U.S. Department of Transportation
Federal Highway Administration

HSM
Highway Safety Manual
AASHTO

Highway Safety Manual Case Study 4: Development of Safety Performance Functions for Network Screening in Illinois

HSM Reference

Safety Performance Functions (SPF) are statistical models used to estimate the average crash frequency for a specific site type (with specified base conditions), based on traffic volume and roadway segment length. Part B of the American Association of State Highway and Transportation Officials' (AASHTO) *Highway Safety Manual* (HSM) demonstrates the use of SPFs for network screening, while Part C uses SPFs to predict the number of crashes for a particular site given specific "base" conditions.

SPFs are developed through statistical regression modeling using historical crash data. Although they require more data, SPFs developed using the Empirical Bayes (EB) approach are more sophisticated than crash frequency or crash rate as a predictor because they account for the regression to the mean bias and random fluctuations in crash data over any period of time. Across the country, SPFs have been developed for a variety of analysis purposes and should be tailored to the analysis being completed and the available data to ensure the most reliable results.

SPFs used for network screening are more general and require less data than the predictive methods and allow agencies to identify high-priority locations for potential improvement. The SPFs in Part C of the HSM were developed based on multistate data and require a local calibration factor to accurately apply them to specific locations. The HSM provides instructions on the calibration process and safety analysis tools such as *SafetyAnalyst* and the Interactive Highway Safety Design Model (IHSDM) automatically calibrate the models. Although models based on multistate data sets are helpful, they produce generalized results and may not be as accurate for localized conditions. Alternatively, agencies with robust data sets may develop state-specific SPFs to model their conditions more precisely.

Description

In 2006, the Illinois Center for Transportation, Illinois Department of Transportation (IDOT) and the University of Illinois at Urbana-Champaign performed a research project to develop state-specific SPFs to use in the State's network screening process. Prior to 2006, IDOT used the High Accident Location Identification System (HALIS) to identify High Accident Locations (HAL) and wet pavement cluster/segments that were based on crash frequency, rate, and equivalent property only. This project addressed the following specific challenges: 1) linking crash and roadway data, given each had a different linear referencing system; 2) establishing the criteria to assign each roadway segment to a peer group; 3) using "reference points" to establish intersection locations; 4) currency of crash and traffic data; 5) processing a large volume of crash and roadway data; and 6) helping users understand the meaning of the results.

Discussion

The Federal Highway Administration/National Highway Institute course, New *Approaches to Highway Safety Analysis,* inspired IDOT to begin the transition to more scientific approaches to transportation safety analysis. The team reviewed the available data and modeled the development of SPFs after the *SafetyAnalyst* peer groups (for example, rural two-lane highways, rural multilane divided highways, etc.). The fundamental roadway data elements were used to define roadway segments or intersections into peer groups, as shown in Table 1, and crashes were assigned to the appropriate roadway segments or intersections.

Table 1: Illinois SPF Peer Groups

Segments	Intersections
1 – Rural two-lane highways	1 – Rural minor-road STOP control
2 – Rural multilane undivided highways	2 – Rural all-way STOP control
3 – Rural multilane divided highways	3 – Rural signal control
4 – Rural freeways – four lanes	4 – Rural undetermined
5 – Rural freeways – six-plus lanes	5 – Urban minor-road STOP control
6 – Urban two-lane arterials	6 – Urban all-way STOP control
7 – Urban multilane undivided arterials	7 – Urban signalized
8 – Urban multilane divided arterials	8 – Urban undetermined
9 – Urban one-way arterials	
10 – Urban freeways – four lanes	
11 – Urban freeways – six lanes	
12 – Urban freeways – eight-plus lanes	

SAS statistical software was used to develop negative binomial equations with over dispersion parameters for each of the peer groups for three crash categories: fatal crashes, A-injury or incapacitating injury crashes, and B-injury or non-incapacitating injury crashes, resulting in 60 models in total. The models were based on crash frequency of state highways for the years 2001 to 2005 with available average daily traffic (ADT).

As shown in Figure 1, the SPFs provide the predicted number of fatal, A-injury type, or B-injury type crashes for a given segment or intersection based on the annual ADT. The EB technique was applied to adjust the observed number of crashes by severity at a segment or intersection. The difference of the EB adjusted average crash frequency and the predicted average crash frequency from a SPF is referred to as the potential for safety improvement, or PSI.

The HSM refers to this value as the excess expected average crash frequency.

IDOT put further emphasis on the most severe crashes by applying a weighting factor of 25 times a fatal crash, 10 times a A-injury crash, and one time a B-injury crash to obtain a weighted PSI for each roadway segment or intersection. Intersection sites were ranked sequentially from highest PSI to lowest PSI by peer group to identify high-priority locations for further review and potential implementation of safety countermeasures. Sliding window analysis was performed on the roadway segments to aggregate the performance measure over one rural mile (minimum) or 0.25 urban mile (minimum). The analysis segments were shifted incrementally to identify the locations with the most severe needs. Ultimately, overlapping analysis segments were removed to obtain one unique value for each roadway segment. The PSI values for roadway segments were also ranked from highest to lowest to identify the routes with the greatest potential to respond to safety improvements.

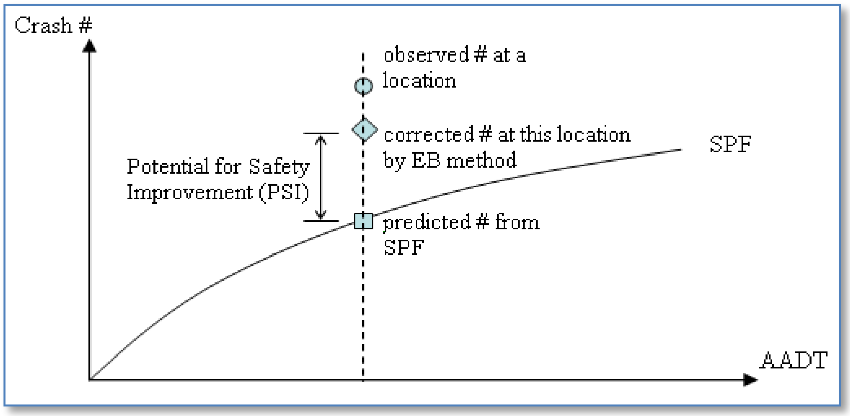

Figure 1: IDOT Potential for Safety Improvement Graphical Definition

Training Needs

Although IDOT did not conduct formal training to cover the actual analysis, the Bureau of Safety Engineering met with each of the IDOT Districts to discuss the process and make sure the District staffs had a basic understanding of the terminology and the process.

Coordination with the District staffs also focused on using the results of the new screening techniques, including identifying contributing factors and developing recommendations for potential countermeasures to address the locations with high PSI values.

Benefits

A variety of benefits have emerged from the development of SPFs for Illinois. The use of SPFs developed using the EB technique to identify high-priority locations is a more-sophisticated crash analysis approach that is more accurate than using crash frequencies or crash rates because they account for the effect of regression to the

> "We produced safety performance functions based on the data we had available which has been applied to our entire state system to provide network screening results and high priority locations for further investigation and project development. The Part C Highway Safety Manual SPFs with the Empirical Bayes technique used for crash prediction requires additional roadway data, but has improved the sophistication of safety analyses in Illinois resulting in better decisions to allocate limited safety resources."
>
> *- Dave Piper, Illinois Department of Transportation*

mean. The use of SPFs also provides a rigorous analytical approach that is objective and consistent. The development and use of SPFs has helped the agency to shift the analysis approach from all crashes to fatal and severe crashes, from basic to more advanced analytical methods, and from congested roadways to a broader range of roadways. The modified process helped to allocate limited safety dollars to areas with the greatest need as a result the number of fatal and severe crashes in Illinois have been reduced significantly and Illinois roadways have the lowest number of annual fatalities since 1921.

Contact

David Piper, P.E.
Illinois Department of Transportation
Phone: (217) 558-1793
E-mail: David.Piper@illinois.gov