NCHRP 17-50 TECHNICAL BRIEFINGS

This series of technical briefings provides a reference for highway agencies that are interested in initiating the implementation of the American Association of State Highway and Transportation Officials (AASTHO) Highway Safety Manual (HSM) 1st Edition principles and philosophy within their organization. The series summarizes lessons learned, best practices, challenges, and other aspects of implementation of the 13 lead states and 8 support states that participated in the research project.

Background

The HSM provides tools for estimating the potential crash frequency and severity on highway networks. It allows state and local agencies to better understand potential safety risks and how to improve the safety of highway systems during the project development process. Crash frequency estimation is done through the application of Safety Performance Functions (SPFs) from the HSM or jurisdiction-specific data. States are currently in the process of calibrating the HSM SPFs and/or developing their own using jurisdiction-specific data. Lead and support states requested additional guidance on whether they should calibrate or develop their own models.

This technical briefing provides a summary of best practices in SPF development and calibration, as well as a status update on SPF implementation in states participating in National Cooperative Highway Research Program (NCHRP) 17-50 project.

Safety Performance Functions

SPFs are regression models used for predicting the average number of crashes per year at a location as a function of traffic and, in some cases, site characteristics. SPFs are developed though statistical regression techniques using historical crash data from base sites with similar characteristics. The main predictor variable is annual average daily traffic (AADT), but SPFs may also include other features such as lane and shoulder width, median width, and intersection traffic control type. A sample SPF for undivided roadway segments on a multilane highway is shown below:

$$N_{spf\ ru} = e^{(-9.653+1.176\times ln(AADT)+ln(L))}$$

Where:

$N_{spf\ ru}$ is the base total average crash frequency, (L) is the segment length, and AADT is the annual average daily traffic.

SPF Applications

The HSM discusses three methods used to calculate the predicted number of crashes. The three methods are network screening, project-level applications, and project evaluations.

Network Screening

Application of SPFs in the network screening process is typically done to identify and rank sites with potential for safety improvement or sites that may benefit the most with the application of safety treatments. The HSM part B discusses methods for network screening with different levels of reliability. Network screening tools like SafetyAnalyst are used to identify these sites with high crash severities and with a high proportion of specific crash types. SafetyAnalyst is a set of software tools that are used for roadway safety management. It incorporates SPFs for roadway segments, intersections, and ramps.

Project-level Applications

Project-level applications (planning and programming projects and resources) requires understanding the safety effectiveness of an improvement. The HSM Part C provides SPFs for predicting the average crash frequency of an existing or new site. SPFs can be used to determine the safety impacts of design changes and alternatives. The prediction method applies the SPF to determine the crash prediction of a base condition, and adjusts this prediction with the application of Crash Modification Factors to match local conditions or any departure from the base condition. Some states have developed jurisdiction-specific SPFs for facilities that are not included in the HSM (i.e., Alabama developed SPFs for railroad at-grade crossings).

Before-After Project Evaluations

The HSM covers various methods outlining the process of evaluating the safety effectiveness of how a treatment(s) has affected crash frequencies and severities.

The observational before/after evaluation studies using SPFs is the method most commonly used. SPFs in this method are used to obtain crash predictions for a hypothetical after evaluation without the treatment, and is used as a baseline to compare the change after implementation of the treatment. Application of the Empirical Bayes method accounts for regression-to-the-mean bias.

Calibrate versus Develop SPFs

State Departments of Transportation and other agencies have been trying to decide how to approach SPFs. One option is to calibrate SPFs, which is accomplished by adjusting the HSM SPFs (project-level SPFs) to local conditions using jurisdiction-specific data. The second option is to develop state-specific SPFs using local data. Developing SPFs improves the accuracy of crash predictions. However, the latter requires statistical knowledge in regression modeling.

Developing jurisdictional SPFs, while remaining as extensive as the calibration process, ultimately improves prediction accuracy and increases the reliability of the Predictive Methods in HSM Part C. The following section describes the parallels and differences between the two approaches.

Calibrating SPFs

HSM SPFs have been developed using data from various geographies at a specific period in time and may have slight differences among the different states. Some differences include climate, driver behavior, and crash reporting thresholds. The HSM SPFs are accompanied by crash severity and collision type distribution tables and adjustment factors, which were developed with the same dataset and can also be calibrated.

SafetyAnalyst software tool performs the calibration of its embedded SPF models automatically within the software using local-jurisdiction data. However, if other network screening SPFs are used, they can also be calibrated using a similar methodology as the project-level SPFs. Detailed information about calibration is provided in the SPF Calibration Guide. Below is a list of the steps required to perform calibration for network screening and project-level SPFs.

- Step 1 – Identify facility types for which the applicable predictive model is to be calibrated
- Step 2 – Select sites for calibration of the predictive model for each facility type
  - Network screening SPFs use data for the entire network for a specific facility type
  - Project-level SPFs require only a reasonable sample size
- Step 3 – Obtain data for each facility type applicable to a specific calibration period

- Step 4 – Apply the applicable predictive model to calculate predicted crash frequency
- Step 5 – Compute calibration factors for use in Part C predictive method

Developing SPFs

The process of developing jurisdictional SPFs is more statistically rigorous than calibration. However, the results obtained from the developed SPFs may improve accuracy in the predicted values as well as increase reliability of the HSM Part C predictive method. Jurisdiction-specific SPFs provide the opportunity to explore other functional forms instead of using the default forms from the HSM and SafetyAnalyst. Additional details on developing SPFs are provided in the SPF Development Guide. The following list describes the steps required to develop SPFs:

- Step 1 – Identify facility type
- Step 2 – Compile necessary data
  - For network screening SPFs, the number of crashes and traffic volume for the facility type is required. For project-level SPFs, in addition to AADT and crashes, other sites characteristics are required
- Step 3 – Determine functional form
  - HSM Part C and SafetyAnalyst SPFs are negative binomial regression models. Some states are using exploring with other functional forms to represent the relationship between crash frequency and site characteristics
- Step 4 – Develop the SPF using a statistical software
- Step 5 – Conduct model diagnostics
- Step 6 – Re-estimate the SPF

Level of Effort

An understanding of the level of effort required to calibrate versus develop jurisdiction-specific SPFs is an important consideration for states to decide what approach to use. The SPF decision guide provides estimated ranges of man hours required for calibrating/developing project-level SPFs and network screening SPFs.

- For project-level SPFs, calibrating the HSM models can take up to 350 hours, whereas developing SPFs can take up to 1,100 hours, which includes 40 hours for a statistical expert
- For network screening, the estimated number of hours for SPF calibration or development is pretty similar, which is under 100 hours. According to the decision guide, this assumes that the data required for analysis is available in the agency's inventory file

These estimated number of hours may vary based on data quality, local jurisdiction conditions, and other project-specific factors.

States SPF Implementation Status

Table 1 provides details of the states that either have completed or are in the process of developing or calibrating SPFs.

Table 1: Summary of State SPF Calibration and Development Efforts

Legend
- 100%, 75%, 67%, 50%, 33%, 25%
- L Lead States
- S Support State
- PF HSM Pooled Fund
- C SPF Calibration
- D SPF Development

	Group	Part B				Chapter 10				Chapter 11				Chapter 12				Chapter 18		Chapter 19		Other
		Segment		Intersection		Segment		Intersection		Segment		Intersection		Segment		Intersection		Freeways		Ramp		Other
		C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	
Alabama	L						100%				100%			100%								Rail Road Crossing
Arizona	S																					
Colorado	L/PF						100%		100%		100%						100%		100%		100%	Other
Florida	L					100%		100%		50%		67%		100%		50%						
Idaho	S/PF					100%		33%														
Illinois	L/PF		100%		100%	100%		100%		100%		100%		100%		100%						
Kansas	S/PF					100%		33%		100%												
Louisiana	L/PF					100%				100%												
Maryland						100%		100%		100%		100%		100%		100%						
Michigan	L/PF																100%					
Missouri	L/PF					100%		33%		50%		33%		75%		100%						
North Carolina	S/PF		100%		100%		100%	100%		50%		33%		100%		100%						
Ohio	L/PF																					
Oklahoma	PF						100%			100%				100%					100%			Curves
Oregon	PF					100%		100%	33%	100%		100%	33%	100%		100%	25%					
Pennsylvania	S/PF		100%		100%																	
Utah	L/PF						100%															
Virginia	L		100%		100%																	
Washington	L/PF						100%		100%		100%		100%		100%		100%					

Resources

Highway Safety Manual Users Guide (http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP17-50_UserGuide.pdf).

Highway Safety Manual Lead State Peer Exchange Irvine, California (http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP17-50_PeerExchange1_Report.pdf).

Highway Safety Manual Lead State Second Peer Exchange Baltimore, Maryland (http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP17-50_PeerExchange2_Report.pdf).

Highway Safety Manual Lead State Third Peer Exchange Nashville, Tennessee (http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP17-50_PeerExchange3_Report.pdf).

SPF Decision Guide (http://safety.fhwa.dot.gov/rsdp/downloads/spf_decision_guide_final.pdf).

SPF Development Guide (http://safety.fhwa.dot.gov/rsdp/downloads/spf_development_guide_final.pdf).

User's Guide to Develop Highway Safety Manual SPF Calibration Factors (http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-07(332)_FinalGuide.pdf).

Summary of States' SPF Development and Calibration Efforts http://www.pooledfund.org/Document/Download/5221.

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