety management process and the management process in the HSM. After their gap-analysis they will have a better idea of what needs to be improved. They know they need to do more dis-aggregation of the data to volume when they calculate their average accident rates.

A7. Have you found any major deficiencies in the HSM?

It's a lot to digest. It's comprehensive, which if you're a state that doesn't have anything in place, then it's great to have an all-encompassing process in one manual. They had a pretty solid foundation before the HSM existed though, so they are struggling with deciding in what ways their existing process is better and in which ways the HSM could improve their process. Don't want to adopt HSM and retrain everyone and rebuild their information systems if they aren't going to get that big of an incremental gain in outcome.

North Carolina

Contact Person: Brian Murphy

Safety Planning Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Yes

A2. Can you briefly describe the scope of your HSM use?

Use it more for alternative analysis- being able to quantify the safety performance of different alternatives as they go through the NEPA process.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

No

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

They have had some training on it, but they are mostly self-taught/they learn to use it as they need it.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

They reference them but they have their own list in North Carolina that have been agreed upon by their project development staff. They give importance to this list, but have referenced the CMFs from the HSM before.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

They are trying to implement the HSM on more projects but their main focus is on the predictive analysis for alternative comparison. They have also used it some on their project evaluation- for before and after comparison using SPFs.

A7. Have you found any major deficiencies in the HSM?

No, but it is a little hard to follow. The chapters are not always consistent with each other with how the SPFs are laid out. Their biggest complaint is that it can be hard to find what you are looking for in the HSM, so how it is laid out.

North Dakota

Contact Person: Shawn Kuntz

Traffic Operations Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

No.

C2. Would your department consider using the HSM in the future?

Yes; they do use it to prioritize their engineering projects based on crash reduction factors a little bit. They are talking about using it more, but they have other projects they need to finish up before they take a more in-depth look at the HSM.

Ohio

Contact Person: Dereck Troyer

Transportation Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

For certain ones, yes.

A2. Can you briefly describe the scope of your HSM use?

Most of it is related to safety funded projects. Any project requesting funding from HSIP money has to use the HSM to obtain funding and show the benefits of the project. They are also using it for some of their design exception projects; at a planning level they use Safety Analyst to analyze any documented design exceptions. They are moving towards more of an alternatives analysis for all projects that are changing a typical intersection, to run the safety analysis almost like a capacity analysis, but they aren't there quite yet. They are hoping to do this sometime this year.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

Yes, they do priority lists for Safety Analyst which essentially is implementing Part B of the HSM.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Yes. Not everybody is, but they have between five to six trainings a year and mainly this has included people involved with the safety studies. However, as they have incorporated the design exceptions, more and more people have been trained.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Definitely; they use a combination of the CMFs in Part D of the HSM and those found in the CMF clearinghouse.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

For any project that is going to greatly impact the typical intersection they are wanting to start doing a HSM comparison for alternatives. For example, if there is a right-hand turn lane there isn't really an alternative, either you have a turn lane or you don't; so they aren't wanting to require HSM use on this type or scale of project. For any project where a lane is being added or a bridge is widened, then they want to use the HSM to know the other impacts a change will have throughout that area of roadway. It is hard to define when to use the HSM and when not to, but they are working on that right now.

A7. Have you found any major deficiencies in the HSM?

It is new, so it can be complicated to read. They are missing a few things that research is trying to address. As an example, for the urban models of intersections for the number of lanes is not currently included so it's hard to do an alternatives analysis when you want to add capacity by adding lanes and you get no benefit. They are also expanding certain types so there are more types available. For example, rural three-legged signalized is not a current model but they are developing those with research that is not currently included in the HSM.

Oklahoma

Contact Person: Matt Warren

Collision Analysis and Speed Studies Engineering Manager

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

To an extent, yes

A2. Can you briefly describe the scope of your HSM use?

Don't use the methods for non-safety projects, but they use it for network screening, site selection, and systemic projects. They have also used the methods to help develop policies, to evaluate the safety effects of projects and to evaluate the possible benefits of projects.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

No

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

No

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

They use the CMF clearinghouse for that; when he pulls a CMF he doesn't check to see if it was included in the HSM or not, he more looks at how closely it matches what they need and how many stars they have given it.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Yes, they have a contract underway with a local university to modify their database interface so the methods in the HSM are accessible to people who may not understand the math behind it.

A7. Have you found any major deficiencies in the HSM?

Yes, one weakness is that the SPFs in it have too simplistic of a fit to AADT. The behavior of crashes with respect to AADT is not log-linear in many cases and they have found a need to use their own SPFs. Also, the system in the HSM of calculating SPFs and then applying CMFs to them makes them impossible to use with the tools they currently have. The HSM says that the quality of an SPF should be judged by the over-dispersion parameter that goes with it and that is not true in their experience. There are unresolved issues with the method itself and its derivation. One of those is the behavior of the dispersion parameter with respect to segment length; the derivation of that formula is based on some simplifying assumptions that break down in real life. Another problem is the variation of site characteristics over time and no way to go back and look at that; the dispersion parameter should consider the number of years considered. Another overall weakness of the HSM is that it was larger than it needed to be.

Oregon

Contact Person: Kevin Haas

Traffic Investigations Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Not formally

A2. Can you briefly describe the scope of your HSM use?

Informally it is more along the lines of some network screening and project development and planning processes

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

No

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Some staff

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Yes; thought about incorporating the HSM into the design exception process

A7. Have you found any major deficiencies in the HSM?

Yes, the lack of civil facilities in the first edition. The freeways chapter was just published and the lack of one-way couplets, the lack of application in rural freeways- freeways are all kind-of treated the same. The one-way couplet is a big one. Freeway ramp terminal analysis is somewhat included in the freeway chapter but those chapters were recently published so they are still trying to figure out how to integrate that in.

Rhode Island

Contact Person: Robert Rocchio

Managing Engineer/Traffic Design

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Yes; just began using it

A2. Can you briefly describe the scope of your HSM use?

They use it to run the safety performance functions they're developing in house and with University of Rhode Island and are looking at the risk level of road ways at signalized intersections.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

No.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Yes, they have had HSM training

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes, that is where they get their benefit-cost ratios.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Yes, they are trying to go to the predictive method. Right now they use the severity based on index severity like at the site of the crash course to see fatalities and risk injuries but they want to get away from that and go to the empirical based predictive methods. They

want to use it on all segments, all intersections and in rural and urban as opposed to just starting out on signalized intersections.

A7. Have you found any major deficiencies in the HSM?

None major; some minor deficiencies but nothing major. They have an undivided bridge, no barriers in between that has four 12-foot lanes with 2-foot shoulders and they wanted to see if it was more dangerous or less dangerous if they put a barrier in and go down to 11-foot lanes and no offsets but there was no way of doing this with the HSM because there wasn't enough data points. Minor shortcomings are not enough data points in certain circumstances.

South Carolina

Contact Person: Joey Riddle

Safety Program Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

To a limited extent.

A2. Can you briefly describe the scope of your HSM use?

They currently have research going on with Clemson University that is developing calibration factors for South Carolina specifically, so they haven't incorporated the HSM in too much besides using the CMFs and that type of thing.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

No, not at this point

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Yes; they have had HSM training so yes, probably semi-trained

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes

A6. Do you know if changes to how your department utilizes the HSM are being considered?

No, he does not know of any changes at this time

A7. Have you found any major deficiencies in the HSM? *No*

South Dakota

Contact Person: Andy Vandel

Traffic Safety Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

At this time, a little bit

A2. Can you briefly describe the scope of your HSM use?

Used it more as an existing condition for safety improvements ahead of design during the scoping process; they would like to use it more but do use it during design

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

No

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Not the designers, just the highway safety planning engineers/safety engineers

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Yes, going to be moving towards including that in the scope of work for consultant reviews on different interstate interchange configuration alternatives

A7. Have you found any major deficiencies in the HSM? No, not Major.

Tennessee

Contact Person: Ali Hangul

Assistant Director, Design Standards and Policy

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

No; they are planning on having a training session very soon for the operations folks but for the design division they do not have anything yet.

C3. Would your department consider using the HSM in the future?

They would like to use the manual to justify design exceptions or justifying some of the decision making procedures for this way or that way to see the operational consequences of those decisions. However, they are not there yet and are still working towards that goal.

Texas

Contact Person: Darren McDaniel

Transportation Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Yes

A2. Can you briefly describe the scope of your HSM use?

They use the HSM a lot. Use it for determining crash reduction factors. From the design perspective, they use the HSM in a limited manner; some of them have never really heard of it whereas some of them are very familiar with it. In the design process they use it for design exceptions, on interstate access justifications, and they are starting to look at performance based practical design. Performance based practical design is their initiative for this year and have attended a few seminars on that and have had some folks come to the design centers in Texas and give presentations on that as well.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

No, interested in moving to that, but not currently doing it.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

They do have SPFs calibrated for Texas and are in the process of exploring predicting the expected crashes but they haven't done it yet.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes, they get most of theirs from the CMF clearinghouse.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Yes. Right now they are a hot spot state based on crash histories and they are looking to go towards more of an empirical based methods and they are starting to use network screening. Also they are wanting to incorporate systemic types of improvements. Want to incorporate the principles in the HSM into their Highway Safety Improvement Program.

A7. Have you found any major deficiencies in the HSM?

They are still new at using it so they don't have any complaints. The HSM is somewhat difficult to read is one complaint.

Utah

Contact Person: Scott Jones

Safety Programs Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

We don't use the HSM on every project at this point, but we have used HSM methodologies on some specific projects where we felt it made particular sense to do so. Most of those have been corridor studies where we were evaluating different cross sections and we used the HSM to run some relative expected crash scenarios to help us get an idea of the safety benefits/drawbacks of making particular design decisions.

A2. Can you briefly describe the scope of your HSM use?

Aside from what I mentioned above, we generally follow the HSM's network screening process and we use CMFs to evaluate the potential safety benefits of location-specific projects.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

Yes, but the process is not used on all projects. It is used only upon request or when the project is funded through the Safety Division. Utah has developed a statewide model similar to the process in the HSM. The model performs the network screening, diagnosis, and helps to select countermeasures. The results of the model are used to recommend safety projects on the State's highway system.

All individual projects that request federal HSIP safety funds are required to apply the Roadway Safety Management Process outlined in Part B but most of the more advanced statistical measures are not implemented at this time. Projects are currently ranked and funded based on the predicted crash reduction.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

We have more or less made the business decision that our in-house safety staff won't remain in their positions long enough to warrant investment in staff training. Instead, we

look to the consultant community to do HSM analyses for us. This has worked out well for us so far.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes, mostly for design and limited use on policy decisions.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

I think we are fairly established/static with how we're using it right now.

A7. Have you found any major deficiencies in the HSM?

The first edition is very complete but there are a few challenges with the methodology:

1. *There is an inconsistent message from FHWA concerning the value of crashes. The methodology outlined in Chapter 7 is not the same method that FHWA outlines in the VSL memorandum sent yearly.*
2. *The calibration data requirements are very labor intensive for the corresponding level of assurance. Typically we use a calibration of 1.0 (no calibration).*
3. *Though the number of CMFs is increasing, there are a number of circumstances where the CMF must be estimated by judgement rather than by research. This estimation often results in very high CMFs resulting in conservative benefit projections.*
4. *Background information is limited through the CMF Clearinghouse. There is considerable risk of mis-applying a CMF.*

Vermont

Contact Person: Bruce Nyquist

Traffic and Safety Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

They aren't using it very much; it is something they want to get into more though.

A2. Can you briefly describe the scope of your HSM use?

They have used some of the predictive equations. They used it in a situation where a town wanted them to put in a roundabout at a three-way intersection but it wouldn't have fit in that area well so they used the HSM and the predictive equations to prove that the safety from the roundabout would be similar to the current safety. They use it for specific applications but it isn't integrated into their process completely.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

Not sure, but doesn't think so.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Not very many. They have one person in the highway safety group that does most of it. They did have the IHSDM training there 15 years ago and they tried that in a couple projects.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes, use them for their HSIP process frequently.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Not sure off the top of his head but they are being encouraged to go into data driven highway safety plans and using the HSM. Their safety group is pretty minimal so not sure if they are going to be able to make great strides in the near future of integrating something new into the design process.

A7. Have you found any major deficiencies in the HSM?

He hasn't found anything that they have had disagreements with what is presented in the HSM, so no.

Virginia

Contact Person: Stephen Read

HSIP Planning Manager

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

They have started to on some designs but it's not policy, it's more of a pilot use of Part C and Part D on the project development side.

A2. Can you briefly describe the scope of your HSM use?

They have fully implemented Part B for the management program in terms of network screening, etc. But project development has been project by project to test out the tools but it isn't really written into the policy right now. For example, for a two lane road project that it makes sense to use it for they have tried it. Now, they have a big interstate project where they are using the new freeway chapters. There aren't necessarily parts to the HSM available for some of the projects they have so they haven't written it in to the policy for that reason.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

Yes, definitely. They have fully implemented the network screening step and the economic development/assessment step and some of the methods for project prioritization. They aren't using the best methods for project prioritization but they are using one of them. Where they have a little bit of a wait is to get enough projects to do a full HSM evaluation of a project. To do a full EB evaluation of some of their projects is tough because they have so many different countermeasures with each project and it's hard to gather enough samples to use the full EB method.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

They have done training; they did some training back in 2011 the year after the HSM came out. They do need to refresh their staff on its use though, particularly on Parts C and D and also on the new freeway chapters in the supplement.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

The HSM is one of their sources, but there are many newer and improved studies in the clearinghouse. They point everyone to the clearinghouse but tell them to be careful of the base conditions that were assumed for each study so that they don't confuse the CMF that is being used with the target crashes and the base condition. This is an ongoing education issue with their staff; you almost need experts that understand everything who can support field staff who can't understand everything when they just open up the HSM or go into the clearinghouse.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Yes, definitely. They would like to write more of it into their policy, so they plan to do a review on the application of their design guidelines and instructional memos. They are wanting to see if they can write-in more use of the HSM; particularly early on in the alternatives analysis. They want to figure out how early they can work safety into the alternative analysis.

A7. Have you found any major deficiencies in the HSM?

Yes. He is eagerly awaiting the roundabout chapter/sections for intersections and the section on going from 4 to 6 to 8 lane arterials which should be due out next year. Not having the section on increasing number of lanes in arterials has been holding them back, as they tend to work on those types of facilities and do not have good SPFs and CMFs for the highway level arterials. For example, there is no CMF for adding a second left-turn lane and they are even adding triple left-hand turn lanes and double right-hand turn lanes.

Washington

Contact Person: Jennene Ring

Regional Traffic Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

Yes

A2. Can you briefly describe the scope of your HSM use?

They use the HSM when programming projects for prioritization. Use it during design, for example if they need to do a safety related deviation from the standard. Also use it for countermeasure selection, but that is more in the prioritization process.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

Yes, they use it for prioritization process for projects.

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

Not everyone is, but every region has people that have been trained to use the predictive methods.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes, sometimes use CMFs from HSM and sometimes from the clearinghouse. They also have a short list of approved CMFs that they use for consistency.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

They are changing their policy to do performance based practical design which uses the HSM predictive methods to help them decide what safety work will be included in a project rather than just going with the nominal standards.

A7. Have you found any major deficiencies in the HSM?

No major deficiencies, but they are watching as time goes on because they expect the HSM to get better with time and as people become more familiar with it.

Wisconsin

Contact Person: Brian Porter

State Traffic Safety Engineer

A1. Thank you very much. First off, does your department use the HSM in your design or review processes? (If YES, continue to A2; If NO, skip ahead to Section C)

A little bit but not much.

A2. Can you briefly describe the scope of your HSM use?

They use it in the standard project development process, planning and preliminary design phase when looking at different alternatives. They have also used it in safety effectiveness evaluations.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

No

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

There has been training there but it has been a while and was pretty limited, so he said probably no.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Yes; they are discussing where in their process it would be best to implement the manual, what would provide them the most value, what the limitations are, and how to communicate the results to decision makers and the public.

A7. Have you found any major deficiencies in the HSM?

Partly, they don't know enough at this point to say but the biggest challenge they have run into recently is not having a roundabout SPF. They are still gaining momentum though and finding the staff resources to help move the HSM forward.

Wyoming

Contact Person: Matt Carlson

Program Manager, Highway Safety Program

A1. Thank you very much. First off, does your department use the HSM in your design or review processes?

They are just starting to use it; they are using the manual sparingly

A2. Can you briefly describe the scope of your HSM use?

Once they have a project identified, they will review aspects of the project for safety based on the HSM techniques and if they see they have missed something or have something not as beneficial as they thought, they consider altering what they are doing on the project.

A3. Do you utilize the Roadway Safety Management Process as it is detailed in the HSM?

No

A4. Are your employees trained to use the Predictive Method outlined in the HSM?

No, they are currently looking at doing the NHI training course.

A5. Do you use the Crash Modification Factors that are suggested by the HSM when evaluating the potential effectiveness of a change in design or policy?

Yes, they modify them though. They look at what HSM has and what the clearinghouse has and then come to an agreement on what they are going to use department-wide for CMFs.

A6. Do you know if changes to how your department utilizes the HSM are being considered?

Yes, they are progressing in adopting the concepts in the HSM but their progress has been somewhat slow.

A7. Have you found any major deficiencies in the HSM?

One issue is that the data necessary to utilize the manual is not readily available.

States Not Participating in Phase 2 Survey

- **California- Participated only in the Phase 1 (initial) survey**
- **Delaware- Did not participate**
- **Illinois- Did not participate**
- **Maine- Did not participate**
- **Maryland- Did not participate**
- **New Hampshire- Participated only in the Phase 1 (initial) survey**
- **New Jersey- Did not participate**
- **Pennsylvania- Did not participate**
- **West Virginia- Did not participate**

Appendix D: Calculation of SPF & CMF for Case Study (Special Pavement Markings)

This section presents a sample calculation for conducting the Empirical Bayes (EB) safety analysis, arriving at the calculation of the CMF and its significance. As described in the main text, this application is aimed at evaluating the effectiveness of special pavement markings (converging Chevrons) in reducing roadway departure crashes from a low-radius high speed ramp. This evaluation compares before/after data from two treatment locations (I-285 Eastbound to I-75 Northbound in Cobb County and I-75 Southbound to I-85 Northbound in Fulton County) in the Metro-Atlanta area. These data will be compared with seven other similar Metro-Atlanta freeway ramps without treatment over the same time periods. Calculations using other base conditions, SPFs, and different evaluation time periods can use the same procedure.

STEP 1: Basic Input Data

The basic input data for the safety effectiveness evaluation, including the yearly observed crash data and before- and after-period observed crash data for the two treatment ramps, are presented below:

Site No	Site Name	County	Roadway Data			
			Ramp Section	Ramp Condition	Radius in Feet	No of Lanes
2	75sb to 85nb [treatment]	121	2	0	141	2
8	285eb to 75nb [treatment]	67	2	0	720	2

Site No	Crash & AADT Data									
	Observed Crash Frequency by Year			AADT			Observed Crash Frequency by Study Period		Before AADT	After AADT
	2007	2008	2009	2007	2008	2009	BEFORE	AFTER		
2	44	26	24	29750	28390	29590	43	21	29297	28790
8	19	18	30	32000	31000	30000	21	20	31667	30667

STEP 2: Select the applicable SPFs.

These SPFs were developed based on the crash and traffic volume data obtained for the treatment and control ramps.

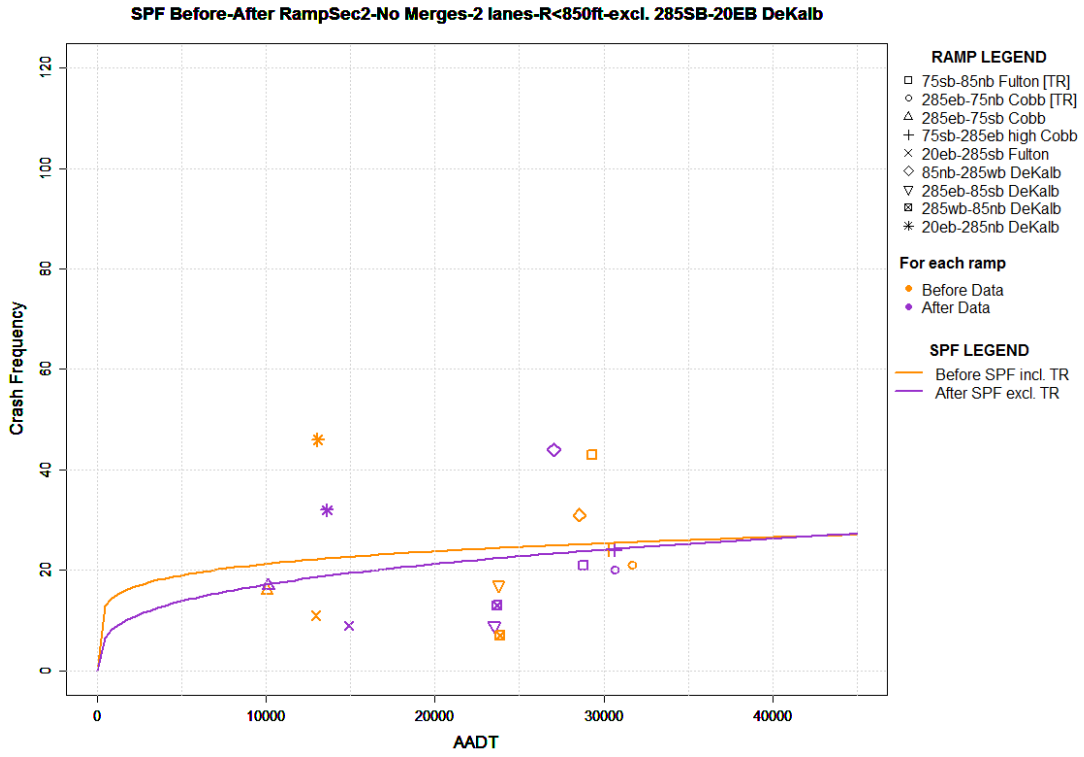
The Before-Period SPF is the following:

$N_{BEFORE} = e^{1.5856 + (0.1598 * lnAADT)}$ with an over-dispersion parameter, k = 0.2475

The After-Period SPF is the following:

$N_{AFTER} = e^{0.01044 + (0.3076 * lnAADT)}$ with an over-dispersion parameter, k = 0.2513

The SPF plots are presented below:



STEP 3: Using the above SPF and the before AADTs, calculate the predicted average crash frequency during the Before Period.

For the I-75SB to I-85NB ramp, using an AADT of 29297, the predicted average crash frequency during the Before Period is:

$$N_{predicted\ before-site2} = e^{1.5856 + (0.1598 * \ln(29297))} = 25.3\ crashes$$

Similarly for the I-285EB to I-75NB ramp, using an AADT of 31667, the predicted average crash frequency during the Before Period is 25.6 crashes.

The sum of these predicted average crash frequencies is 50.9 crashes, which will be used in later calculations.

STEP 4: Calculate the weighted adjustment, w, for each treatment site for the Before Period.

The weight, w, for each site, is determined as:

$$w = \frac{1}{1 + k * N_{predicted}}$$

Thus, for the I-75SB to I-85NB ramp, the weighted adjustment is:

$$w_{site2} = \frac{1}{1 + 0.2475 * 25} = 0.1379$$

For the I-285EB to I-75NB ramp, the weighted adjustment is:

$$w_{site8} = \frac{1}{1 + 0.2475 * 26} = 0.1364$$

STEP 5: Using the calculated weighted adjustments, calculate the expected average crash frequency in the Before Period.

This is calculated as:

$$N_{expected} = w\, N_{predicted} + (1 - w) N_{observed}$$

Thus, for the I-75SB to I-85NB ramp, the expected average crash frequency in the Before Period is:

$$N_{expected,B} = 0.1379 * 25 + (1 - 0.1379) * 43 = 40.55\ crashes.$$

This is very close to the observed number of crashes of 43, indicating that the SPF was able to model the crashes accurately in the Before Period.

Similarly for the I-285EB to I-75NB ramp, the expected average crash frequency in the Before Period is calculated to be 21.62 crashes. This again is very close to the observed number of crashes of 21, indicating that the SPF was able to model the crashes accurately in the Before Period.

The sum of these expected average crash frequencies is 62.18 crashes, which will be used in later calculations.

STEP 6: Using the above SPF and the after AADTs, calculate the predicted average crash frequency during the After Period.

For the I-75SB to I-85NB ramp, using an AADT of 28790, the predicted average crash frequency during the After Period is:

$$N_{predicted\ after-site2} = e^{0.01044 + (0.3076 * \ln(28790))} = 23.8\ crashes$$

Similarly for the I-285EB to I-75NB ramp, using an AADT of 30667, the predicted average crash frequency during the Before Period is 24.2 crashes.

The sum of these predicted average crash frequencies is 48 crashes, which will be used in later calculations.

STEP 7: Calculate an adjustment factor, r, to account for the differences between the Before and After Period SPFs.

The adjustment factor is determined as:

$$r = \frac{N_{predicted\ after}}{N_{predicted\ before}}$$

For the I-75SB to I-85NB ramp, the adjustment factor is: 23.8/25.3 = 0.941

For the I-285EB to I-75NB ramp, the adjustment factor is: 24.2/25.6 = 0.945

As a group of treatment ramps, the adjustment factor is: 48/50.9 = 0.943

STEP 8: Calculate the expected average crash frequency in the After Period in the absence of the treatment.

This is calculated as:

$$N_{expected,A} = N_{expected,B} * r$$

For the I-75SB to I-85NB ramp, the expected average crash frequency in the After Period is: 40.55 * 0.941 = 38.16 crashes.

For the I-285EB to I-75NB ramp, the expected average crash frequency in the After Period is: 21.62 * 0.945 = 20.43 crashes.

To get the overall expected average crash frequency, the sum of the two calculated values is simply taken: 38.16 + 20.43 = 58.59 crashes.

STEP 9: Calculate the variance of the overall expected average crash frequency.

This is determined by calculating the variance of the expected average crash frequency for each site and then taking their sum.

The variance of the expected average crash frequency for each site *i* is determined as:

$$Var\left(N_{expected,A,i}\right) = (r_i)^2 * N_{expected,B} * (1 - w_i)$$

For the I-75SB to I-85NB ramp, this variance is calculated as:

= $(0.941)^2$ * 40.55 * (1 – 0.1379) = 30.95

For the I-285EB to I-75NB ramp, this variance is calculated as:

= $(0.945)^2$ * 21.62 * (1 – 0.1364) = 16.67

Therefore, the variance of the overall expected average crash frequency is:

30.95 + 16.67 = 47.62

STEP 10: Calculate the Crash Modification Factor (CMF) associated with the treatment.

The CMF is calculated as follows:

$$CMF = \frac{\frac{\sum N_{Observed,A}}{\sum N_{Expected,A}}}{1 + \frac{Var(overall)}{\left(\sum N_{Expected,A}\right)^2}} = \frac{\frac{41}{58.59}}{1 + \frac{47.62}{58.59^2}} = \mathbf{0.689}$$

This result shows that the presence of the treatment reduces the average probability of crashes by approximately 30%. While this is a significant reduction, we need to confirm that treatment is effective by calculating the confidence interval of the CMF. This calculation is illustrated in the next step.

STEP 11: Calculate the precision of the CMF, including the variance, the standard error, and the 95% confidence interval.

$$Var(CMF) = \frac{(CMF^2) * \left[\frac{1}{N_{Observed,A}} + \frac{Var(overall)}{\left(\sum N_{Expected,A}\right)^2}\right]}{\left[1 + \frac{Var(overall)}{\left(\sum N_{Expected,A}\right)^2}\right]^2}$$

$$Var(CMF) = \frac{(0.689^2) * \left[\frac{1}{41} + \frac{47.62}{58.59^2}\right]}{\left[1 + \frac{47.62}{58.59^2}\right]^2} = 0.0176$$

$$SE(CMF) = \sqrt{Var(CMF)} = \sqrt{0.0176} = 0.133$$

95% Confidence Interval Upper Limit = CMF + (1.96 * SE(CMF)) = 0.689 + (1.96 * 0.133) = 0.949

95% Confidence Interval Lower Limit = CMF – (1.96 * SE(CMF)) = 0.689 – (1.96 * 0.133) = 0.428

This result shows, that while we are confident that the treatment is effective, the range of calculated reductions is relatively wide.