CMF

CRASH MODIFICATION FACTORS **IN PRACTICE**

INTRODUCTION TO SAFETY PERFORMANCE FUNCTIONS

DEFINITION A safety performance function (SPF) is an equation used to predict the average number of crashes per year at a location as a function of exposure and, in some cases, roadway or intersection characteristics (e.g., number of lanes, traffic control, or median type) *(1)*. For highway segments, exposure is represented by the segment length and annual average daily traffic (AADT) associated with the study section as shown by the sample SPF in Equation 1.

$$\text{Predicted Crashes} = \exp[a + \beta * \ln(\text{AADT}) + \ln(\text{Segment Length})] \qquad \{1\}$$

For intersections, exposure is represented by the AADT on the major and minor intersecting roads as shown by the sample SPF in Equation 2.

$$\text{Predicted Crashes} = \exp[a + \beta_1 * \ln(\text{AADT}_{major}) + \beta_2 * \ln(\text{AADT}_{minor})] \qquad \{2\}$$

Example 1: The SPF from the Highway Safety Manual (1) for total multiple-vehicle (MV) crashes at urban, four-legged signalized intersections using Equation 2 where a, β1 and β2 were calculated separately is:

$$\text{Predicted MV crashes} = \exp[-10.99 + 1.07{*}\ln(\text{AADT}_{major}) + 0.23{*}\ln(\text{AADT}_{minor})]$$

For an urban, four-legged signalized intersection with a major road traffic volume ($AADT_{major}$) of 25,000 vehicles per day and a minor road traffic volume ($AADT_{minor}$) of 10,000 vehicles per day, the predicted number of MV crashes is computed as follows for the given SPF.

$$\text{Predicted MV crashes} = \exp[-10.99 + 1.07{*}\ln(25{,}000) + 0.23{*}\ln(10{,}000)] = 7.13 \text{ crashes/year}$$

APPLICATION SPFs are used to predict crash frequency for a given set of site conditions. The predicted crashes from the SPF can be used alone or in combination with the site-specific crash history (i.e., Empirical Bayes method) to compare the safety performance of a specific site under various conditions. The Empirical Bayes method is used to estimate the ***expected*** long-term crash experience, which is a weighted average of the ***observed*** crashes at the site of interest and the ***predicted*** crashes from an SPF *(2)*.

The predicted number of crashes calculated using SPFs is instrumental for a number of activities in the project development process, including: 1) network screening, 2) countermeasure comparison, and 3) project evaluation.

1) Network Screening

SPFs can be used in the network screening process to determine whether the observed safety performance at a given location is higher or lower than the average safety performance of other sites with similar roadway characteristics and exposure. This is useful in the safety management process to identify sites with potential for safety improvement.

2) Countermeasure Comparison

SPFs can be used to predict the baseline crash frequency for given site conditions when comparing potential countermeasures. SPFs are used alone or in conjunction with the crash history to estimate the long-term crash frequency for baseline conditions (without treatment) and crash

References

1. American Association of State Highway and Transportation Officials (AASHTO). *Highway Safety Manual*, 1st Edition, Washington, DC, 2010.
2. Hauer, E. *Observational before-after studies in road safety.* Pergamon Press, Elsevier Science Ltd., Oxford, England, 1997.
3. Introduction to Crash Modification Factors. Federal Highway Administration. Available online at: http://safety.fhwa.dot.gov/tools/crf/resources/cmfs/.
4. Van Schalkwyk, I., Wemple, E.A., and Neuman, T.R. *Integrating the HSM into the Highway Project Development Process.* Publication FHWA-SA-11-50, Federal Highway Administration, Washington, DC, 2012.

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modification factors (CMFs) are applied to estimate the crashes with treatment as shown in Equation 3. This is useful in activities where there are multiple alternatives to address safety concerns and it is desirable to quantify and compare the potential benefits of each treatment. Readers can refer to the *Introduction to Crash Modification Factors* for more information on CMFs and how they are applied *(3)*.

Predicted Crashes WITH Treatment = CMF * Predicted Crashes WITHOUT Treatment {3}

Example 2: Estimate the change in predicted crashes for installing left-turn lanes on two of the approaches at an urban, four-legged signalized intersection with a major road traffic volume ($AADT_{major}$) of 25,000 vehicles per day and a minor road traffic volume ($AADT_{minor}$) of 10,000 vehicles per day. The CMF for installing left-turn lanes on two approaches at an urban, four-legged signalized intersection is 0.81 (1).

*Predicted crashes WITH treatment = CMF * Predicted crashes WITHOUT treatment (from Example 1)*

*Predicted crashes WITH treatment = 0.81 * 7.13 crashes/year = 5.78 crashes/year*

The change in predicted crashes is a reduction of 1.35 crashes per year (7.13 – 5.78 crashes per year).

3) Project Evaluation
It is important to evaluate the safety effectiveness of roadway improvements to provide input to future planning, policy and programming decisions. The current state-of-the-practice is to employ the Empirical Bayes method in an observational before-after study to develop CMFs. SPFs are a critical component of the Empirical Bayes method, which combines the crash history for a given site with the predicted crashes from an SPF. In particular, the SPF helps to account for changes in traffic volume over time.

CALIBRATION SPFs are developed using data from specific locations at a specific period in time and represent the average conditions for a given facility type. As such, it may be necessary to adjust the SPF through calibration to better reflect your local conditions or a different study period. A calibration procedure is presented in the *Highway Safety Manual* to reflect local conditions or a different study period *(1)*. It is also necessary to adjust the SPF when the conditions at the site of interest differ from the average conditions. The *Highway Safety Manual* identifies the base conditions for each SPF and provides applicable adjustment factors (i.e., CMFs) *(1)*. CMFs are applied using Equation 4.

Adjusted Predicted Crash Frequency = CMF * Base Predicted Crash Frequency {4}

Example 3: Consider a scenario where it is desirable to predict crashes for a rural, two-lane study section with a segment length (L) of 2.0 miles and an AADT of 2,500 vehicles per day. It is determined that the roadway of interest has 11-ft lanes, while the base condition for the applicable SPF in the Highway Safety Manual is for a roadway with 12-ft lanes. All other conditions are similar to the base conditions. In this case, it is necessary to adjust the predicted crash frequency to reflect the different base condition using Equation 4. From the Highway Safety Manual, the applicable CMF for 11-ft lanes is 1.05 (1). The SPF for total crashes on rural, two-lane roads is similar to Equation 1 where a and β were calculated separately and shown in the following equation (1).

*Predicted total crashes = exp[-15.22 + 1.68*ln(AADT) + ln(L)]*

*Base predicted crash frequency = exp[-15.22 + 1.68*ln(2,500) + ln(2.0)] = 0.25 crashes/year*

*Adjusted predicted crash frequency = CMF * Base predicted crash frequency*

*Adjusted predicted crash frequency = 1.05 * 0.25 crashes per year = 0.26 crashes per year*

Readers can refer to the *Highway Safety Manual (1)* and FHWA's *Integrating the HSM into the Highway Project Development Process (4)* for additional information and examples. The *Highway Safety Manual* provides specific SPFs for various facility types and details regarding the calibration process.