How to Choose Between Calibrating SPFs from the HSM and Developing Jurisdiction-Specific SPFs

Draft Report

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# 1. Background and Context

This guidebook is intended to provide guidance on whether an agency should calibrate the safety performance functions (SPFs) from the Highway Safety Manual (HSM) (AASHTO, 2010) or develop jurisdiction-specific SPFs. The guidebook discusses the factors that need to be considered while making the decision. It is intended to be of use to practitioners at state and local agencies and to researchers.

This document is part of a series of documents currently being developed by the Federal Highway Administration (FHWA) and the National Cooperative Highway Research Program (NCHRP) to facilitate the implementation of the HSM by the States. Following is the list of the series of documents:

* NCHRP Project 20-7 (Task 332): This effort, led by Dr. Geni Bahar of NAVIGATS will develop a *User’s Guide to Develop Highway Safety Manual Safety Performance Function Calibration Factors* (hereafter referred to as the ***SPF Calibration Guide***). This document will provide guidelines to assist an agency in developing statistically sound calibration factors. This document will also provide guidance for assessing the quality of a calibration factor after it is developed.
* *How to Guidebook for States Developing Jurisdiction-Specific SPFs* (hereafter referred to as the ***SPF Development Guide***). If a jurisdiction decides that developing jurisdiction-specific SPFs will fit their needs, this document will provide the states knowledge of what data, expertise, tools, and other resources are required to develop jurisdiction-specific SPFs. This effort is currently being funded by FHWA.
* *SPF Needs Assessment*: This project, led by Volpe will do a needs and alternatives assessment to determine the set of potential resources that would best satisfy the future needs of the states using SPFs. Part of this project involves conducting interviews with selected States to better understand their needs and requirements regarding SPFs.

# 2. What Are SPFs?

SPFs are crash prediction models. They are essentially mathematical equations that relate the number of crashes of different types to site characteristics. Examples of site characteristics include traffic volume (AADT), lane width, shoulder width, radius/degree of horizontal curves, presence of turn lanes (at intersections), and traffic control (at intersections). Following is an example of a crash prediction model for non-intersection crashes on rural two-lane roads developed by Vogt and Bared (1998) using data from Washington and Minnesota. This model was estimated based on detailed information about the location of horizontal and vertical curves within each roadway section.



where,

Y = predicted mean number of non-intersection crashes on the segment

EXPOm = traffic exposure in millions of vehicle kilometers

LWm = lane width in meters

SHWm = average of left and right shoulder widths in meters

RHR = average roadside hazard rating along segment

DDm = driveway density in driveways per kilometer

STATE = 0 for Minnesota, 1 for Washington

DEGm{i} = degree of curve in degrees per hundred meters of the i-th horizontal curve that overlaps the segment

WH{i} = fraction of the total segment length occupied by the i-th horizontal curve

Vm{j} = absolute change in grade in percent per 100 meters of the j-vertical crash curve that overlaps the segment

WV{j} = the fraction of the total segment length occupied by the j-th vertical crest curve

GR{k} = absolute grade in percent of the k-th uniform grade section that overlaps the segment

WG{k} = fraction of the total segment length occupied by the k-th uniform grade section

# 3. How Are SPFs Used?

The Highway Safety Manual outlines at least three different ways in which SPFs can be used by jurisdictions to make better safety decisions. One application is to use SPFs to determine the safety impacts of design changes at the project level. The second application is to use SPFs as part of network screening to identify sections that may have the best potential for improvements. The third application is the use of SPFs as part of a before-after study to evaluate the safety effects of engineering treatments. Following is a brief discussion of these applications.

## Determining the Expected Safety Impacts of Design Changes at the Project Level

When SPFs are used in project-level decision making, they are used for estimating the *average expected crash frequency* for existing conditions, alternatives to existing conditions, or proposed new roadways. Part C of the HSM provides methods for estimating the average expected crash frequency of a site/project. These methods involve the use of SPFs for predicting the crash frequency for a “base” condition and crash modification factors (CMFs) to adjust the predictions for situations that differ from that base condition. The SPFs for these base conditions along with the CMFs are available in Part C of the HSM. The list of roadway and intersection types with SPFs in Part C of the HSM is provided in Appendix A of this document.

## Identifying Locations with Promise (Network Screening)

SPFs may also be used to identify locations with promise, i.e., locations that may benefit the most from the application of some treatment. This application is also referred to as network screening. Here, SPFs can be used to estimate the average number of crashes for a particular facility type with a particular traffic volume. This average can then be compared to the actual number of crashes at a particular site or to an estimate of the expected number of crashes at that site to determine if that site should be categorized as a site with promise. Methods for using SPFs in network screening are discussed in Part B of the HSM. SPFs that could be used for network screening are available in *Safety Analyst*, a set of software tools that can be used by state and local agencies for safety management. Appendix A of this document provides the list of roadway, intersection, and ramp types for which SPFs are provided in *Safety Analyst*.

## Evaluating the Effect of Engineering Treatments

Researchers commonly conduct safety evaluation studies to determine the effect on crashes (e.g., CMF) from implementing some safety countermeasure.

Most safety researchers agree that before-after studies provide more reliable estimates of the safety effect of engineering treatments than do cross-sectional comparisons of locations with and without a particular treatment. Since many engineering treatments are implemented at locations that may have a higher than normal crash count, before-after studies need to account for potential bias due to regression to the mean. One way to address this bias is to make use of the empirical Bayes (EB) procedure developed by Hauer (1997). SPFs are an integral part of the EB procedure. This guide will not discuss the application of SPFs as part of before-after evaluations. Further discussion of this application can be found in Hauer (1997) and Gross et al. (2010).

For some situations where before-after evaluations are not feasible, the coefficients of the variables from SPFs can be used to estimate the CMF associated with a particular treatment. However, there are a number of issues associated with this approach for developing CMFs. This guide will not discuss the use of SPFs for this application. A detailed discussion of the issues associated with such applications of SPFs is provided in Gross et al. (2010) and Carter et al. (2012).

# 4. Options for Obtaining SPFs for a Jurisdiction

An agency has two choices for obtaining SPFs to use in the above applications – calibrating existing SPFs or developing jurisdiction-specific SPFs (hereafter referred to as “calibrating SPFs” and “developing SPFs”, respectively). These options are described in the following sections.

## Calibrating SPFs

One option for obtaining SPFs is to take existing SPFs that were developed in other geographic areas and calibrate them for the local jurisdiction. If an agency wants to make use of existing SPFs from sources such as the HSM or Safety Analyst, they need to be calibrated for the conditions in the jurisdiction. Calibration is necessary because “the general level of crash frequencies may vary substantially from one jurisdiction to another for a variety of reasons including crash reporting thresholds and crash reporting system procedures” (HSM, page C-18). This section provides an overview of calibration. Further discussion of the issues and steps will be available from the *SPF Calibration Guide* that is being developed under NCHRP Project 20-07.

### Sources of Existing SPFs

Existing SPFs may be obtained from sources such as Part C of the Highway Safety Manual (for project level analysis) or *Safety Analyst* (for network screening). Regarding the SPFs in Part C of the HSM, Chapter 10 includes SPFs that were estimated for rural two-lane, two-way roads developed using state data from Minnesota, Washington, Michigan, and California. Chapter 11 includes SPFs that were estimated for rural multilane highways using data from Texas, California, Minnesota, New York, and Washington. Chapter 12 includes SPFs for roadway segments in urban and suburban arterials that were estimated using data from Minnesota, Michigan, and Washington; the SPFs for intersections in urban and suburban arterials were estimated using data from Minnesota, North Carolina, Florida, and Toronto (Ontario). It should be noted that before these SPFs were included in the HSM, the roadway segment SPFs were calibrated using data from Washington and the intersection SPFs were calibrated using data from California (Srinivasan et al., 2008).

*Safety Analyst* includes SPFs for roadway segments, intersections, and ramps. SPFs for roadway segments were estimated using data from Ohio, North Carolina, Minnesota, California, and Washington. SPFs for intersections were estimated using data from Minnesota, and SPFs for ramps were estimated using data from Washington. Although the *Safety Analyst* program and technical support are only available through purchase from AASHTO, the default SPFs used in *Safety Analyst* are documented in Appendix E of Harwood et al., (2010).

The SPFs in Part C of the HSM and in *Safety Analyst* are negative binomial (NB) regression models estimated using a procedure called generalized linear models (GLM). In these models, the relationship between the dependent variable (crash frequency) and the independent variables (site characteristics) is log-linear.

### Calibration Process

As discussed earlier, SPFs are essentially mathematical equations that relate the number of crashes of different types to site characteristics. Mathematically speaking, an SPF can be represented in the following manner:

Np = f(AADT, X1, X2, X3, X4,….)

Where Np is the predicted number of crashes during a particular time as a function of traffic volume (AADT), and other site characteristics, X1, X2, X3, X4, and so on (f is mathematical function that relates the predicted number of crashes with AADT and other site characteristics). The relevant site characteristics (X1, X2, X3, X4 and so on) may also be different depending on the type of road and whether it is a roadway segment, intersection, or ramp. For example, in the case of intersections, AADT may be replaced by major road AADT and minor road AADT.

In the context of calibration, it is important to understand the distinction between the SPFs from Part C of the HSM that are intended for project level analysis and the SPFs in *Safety Analyst* that are intended for network screening. As mentioned earlier, the prediction methods in Part C of the HSM involve the use of SPFs for predicting the crash frequency for a “base” condition and crash modification factors (CMFs) to adjust the predictions for situations that are different from a base condition. For roadway segments, the prediction methods provide estimates for the number of crashes per mile per year, and for intersections, the prediction methods for base conditions provide estimates for the number of crashes per intersection per year. Typically, the SPFs for base conditions include AADT (for roadway segments) as the independent variable, and major and minor road AADTs as independent variables for intersections. CMFs are then used to adjust this prediction for situations other than the base condition.

The SPFs for roadway segments and ramps in *Safety Analyst* also estimate the number of crashes per mile per year and include AADT as the only independent variable. Similarly, the SPFs for intersections in *Safety Analyst* estimate the number of crashes per intersection per year and include major and minor road AADT as the only independent variables. However, the SPFs in *Safety Analyst* were not estimated for any particular base condition. These SPFs are intended to provide the average number of crashes for a particular traffic volume level for a particular type of facility (the list of facility types covered in Safety Analyst is provided in Appendix A of this document).

Below is a brief listing of the steps involved in calibrating project level SPFs from Part C of the HSM and network screening SPFs from *Safety Analyst*.

### Steps in Calibrating Project Level SPFs

Based on the discussion in the HSM, following are steps that can be used to calibrate the HSM SPFs:

* Step 1 – Identify facility types for which the applicable Part C predictive model is to be calibrated. As discussed earlier, Part C of the HSM provides predictive methods for three types of facility types: rural two-lane, two-way roads, rural multilane roads, and urban and suburban arterials. For each facility type, models are provided separately for roadway segments and intersections.
* Step 2 – Select sites for calibration of the predictive model for each facility type. The HSM indicates that sites should be selected without regard to the number of crashes. This can be accomplished by selecting sites at random from the pool of available sites. In most states, it may not be appropriate to develop a single calibration factor for a particular facility type across the entire state. Depending on the variation in terrain, climate, topography, crash reporting practices, driver population, animal population, and other factors across the state, multiple calibration factors may be necessary based on somewhat homogeneous subsets of sites of that particular facility type. In addition to considering these factors, Persaud et al., (2002) has argued that different calibration factors may also be necessary for different levels of traffic volume within a particular facility type. With regard to sample sizes needed for calibration, the HSM indicates that 30-50 sites that experience at least 100 crashes per year should be a desirable minimum sample size. This guideline in the HSM was introduced based on engineering judgment and has been challenged by a few researchers (e.g., Banihashemi, 2012).
* Step 3 – Obtain data for each facility type applicable to a specific calibration period. Data are needed on crash frequency and site characteristics. The list of site characteristics is available from Appendix C of the HSM. The characteristics which the HSM considered to be high impact are called *required* and other characteristics which the HSM considered as being not that sensitive to crash propensity are called *desirable* for which default values are provided in the HSM.
* Step 4 – Apply the applicable Part C predictive model to predict total crash frequency for each site during the calibration period as a whole. The predictive method and the SPFs from Chapters 10, 11, and 12 are used to compute the predicted number of crashes for each site in the calibration sample.
* Step 5 – Compute calibration factors for use in Part C predictive model. The calibration factor for a facility type is then defined as the ratio of the total number of observed crashes in the calibration sample to the total number of predicted crashes from Step 4. If the calibrated models are used to estimate the expected number of crashes based on the EB procedure, then the overdispersion parameter of the negative binomial SPF needs to be included in this calculation. For this calculation, both the HSM procedures and *Safety Analyst* make use of the overdispersion parameter that was estimated from the data used to estimate the original SPFs in *Safety Analyst* and the HSM. Some researchers have suggested that the overdispersion parameters should be recalibrated based on the data from the calibration sample (CDOT, 2009).

It is important to note that in applying these steps, the implicit assumption is that the CMFs in Part C of the HSM (for adjusting the predictions to situations other than the base conditions) are universal, i.e., they are applicable for all the States and are not functions of specific site characteristics. Persaud et al., (2012) and Sacci et al., (2012) have challenged this assumption based on their work when calibrating the HSM prediction models using data from Ontario and Italy, respectively.

### Steps in Calibrating Network Screening SPFs

The steps involved in calibrating network screening SPFs are similar to those when calibrating project-level SPFs since the ultimate aim is to determine the ratio of the total number of observed crashes to the total number of predicted crashes. However, there are differences in the details of these steps since both the SPFs and the data requirements are different. Following is an outline of the steps:

* Step 1 – Identify facility types and appropriate SPFs. As discussed earlier, the SPFs in *Safety Analyst* are a logical starting point since SPFs are available for a large number of facility types and have already been used in the software. However, there is no reason why a jurisdiction could not make use of similar SPFs that were developed by other researchers, particularly if they had been estimated using data from the same jurisdiction from an earlier time period. In this context, it is important to note that for those who currently use the *Safety Analyst* software, calibration is automatically done within the software before further analyses are conducted. Hence, the discussion of these steps are intended for those users who may want to use *Safety Analyst* type SPFs for network screening without actually using the software package.
* Step 2 – Select sites for calibration. Unlike project level analysis where individual sites or group of sites are examined one at a time, network screening makes use of data from the entire network (for a particular facility type). Hence, the sample for calibration needs to cover the network that needs to be screened. Again, depending on the variation in terrain, climate, topography, crash reporting practices, driver population, animal population, and other factors across the jurisdiction, multiple calibration factors may be necessary if the jurisdiction feels that screening should be done separately for different groups based on these factors.
* Step 3 – Obtain data for each facility type. Apart from crash counts, data for calibrating network screening SPFs could simply include AADT and segment length (for roadway segments and ramps) and major and minor road AADTs for intersections.
* Step 4 – Apply the SPFs to predict total crash frequency for each site during the calibration period. The SPFs from *Safety Analyst* could be used to predict the number of crashes at each site.
* Step 5 – Compute calibration factors for use in Part C predictive model. The calibration factor for a facility type is then defined as the ratio of the total number of observed crashes in the calibration sample to the total number of predicted crashes from Step 4.

## Developing SPFs

As discussed earlier, instead of calibrating existing SPFs, an agency may choose to develop their own SPFs in order to improve the accuracy of the predictions. The HSM indicates that jurisdiction-specific SPFs “are likely to enhance the reliability of the Part C predictive method” (HSM, page A-9). The advantages of jurisdiction-specific SPFs are also discussed in previous studies (e.g., Lu et al., 2012; Sacci et al., 2012). Jurisdiction-specific SPFs also provide the opportunity to examine alternative functional forms (depending on the data) rather than using the default forms in the HSM and *Safety Analyst*. Further discussion will be provided in the *SPF Development Guide* that is being developed through funding from FHWA.

In order to develop SPFs, it is necessary, at the minimum, to have an analyst with statistical expertise for estimating simple negative binomial regression models using generalized linear modeling techniques. The analyst also needs experience with the statistical tools discussed earlier. Such experience is available in many Universities and research institutes across the country. Hence, at least a few states have estimated jurisdiction-specific SPFs for network screening, especially for roadway segments (e.g., Srinivasan and Carter, 2011; Tegge et al., 2010).

With respect to project level SPFs, Appendix A to Part C of the HSM outlines two possible approaches for developing SPFs. Following is a quote from page A-10 of the HSM:

“Two types of data sets may be used for SPF development. First, SPFs may be developed using only data that represent the base conditions, which are defined for each SPF in Chapter 10, 11, and 12. Second, it also acceptable to develop models using data for a broader set of conditions than the base condition. In this approach, all variables that are part of the applicable base-condition definition, but have non-base-condition values, should be included in the initial model. Then, the initial model should be made applicable to the base conditions by substituting values that correspond to those base conditions into the model”.

With either approach, detailed information is necessary about the site characteristics in addition to traffic volume so that it can be determined whether the characteristics of the site correspond to the base condition or not. As discussed earlier, at a minimum, data are needed for the site characteristics that are considered required by the HSM for calibrating the Part C prediction (project level) models. Unlike calibration, developing SPFs requires such data needs to be available or compiled for a relatively large sample of sites (see Table 1[[1]](#footnote-1) for sample size estimates). Very few states have such a database. States that do not have a sufficiently detailed database may begin with calibrating SPFs from existing sources but might find it cost prohibitive to develop SPFs.

### Steps in Developing SPFs

Below is an overview of steps that are needed in developing SPFs.

* Step 1 - Identify Facility Type. The first step is to identify the type of facility for which SPFs will be developed. Depending on whether the SPF is being estimated for project-level analysis or network screening, the jurisdiction can decide which facility types they are most interested in.
* Step 2 - Compile Necessary Data. Depending on whether the SPFs will be used for project level analysis or network screening, the data needs are quite different.
  + For network screening SPFs, for each facility type, the number of crashes for each unit (intersection, segment, or ramp), and the traffic volume (AADT) associated with that unit are required. For intersections, it is recommended that AADT for both major and minor roads be available. If SPFs are to be estimated for a particular crash type or severity, the number of crashes by severity and type will be necessary for each unit.
  + For SPFs that will be used for project-level analysis, data on other site characteristics (apart from AADT) will be necessary. A good starting point is the list of variables that are considered required by the HSM for calibrating the Part C prediction models. This list for the different facility types is available in the Appendix to Part C of the HSM.
  + At this stage, the sample size that is required for developing jurisdiction specific SPFs needs to be determined. This sample needs to be substantially higher than the minimum sample size suggested by the HSM for calibration (see Table 1).
  + A decision needs to be made on how routes will be divided into segments for the analysis. A common approach is to use homogenous segments with respect to site characteristics and traffic volume. This often results in short segments. However, others have suggested using longer, though non-homogenous, sections to account for spatial correlation (Marinelli et al., 2009).
* Step 3 - Determine Model and Functional Form*.* As mentioned earlier, the SPFs in Part C of the HSM and in SafetyAnalyst are negative binomial regression models with a log-linear relationship between crash frequency and site characteristics. However, that may not be most appropriate form (Hauer, 2004; Kononov et al., 2011). Different types of exploratory analysis need to be conducted to determine the appropriate functional form of the relationship between crash counts and independent variables, and the possible need for including interaction terms between independent variables. Examples include using plots to illustrate the functional form of the relationship between crash counts and different independent variables and a discussion of methods such as classification and regression trees (CART) to identify which independent variables and interactions are relevant in the model. This step is easier to accomplish for network screening SPFs where fewer variables (usually just AADT) are involved.
* Step 4 - Develop the SPF*.* A number of statistical tools (statistical software) are available to develop SPFs. Common ones include SAS, STATA, and GENSTAT (all commercially available software packages). However, other software tools including R, an open source programming language, and Microsoft Excel, can be used as well. It is, however, important to consider in the modeling effort that crashes typically follow a negative binomial distribution, not a normal distribution
* Step 5 - Conduct Model Diagnostics*.* There are different steps involved in conducting effective diagnostics to determine if the estimated SPF is reasonable. These include checking the sign of the parameters’ coefficients, examining residuals via residual plots and cumulative residual plots (i.e., CURE plots), identifying potential outliers using Cook’s D or other tools, and examining goodness-of-fit measures.
* Step 6 - Re-estimate the SPF*.* Based on the results of Step 5, the SPF may have to be re-estimated using a different statistical model or functional form. The SPF may also need to be re-estimated after removing outliers that were identified in the diagnostics step.

# 5. Decision Process: How an Agency Obtains SPFs

An agency will have to undergo a process for determining the appropriate course to take when deciding on the final SPFs to use. This may involve only calibrating existing models or going further to develop their own SPFs. Several factors can affect this process, including intended use of the SPF, intended facility type, available sample size, quality of existing roadway data, and available analytical expertise. The process is outlined below.

## Step-by-Step Process

This process outlines the steps that an agency needs to take in order to obtain the final SPF to be used in its jurisdiction. This process begins with SPF calibration and then moves to SPF development if the calibration is deemed too low quality.

### Step 1. Determine intended use of SPF.

As discussed in Section 3 of this guidebook, the two main uses of SPFs in this context are *project level* and *network screening level*. Project level SPFs are used to determine the safety impacts of design changes at the project level. Network screening level SPFs are used to identify sites that may have the best potential for improvements. The agency must determine the intended use of the SPF. For more description of these uses, see Section 3.

### Step 2. Determine facility type.

The agency must determine which facility type will be addressed by the SPF. Facility types include roadway segments, intersections, and ramps. The type of facility to be addressed by the SPF will affect the type of data to be collected and will direct the identification of existing SPFs. Additionally, it is conceivable that an agency may decide to develop jurisdiction-specific SPFs for certain facility types, but calibrate existing SPFs (i.e., from the HSM or *Safety Analyst*) for other facility types. Developing SPFs for project-level analysis will require assembling a database with sufficient number of sites with detailed information on site characteristics. Depending on the variables available in the State’s roadway inventory files, the process of assembling a database may be easier for some facility types than for others.

### Step 3. Identify existing SPF.

The agency must identify an existing SPF according to the intended use and facility type. As described in Section 4, existing SPFs for project level analysis may be obtained from sources Part C of the Highway Safety Manual. Existing SPFs for network screening may be obtained from *Safety Analyst*. Appendix A lists the types of facilities for which SPFs are available in these resources (e.g., rural two-lane roads, etc.).

### Step 4. Consider sample size necessary for calibrating SPF.

The agency must consider what sample size is required to calibrate the SPF. For project level SPFs (as determined in Step 1), the HSM specifies that 30 to 50 sites with at least 100 crashes per year would be a reasonable sample for calibrating the HSM SPFs (this specified minimum sample may be updated by the work in the upcoming *SPF Calibration Guide*). Thus, the agency must consider how to identify the required number of sites and a group of sites that would have a sufficient number of crashes to serve as a stable base for calibration.

For the number of sites, the HSM requires the agency to be able to identify 30-50 sites (i.e., segments or intersections) of the intended facility type (as determined in Step 2). For facility types that are fairly common (e.g., rural two-lane roads), this would be a fairly easy task. For facility types that may be less common (e.g., rural four-lane undivided), this could be more challenging and time consuming. In some cases, the number of sites or miles of a particular facility type may be so small that developing a calibration factor for that facility type would be of low priority, and the agency should consider whether it is worth the cost of undergoing the calibration process for that facility type.

For the number of crashes, the HSM specification requires the group of sites to be used for calibration to have at least 100 crashes per year all together. For urban facilities, this target crash number would likely be met with a small number of sites (given the higher traffic and crash frequencies at urban sites). For rural facilities, it is likely that the agency would need to identify a larger group of sites in order to meet the required minimum number of crashes per year to establish a good statistical base for calibration.

It should be noted that this group of sites for calibration should NOT be selected on the basis of crash counts. That is, the agency should not hand pick a group of high crash sites simply to meet the minimum crash frequency requirement. Doing so would strongly bias the calibration process. Rather, the selection should be random from the population of the appropriate facility type (i.e., random selection of X number of sites from the entire list of rural four-leg signalized intersections throughout the agency).

With respect to network screening SPFs, these SPFs will be used on a broad scale basis across the whole network. Thus, all sites of the particular facility type (as determined in Step 2) over the entire network should be used for the calibration effort.

### Step 5. Consider roadway data necessary for calibrating SPF.

The requirements for roadway data depends on the intended use of the SPF (product of Step 1) and the intended facility type (product of Step 2). In general, calibrating project level SPFs requires more detailed data than calibrating network screening level SPFs. For project level SPFs, an agency would calibrate an SPF from the HSM. Calibrating the HSM SPFs requires detailed roadway data for calculating the various crash modification factors (CMFs) that are part of the HSM predictive process. The list of site characteristics is available from Appendix C of the HSM. The characteristics which the HSM considered to be high impact are called *required* and other characteristics which the HSM considered as being not as sensitive to crash propensity are called *desirable* (default values for desirable characteristics are provided in the HSM).

For calibrating network screening level SPFs, the data requirements would be less stringent, including only AADT and segment length (for roadway segments and ramps) and major and minor road AADT for intersections. The data requirements are less detailed, since the intended use of network screening level SPFs is on the broad scale across the whole network in order to select sites with promise for safety improvements. Traffic volume data for roadway segments is available in most states. On the other hand, many states do not have an inventory of intersections and ramps. Some have an inventory of intersections on their state maintained roads but may not have minor road AADT, especially if the minor roads are not state maintained. If this is the case, then the time required for site identification and data collection will increase.

The agency must evaluate the roadway data requirements and compare to its own roadway inventory. If the level of detail available in the agency’s existing roadway inventory is high, then the work required to assemble the data necessary for calibration will be minimal. However, if the existing roadway inventory has only very basic data, then a more significant effort will be required to assemble the necessary data. Table 1 provides an estimate of the hours required for data collection.

### Step 6. Calibrate existing SPF.

Once the previous steps have been executed, and the agency has determined the intended use of the SPF, identified the facility type to be addressed, identified an SPF from the HSM or Safety Analyst, and considered the requirements for sample size and roadway data, the agency can undertake the calibration process. Calibration can be done by staff with limited to no statistical experience and can be implemented using spreadsheet software such Microsoft Excel. See section 4 for step-by-step description of the calibration process. The result of this process is a calibration factor that is used to adjust the crash predictions of the SPF to be accurate to the agency’s jurisdiction. A complete guide on this process is available in the *SPF Calibration Guide*.

### Step 7. Assess quality of calibration factor.

Once the calibration factor has been developed, the agency must assess the quality of the calibration process. Guidance on assessing the quality of the calibration is provided in the *SPF Calibration Guide*.

In short, if the SPF crash predictions match exactly to the agency’s observed crashes, then the process would produce a calibration factor of 1.0 (reflecting the lack of need to adjust the crash predictions). If the SPF under predicts an agency’s crashes, the calibration factor would be greater than 1.0. If the SPF over predicts, the calibration factor would be less than 1.0. If the calibration factor is very different from 1.0 (i.e., much less or much greater), this would indicate that the agency’s crash experience is much different from that of the SPF development and would indicate that the agency should consider developing their own SPF.

For project level SPFs, if the calibration factor is of good quality, then it can be used along with the HSM predictive methodology to conduct project level analysis. For network screening SPFs, if the quality of the calibration factor is considered good, then it can be used along with the Safety Analyst SPFs for network screening. If the calibration factor is not of good quality, then the agency should follow Steps 8-10 below to develop SPFs using the procedure discussed in the upcoming *SPF Development Guide*.

### Step 8. Consider statistical expertise necessary for developing SPF.

Calibrating existing SPFs and developing new SPFs require different skill levels. As mentioned in Step 6, calibration requires little to no statistical experience. However, developing SPFs requires personnel with a background in statistical modeling. Agencies without such in-house expertise might consider hiring a consultant (e.g., university consultants).

### Step 9. Consider sample size necessary for developing SPF.

As compared to calibrating SPFs, developing SPFs would typically require a larger sample. The amount of sample required depends on the intended use (product of Step 1). For project level SPFs, the agency should identify 100-200 intersections (for intersections models) or 100-200 miles (for segment models) with at least 300 crashes per year for the whole group.

With respect to network screening SPFs, these SPFs will be used on a broad scale basis across the whole network. Thus, all sites of the particular facility type (as determined in Step 2) over the entire network should be used for the calibration effort. However, if the agency cannot assemble a group of at least 100-200 intersections or 100-200 miles with at least 300 crashes per year for the total group, then the reliability of SPF development may be questionable.

### Step 10. Determine crash type to be addressed by SPF.

When conducting SPF calibration, only total crash counts are used to calculate the calibration factor. However, when developing SPFs, there must be separate models to address each crash type. That is, one SPF would be developed to predict total crashes and a separate SPF would be developed to predict run-off-road crashes. The agency must determine which crash type will be addressed by the SPF. Multiple crash types will require multiple SPFs to be developed.

### Step 11. Develop SPF.

Once Steps 8-10 have been executed, the agency can undertake the development of the SPF. Section 4 provides a description of the basic steps involved in developing the SPF. Further detailed guidance on developing an SPF will be provided in the *SPF Development Guide*.

## Staff Time Required

Many agencies will want to have an idea of the cost of the effort to calibrate and/or develop SPFs. Table 1 provides the estimated ranges of staff time required for each endeavor. The staff time required to collect and prepare the data can range greatly depending on the following factors:

* *Whether one or many SPFs are being addressed*. If many SPFs are being calibrated or developed in the same project, then the data collection is more efficient per SPF, since the data collector can obtain data on many types of sites during the same effort. For instance, a data collector who is collecting data on rural two-lane road segments can also gather information on rural two-land road intersections with minimal additional effort.
* *Available data in existing roadway inventory*. If most of the required data elements are contained in the agency’s existing inventory, the data collection time will be minimal. However, the fewer the data elements available in the inventory, the greater is the time needed to assemble the required data. Methods for collecting the data may involving aerial photos, online imagery, construction plans, and/or field visits.

Table 1. Level of Effort Estimates for SPF Calibration and Development

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Intended Use** | **Process** | **Sample needed** | **Staff hours needed - data collection and preparation (per SPF)** | **Staff hrs needed - statistical analyst (per SPF)** |
| Project Level | Calibrate SPF | 30-50 sites; at least 100 crashes per year for total groupa. At least 3 years of data are recommended. | 150 to 350 | n/ad |
| Develop SPF | 100-200 intersections or 100-200 miles; at least 300 crashes per year for total groupc. At least 3 years of data are recommended. | 450 to 1050 | 16 to 40 |
| Network screening | Calibrate SPF | Must use entire network to be screened. No minimum sample specified. At least 3 years of data are recommended. | 24 to 40b | n/ad |
| Develop SPF | Must use entire network to be screened. Minimum sample would be 100-200 intersections or 100-200 miles; at least 300 crashes per year for total groupc. At least 3 years of data are recommended. | 24 to 40b | 8 to 24 |

Notes:

aThis is based on the guidance from the HSM. The SPF Calibration Guide will provide further guidance on this issue.

bIn estimating the staff hours for data collection and preparation for network screening, it was assumed that all the necessary data are available in the jurisdiction’s inventory file.

cThe sample size estimates are based on the judgment of the project team. Methods for estimating the sample size for poisson type regression models are available (e.g., Shieh, 2001), but the project team did not feel that such methods were directly applicable for this situation.

dNo statistical analytical experience is required for calibration.

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# APPENDIX A: Roadway and Intersection Types for which SPFs are Provided in the HSM and *Safety Analyst*

**Facility Types Included in Part C of the HSM**

For roadway sections, Part C of the HSM provides SPFs for the following 8 types:

* Rural two lane roads
* Rural four-lane divided
* Rural four-lane undivided roads
* Two lane urban and suburban arterials,
* Three lane (with center TWLTL) urban and suburban arterials,
* Four lane divided urban and suburban arterials,
* Four lane undivided urban and suburban arterials,
* Five lane (with center TWLTL) urban and suburban arterials.

For intersections, SPFs are available for the following 9 types:

* Three-leg minor road stop controlled intersections on rural two lane roads
* Four-leg minor road stop controlled intersections on rural two lane roads
* Four-leg signalized intersections on rural two lane roads
* Three-leg intersections on rural four lane roads
* Four-leg minor road stop controlled intersections on rural four lane roads
* Three-leg minor road stop controlled intersections on urban and suburban arterials
* Four-leg minor road stop controlled intersections on urban and suburban arterials
* Three-leg signalized intersections on urban and suburban arterials
* Four-leg signalized intersections on urban and suburban arterials

**Facility Types in Safety Analyst**

For roadway segments, SPFs are available for the following 17 types:

* Rural two-lane roads
* Rural multilane undivided roads
* Rural multilane divided roads
* Rural freeways – 4 lanes
* Rural freeways – 6+ lanes
* Rural freeway segments within an interchange area – 4 lanes
* Rural freeway segments within an interchange area – 6+ lanes
* Urban two-lane arterial segments
* Urban multilane undivided arterial segments
* Urban multilane divided arterial segments
* Urban one-way arterial segments
* Urban freeway segments – 4 lanes
* Urban freeway segments – 6 lanes
* Urban freeway segments – 8+ lanes
* Urban freeway segments within an interchange area – 4 lanes
* Urban freeway segments within an interchange area – 6 lanes
* Urban freeway segments within an interchange area – 8+ lanes

For intersections, SPFs are available for the following 12 types:

* Rural three-leg intersections with minor-road stop control
* Rural three-leg intersections with all-way stop control
* Rural three-leg signalized intersections
* Rural four-leg intersections with minor-road stop control
* Rural four-leg intersections with all-way stop control
* Rural four-leg signalized intersections
* Urban three-leg intersections with minor-road stop control
* Urban three-leg intersections with all-way stop control
* Urban three-leg signalized intersections
* Urban four-leg intersections with minor-road stop control
* Urban four-leg intersections with all-way stop control
* Urban four-leg signalized intersections

For ramps, SPFs are available for the following 16 types:

* Rural diamond off-ramps
* Rural diamond on-ramps
* Rural parco loop off-ramps
* Rural parco loop on-ramps
* Rural free-flow loop off-ramps
* Rural free-flow loop on-ramps
* Rural free-flow outer connection ramps
* Rural direct and semidirect connection ramps
* Rural diamond off-ramps
* Rural diamond on-ramps
* Rural parco loop off-ramps
* Rural parco loop on-ramps
* Rural free-flow loop off-ramps
* Rural free-flow loop on-ramps
* Rural free-flow outer connection ramps
* Rural direct and semidirect connection ramps

1. Table 1 is available in Section 5 of this document. [↑](#footnote-ref-1)