IOWA DOT SAFETY ANALYSIS GUIDE

A METHODOLOGY FOR SAFETY PROCESSES AND PROCEDURES ON IOWA'S ROADWAYS

IOWA DOT

Kimley-Horn

December 2021

DRAFT IOWA DOT SAFETY ANALYSIS GUIDE

A METHODOLOGY FOR SAFETY PROCESSES AND PROCEDURES ON IOWA'S ROADWAYS

Prepared for:

Iowa Department of Transportation
Traffic and Safety Bureau
800 Lincoln Way
Ames, Iowa 50010
515-239-1267

Prepared by:

Kimley-Horn and Associates, Inc.
767 Eustis Street
Suite 100
Saint Paul, Minnesota 55114
615-645-4197

2021-12-08 Draft SAG_V4.docx

Table of Contents

List of Appendices

List of Figures

List of Tables

Example Documentation (Separate Documents)

The following examples of documentation have been provided as separate documents to provide samples of what is expected for the various safety analysis types located within this document.

- Relative Comparison of CMFs and CRFs – Example Documentation
- Observed Crashes Adjusted with CMFs and CRFs – Example Documentation
- PCR Calculations using Iowa DOT Website – Example Documentation
- PCR Calculations using HSM Tools – Example Documentation
- HSM Crash Prediction Method Alternatives Analysis – Example Documentation

List of Acronyms

AADT	Average Annual Daily Traffic
AF	Adjustment Factor
BCR	Benefit-Cost Ratio
CMF	Crash Modification Factor
CRF	Crash Reduction Factor (Iowa prefers the use of CRF over CMF)
EB	Empirical Bayes
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
GIS	Geographic Information System
HSIP	Highway Safety Improvement Program
HSM	Highway Safety Manual
HSM2	Highway Safety Manual 2nd Edition
ICAT	Iowa Crash Analysis Tool
ICE	Intersection Control Evaluation
IJR	Interchange Justification Report
IHSDM	Interactive Highway Safety Design Model
IOR	Interchange Operations Report
Iowa DOT	Iowa Department of Transportation
ISATe	Enhanced Interchange Safety Analysis Tool
KABCO	All Crashes (letter identifiers for crash severity as developed by the National Safety Council)

- K — Fatal Crash
- A — Suspected Serious Injury Crash
- B — Suspected Minor Injury Crash
- C — Possible/Unknown Injury Crash
- O/PDO — Property Damage Only Crash
- KAB — Injurious Crashes

mph	Miles per Hour
MPO	Metropolitan Planning Organization
NCHRP	National Cooperative Highway Research Program
PCR/PSI	Potential for Crash Reduction/Potential for Safety Improvement
RPA	Regional Planning Affiliation
RSA	Road Safety Audit

RSMP	Roadway Safety Management Process
RTM	Regression-to-the-Mean
SAG	Safety Analysis Guide
SPF	Safety Performance Function
TIA	Traffic Impact Analysis
TSIP	Traffic Safety Improvement Program
TWLTL	Two-Way Left-Turn Lane

1. Introduction

The Iowa Department of Transportation (Iowa DOT), Department of Public Health, and Department of Safety have committed to an ultimate goal of zero fatalities on Iowa's public roadways. Reducing fatalities and improving safety for all road users can be accomplished through a variety of approaches. Analysis of data and proper application of safety analysis tools are critical to improving safety on Iowa roadways; as such, the Iowa DOT Safety Analysis Guide (SAG) for Practitioners, was developed to assist practitioners with conducting analyses in Iowa.

1.1. Background

The Iowa DOT recognized there was a need to create guidance with respect to safety analysis. The Traffic and Safety Bureau undertook the task of providing direction for conducting safety analysis with input from other Bureaus. This led to the creation of the SAG as an effort to eliminate inconsistencies by standardizing how safety analyses are performed. **The SAG was created with the assumption that users have familiarity with safety datasets and have a basic understanding of the methodologies and procedures involved in conducting safety analysis.**

1.2. Purpose and Intended User

The purpose of the SAG is to standardize safety analysis requirements, procedures, and methods, to the extent possible in Iowa, resulting in consistent results and outcomes. This standardization defines what type and level of analysis is required for different processes and procedures. Additionally, the standardization will result in consistent reviews of safety analyses throughout the Iowa DOT.

The intended users of the SAG are those practitioners who perform safety-related analysis for the Iowa DOT. Safety practitioners include internal DOT employees performing analyses, consultants performing Iowa DOT-related safety analyses, and reviewers of safety analyses. Although the SAG was developed as a guide for safety-related analysis completed for the Iowa DOT, it is anticipated that many of the items contained within the SAG could also be appropriate for application in local agencies, Metropolitan Planning Organizations (MPOs), and Regional Planning Affiliations (RPAs) within Iowa.

1.3. How to use this Guide

The following steps outline how this guide is intended to be used by practitioners:

- Identify the specific safety process or procedure that needs to be conducted.
- Locate the associated safety process or procedure in the Safety Analysis Requirements Table (located in **Section 3**).
- Follow the guidance on how to conduct the analyses and documentation requirements (**Section 4**).
- Reference any relevant introduction and general overview information as needed (**Section 1** and **Section 2**).
- Determine the appropriate tools needed to complete the required analysis. Tools that can be used to perform an analysis are identified in **Section 4.**
- Examples on how to conduct various safety analysis are available online: LINK *TBD*

2. General Overview

This section provides a general overview of safety-related information necessary to conduct safety analyses in Iowa. The overview includes information on the Highway Safety Manual (HSM) Roadway Safety Management Process (RSMP), obtaining crash data, crash modification factors (CMFs), the HSM Predictive Method, predicted versus expected crashes, Iowa calibration factors, Iowa safety performance functions (SPFs), and safety valuations.

2.1. Roadway Safety Management Process

The RSMP, located in Part B of the HSM, outlines the recommended process for agencies to use to monitor and reduce crash frequency and severity on their existing roadway networks. The basic outline of the RSMP is illustrated in **Figure 2.1**. The process is intended to be iterative so that agencies can use it continuously to improve overall safety on their existing roadway network. By implementing projects through a data-informed processes, such as the RSMP, agencies can maximize the effectiveness of available funding sources.

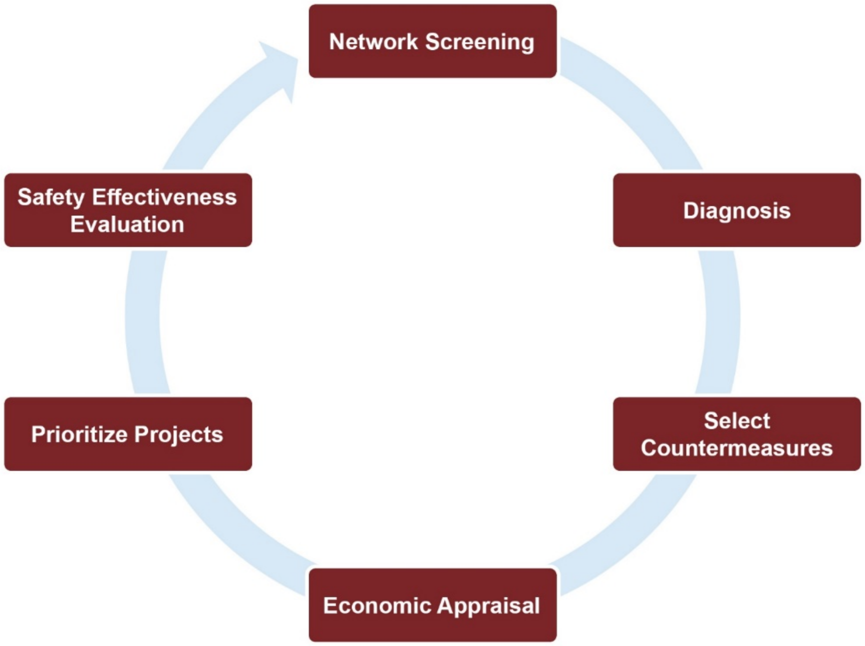


Figure 2.1 – Roadway Safety Management Process

2.2. Obtaining Iowa Crash Data

The following sections contain information on how to obtain Iowa crash, provide direction on how many years of crash data should be utilized for analysis, and provide guidance for determining what should be considered an intersection crash.

2.2.1. Iowa Crash Analysis Tool

The Iowa Crash Analysis Tool (ICAT) is an online tool maintained by the Iowa DOT that houses the latest and most up-to-date crash data for the state. All crash data used in crash analyses should be obtained from ICAT. ICAT can be accessed using the following link.

ICAT: https://icat.iowadot.gov

The Iowa DOT has developed a series of tools within ICAT to assist practitioners with performing crash analyses. Video tutorials are available on the Iowa DOT website to assist practitioners in using ICAT and its associated tools:

- Getting started
- Viewing data
- Navigation tools
- Filtering data
- Selection tools
- Importing a KMZ file
- Creating a map
- Saving your work
- Creating reports
- Creating tables
- Creating charts
- Creating collision diagrams

ICAT TUTORIALS: https://iowadot.gov/traffic/icat-tutorial

2.2.2. Years of Crash Data to Use

When comparing the results of crash analyses performed at different locations, it is important to have consistency not only in how the analysis is performed but also in the number of years of crash data included in the analysis. Most crash data analyses should be conducted using a five-year analysis period; however, sometimes exceptions may be considered based on professional judgment and with approval from the Iowa DOT reviewer. This section describes the typical crash analysis years along with variations from the typical analysis years (construction projects, variations in land use or traffic volumes, and for study areas with no crashes). The number of crash analysis years that should be considered for typical analyses and those with exceptions are detailed in **Table 2.1**. Any adjustments to the number or range of years utilized in a crash analysis must be approved by the Iowa DOT reviewer.

Table 2.1 – Crash Analysis Years

Analysis Scenario ***Explanation***	**Number of Crash Analysis Years**
Typical Crash Analysis *Most recent and complete five calendar years of crash data available in ICAT. The majority of crash data analyses will use the typical crash analysis years.*	5 Years
Construction Project in Analysis Area *Typical crash analysis years may be adjusted to exclude construction years and all prior years (minimum of three full calendar years required).*	3-4 Years
Before/After Crash Analysis *A minimum of three years before and three years after construction should be utilized. The calendar year of construction should be excluded.*	3 Years Before 3 Years After
Land Use or Traffic Volume Changes *When significant land use or traffic volume changes have occurred, then the typical crash analysis years may be adjusted to exclude the prior land use years (minimum of three full calendar years required).*	3-4 Years
No Crashes within Five Years *When no crashes have occurred within the study area in the most recent five years, it is acceptable to use ten years of data when approved by the Iowa DOT reviewer.*	10 Years

2.2.2.1. Typical Crash Analysis

Typical crash analyses should be conducted using the most recent and complete five calendar years of crash data. A calendar year is from January 1 to December 31. The Iowa DOT does not consider the previous calendar year's crash data finalized until April 15 of the following year due to the Fatality Analysis Reporting System (FARS) allowing deaths occurring up to 30 days after the crash to be considered a fatality, as well as delays in crash reporting. As such, crash data for a calendar year should not be considered for analysis until after April 15 of the following year. **Table 2.2** provides an example of the calendar years that should be used in a crash analysis based on when the crash analysis is being conducted.

Table 2.2 – Example of Calendar Years for Crash Analysis

Date Range for Collecting Crash Data	Calendar Years for Crash Analysis
Before April 15, 2022	2016, 2017, 2018, 2019, 2020
After April 15, 2022	2017, 2018, 2019, 2020, 2021

Professional judgment should be used if a practitioner determines that there is a need to utilize data from a calendar year before that year's data is considered final. In these isolated scenarios, the practitioner must clearly document that the analysis was conducted prior to April 15 and provide clear justification for why unfinalized crash data was used for the analysis.

2.2.2.2. Construction Project in Analysis Area

If a construction project occurred within the study area during the typical (five complete calendar years) crash analysis period, the number of years included within the crash analysis may need to be adjusted to eliminate the inclusion of crashes that occurred prior to the completion of the construction project. If significant changes to the roadway network occurred because of the construction, the analysis years should be modified. Significant changes to the roadway network may include traffic control modifications at an intersection (such as adding signalization at an intersection), additional turn lanes, roadway widening, alignment changes, or adding rumble strips. Significant changes to the roadway network do not include replacement of signs, repaving the road, or general maintenance activities. When in doubt, please contact the Iowa DOT reviewer. Practitioners should only include crash data during construction periods if the project did not result in significant changes to the roadway network.

For study areas with a construction project that resulted in significant changes to the network, the number of crash analysis years should be reduced to exclude crash data relating to the old configuration of the roadway network. A minimum of three complete calendar years of crash data post-construction is required to perform a crash analysis.

2.2.2.3. Before/After Analysis

When using crash data to perform a before/after analysis to evaluate the effectiveness of a construction project, a minimum of three complete calendar years of data prior to construction and three complete calendar years of data after completion of the project should be utilized. The full calendar year (or years) during which construction occurred should be excluded from the before/after analysis.

2.2.2.4. Land Use and/or Traffic Volume Changes

The number of analysis years may also need to be adjusted from the typical (five complete calendar years) crash analysis period due to land use and/or traffic volume changes, such as a location where significant and rapid development has occurred resulting in substantial traffic volume changes from one year to the next. For example, if during the analysis period the land use in the study area changed from agricultural to residential housing developments. For study areas with these types of changes, the analysis should be adjusted to eliminate crash data from years that are not indicative of current conditions in the study area. A minimum of three complete calendar years of crash data is required to perform a crash analysis.

2.2.2.5. No Crashes within Five Years

The number of years included in the crash analysis should be increased to 10 complete calendar years when no crashes have occurred within the study area during the typical five-year crash analysis period. The number of years included in an analysis should not be increased to capture additional high-severity crashes that may have occurred outside the typical five-year analysis period as increasing the number of years in the analysis to capture high-severity crash(es) can skew the safety analysis and result in greater safety benefits than are appropriate. Adjustments to the number of years of crash data used in the analysis must be documented and approved by the Iowa DOT reviewer.

2.2.3. Intersection Crashes

Due to the nature of how crashes occur in proximity to intersections it can, at times, be difficult to determine which crashes should be considered related to the intersection. The following sections outline the Iowa DOT's approach for determining intersection-related crashes for project-specific analysis and for network screening analysis.

Intersection-related crashes are not limited to the physical area of the intersection and are often located within the functional area of an intersection. Likewise, there may be crashes located within the functional area of an intersection that are not considered intersection-related (i.e, animal crashes). As shown in **Figure 2.2**, the functional area of an intersection includes areas upstream and downstream of an intersection where drivers perform intersection-related movements, including slowing, stopping, turning, merging, and queuing. Additional information on how to determine the functional area of intersection is located in the Iowa DOT Access Management Manual.

ACCESS MANAGEMENT MANUAL: LINK TBD

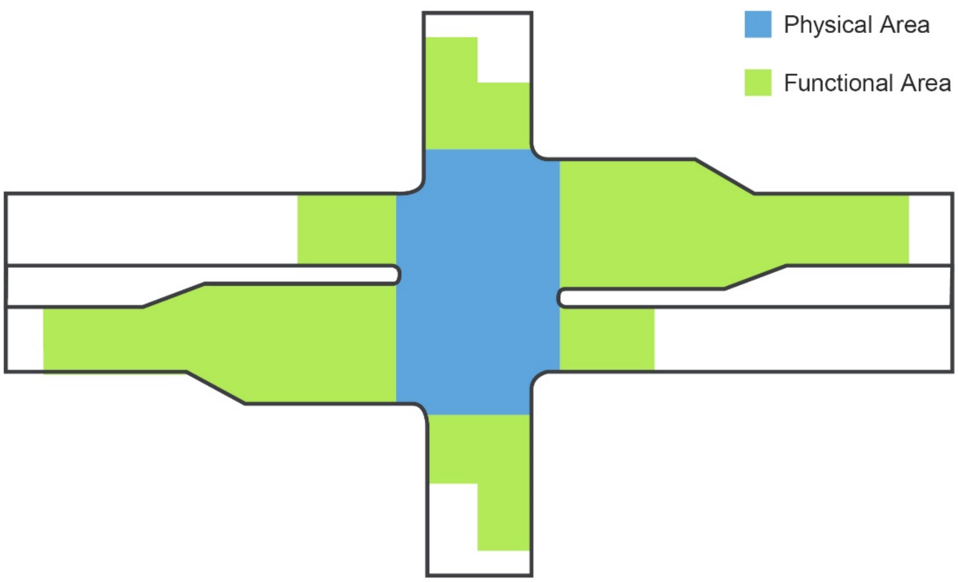


Figure 2.2 – Physical and Functional Areas of an Intersection

2.2.3.1. Project-Specific Intersection Crashes

When conducting safety analyses that include 10 intersections or less, crashes should be evaluated individually for each intersection to determine if the crashes can be attributed to the intersection. The following steps outline the process for determining intersection-related crashes for project-specific crash analysis purposes:

- Determine the functional area of the intersection. The Iowa DOT Access Management Manual provides instructions on how to calculate the upstream and downstream functional distance for each leg of an intersection.
- Use ICAT's selection tool to select all crashes within the physical area and functional area for each leg of the intersection. It is also possible to create a KMZ file of the functional area of the intersection and import the KMZ file into ICAT to assist in the selection of intersection-related crashes.
- Sometimes crashes located within the functional area of an intersection are not related to the intersection and should be removed from intersection analysis. The following crash types should be removed from intersection crash analysis:
  - Animal crashes
  - Construction or work zone related crashes
- Removal of any other crash type from the intersection analysis will require approval from the Iowa DOT reviewer.
- In some cases, the functional area of closely spaced intersections may overlap. When this happens, the practitioner should review crashes within the overlapping areas and assigned them to the proper intersection.

2.2.3.2. Network Screening Intersection Crashes

Some safety analyses cover a large network or area (containing more than 10 intersections) for analysis and screening. The following steps outline the process to follow for each intersection when determining intersection-related crashes for network screening purposes:

- Identify all crashes within a 250-foot radius of the center of the intersection using ICAT's point buffer selection tool.
- Filter for intersection-related only crashes within ICAT. It is important to note that an intersection-related crash is determined by the officer on the crash report, and some intersection-related crashes could be missed depending on how the crash report is filled out by the officer.
- Verify that the 250-foot buffer does not overlap with the buffer of the surrounding intersections. For crashes that occurred within 250 feet of more than one intersection, assign the crash to the nearest intersection.

2.3. Crash Modification Factors

This section provides an overview of CMFs and crash reduction factors (CRFs), discusses the Iowa Planning-Level CRF List, introduces the CMF Clearinghouse, and outlines various methods for applying multiple CMFs.

2.3.1. Crash Modification Factors and Crash Reduction Factors

CMFs and CRFs are values used to compute the anticipated number of crashes after implementing a countermeasure or safety treatment at a specific site. A CMF is a multiplicative factor that can be multiplied by the number of crashes at a specific site to compute the number of anticipated crashes after a countermeasure is implemented. A CRF is similar to a CMF but is stated as the percent reduction in crashes after a countermeasure is implemented at a specific site. CMF and CRF calculations are presented in **Figure 2.3** and **Figure 2.4**, respectively.

$$\text{CMF} = \frac{\text{ANTICIPATED CRASHES WITH TREATMENT}}{\text{ANTICIPATED CRASHES WITHOUT TREATMENT}}$$

CMF = 1.0	Anticipated to have no impact on safety
CMF < 1.0	Anticipated to reduce crashes
CMF > 1.0	Anticipated to increase crashes

Figure 2.3 – Crash Modification Factor Calculation

$$\text{CRF} = (1 - \text{CMF}) * 100$$

Figure 2.4 – Crash Reduction Factor Calculation

2.3.2. Iowa Planning-Level Crash Reduction Factor List

The Iowa Planning-Level CRF List was developed as a resource to provide consistent CRFs for planning-level purposes. It was developed by compiling all known and applicable research related to each countermeasure and determining a planning-level CRF value. One of the main purposes for the development of the Iowa Planning-Level CRF List was to enable the consistent application of CRF values for the same countermeasures whenever possible. This allows projects implementing the same countermeasures to be evaluated equally. The Iowa Planning-Level CRF List includes CRFs for the following facility types:

- Unsignalized intersections
- Signalized intersections
- Road segments
- Curve segments
- Interchanges
- Railroads
- Pedestrians
- Bicycles

The Iowa Planning-Level CRF List should be the first source reviewed when selecting CRFs or CMFs for use in safety analyses. It is anticipated that the CRF list will be updated periodically to include the latest research as it relates to Iowa. The Iowa Planning-Level CRF List is available on the Iowa DOT website.

IOWA PLANNING-LEVEL CRF LIST: https://iowadot.gov/traffic/pdfs/CRFListVersion.pdf

If a desired countermeasure is not located within the Iowa Planning-Level CRF List, then the practitioner should follow the guidance identified in **Section 2.3.3** for using the CMF Clearinghouse to select a CMF.

2.3.3. Crash Modification Factor Clearinghouse

The CMF Clearinghouse is a central, web-based repository of CMFs. This searchable database is funded by the Federal Highway Administration (FHWA) with the purpose of serving three important roles for the transportation safety field:

- Provide CMF data
- Educate CMF users
- Facilitate CMF research

The CMF Clearinghouse website includes both quick and advanced search features to help practitioners search for CMFs applicable to countermeasures. The CMF Clearinghouse is available on the following website:

CMF CLEARINGHOUSE: http://www.cmfclearinghouse.org

The CMF Clearinghouse should only be used to identify CMFs when applicable CRFs are not available in the Iowa Planning-Level CRF List.

2.3.3.1. Star Rating System

CMFs in the CMF Clearinghouse are given a star rating from one to five stars. Star ratings indicate a CMF's reliability and quality, with five stars being the most reliable. Star ratings consider various factors from the study that calculated the CMF(s), including data used, sample size, study design and methodology, and statistical significance of the results. More information on how star ratings are calculated is available on the following link:

STAR RATING SYSTEM: http://www.cmfclearinghouse.org/sqr.cfm

Star rating criteria was changed in February 2021, as part of the National Cooperative Highway Research Program (NCHRP) 17-72 project. This resulted in many CMFs receiving a new star rating based on the updated evaluation criteria. CMF summary reports printed prior to February 2021 may contain star ratings that differ from current criteria.

FEBRUARY 2021 STAR RATING CHANGES: http://www.cmfclearinghouse.org/changes.cfm

It is recommended that CMFs with a star rating of three or higher be used in analysis. Higher star ratings indicate a higher quality CMF based on the study performed to develop the CMF. If the best available CMF has a star rating lower than three, it may be used with approval from the Iowa DOT reviewer. A CMF's ID number and star rating must be documented if used for safety analysis.

2.3.3.2. Selecting Crash Modification Factors

Caution should be used when selecting CMFs. The primary goal is to select a CMF that was developed under the same (or very similar) conditions as the site to which it is being applied. The practitioner should read the abstract and determine if the CMF is applicable to the countermeasure being proposed along with the crash types and severity for the location. The following items should be considered when selecting an appropriate CMF:

- Countermeasure type
- Crash types addressed by the countermeasure
- Crash severity
- Area type
- Annual average daily traffic (AADT) ranges
- Prior conditions
- Similarity to locality where data are used
- Choose CMFs that were developed in similar terrain, weather, and other geographic characteristics to the project area

If multiple CMFs are available and appear to have similar characteristics, then the following CMF quality items should be reviewed to determine the best possible match:

- Star rating
- Score details
- Age of data or study

It is important that sound professional judgment be used when selecting CMFs. Additional guidance on selecting CMFs is available the following link:

SELECTING CMFS: http://www.cmfclearinghouse.org/userguide_identify.cfm

When CMFs from the CMF Clearinghouse are used in an analysis, the CMF ID must be documented and the CMF detail summary page from the CMF Clearinghouse website should be provided. This information should be saved as a PDF and included as an appendix or attachment in the analysis documentation. An example of the CMF detail summary page is in **Appendix B**.

2.3.4. Methods for Applying Multiple Crash Modification Factors

Often roadway projects include multiple safety-related improvements. When multiple safety-related improvements are being planned for a roadway project, there is the possibility that multiple CMFs will be applicable for the situation. Because CMFs are not always independent of one another, sometimes practitioners overestimate the potential for crash reduction when they apply multiple CMFs to a project.

A CMF is considered independent of another CMF if there is no overlap in the crash type that both CMFs have the potential to reduce when applied. For example, the installation of a pedestrian signal would be relatively independent of the installation of a left-turn phase at an adjacent intersection, since one addresses pedestrian-vehicle crashes while the other addresses left-turn opposite-direction crashes. Likewise, the conversion of a left-turn phase from permissive to protected along with the installation of an exclusive right-turn lane would be another example of independent or no overlap in the crash types addressed by CMFs, since the improvements target different crash types.

An example of overlapping or non-independent CMFs is a roadway project that includes multiple countermeasures focused on reducing similar crash types. For example, shoulder rumble strips and enhanced edgeline retroreflectivity would both target roadway departure crashes, so the CMFs for these treatments would be highly related. Other examples of related CMFs would be the use of increased lighting and installation of pavement reflectors, both of which would target nighttime crashes; and the installation of chevrons and advanced curve warning signs, both of which would target curve-related crashes.

Table 2.3 and the following sections provide an overview of the three methodologies that may be used to apply multiple CMFs in Iowa.

Table 2.3 – Methods for Applying Multiple Crash Modification Factors

Method	Brief Description	Iowa DOT Preferred Method
Dominant Common Residuals Method	Apply a Combined CMF Value by Multiplying the Individual CMFs Values Together and then Raising that Value to the Power of the Lowest CMF Value	✓
Dominant Effect Method	Apply Only One CMF with the Lowest CMF Value	
Multiplicative Method	Apply the Combined CMF Value by Multiplying the Individual CMFs Values Together	

Regardless of which methodology is utilized, no more than three CMFs may be applied at a particular site. The following subsections provide more detail on the different methods for applying multiple CMFs and describe when each method may be appropriate for application. It should be noted that multiple CRF's may be applied from the Iowa Planning-Level CRF List. When using multiple CRFs they must first be converted to CMFs before applying one of the methodologies found in this section.

Dominant Common Residuals Method (Iowa DOT Preferred Method)
The dominant common residuals method assumes that the CMFs are not independent or that they overlap one another. The combined effect of the countermeasures being applied is calculated by multiplying the individual CMF values together for each countermeasure and then raising that value to the power of the most effective (lowest) CMF value. The following is an example of how the dominant common residuals method's combined CMF value is calculated.

$$CMF_{Combined} = (CMF_1 \times CMF_2 \times CMF_3)^{CMF_1}$$

This method is more conservative than other methods (such as the multiplicative method), and it is not appropriate for CMFs with values greater than 1.0. When the combined CMF value is raised to a power greater than 1.0 this intensifies the effects of the combined CMF rather than dampening its effects.

The Iowa DOT recommends that the dominant common residuals method be used for applying multiple CMFs even if the CMFs are independent of one another. This method is recommended because it applies a slightly more conservative approach and reduces the potential for overestimating the potential for crash reduction. If an alternative method is used for applying multiple CMFs, the reasoning should be documented, and will need to be approved by the Iowa DOT reviewer.

Dominant Effect Method
The dominant effect method applies only the CMF with the lowest value (the greatest potential for crash reduction). This method is intended to be the simplest and most conservative approach. The primary limitation to this method is that it likely underestimates the combined effects of the overall safety improvements or countermeasures. This method is applicable when the CMFs are non-independent of one another with extreme overlap (i.e., a planned project to install paved shoulders, edgeline rumble strips, and wider edgeline pavement markings) and only the CMF with the lowest value is applied in the analysis.

Multiplicative Method
The multiplicative method estimates the combined effect of CMFs for multiple countermeasures. Individual CMF values for each countermeasure are multiplied together to determine a combined CMF value. The following is an example of the multiplicative method:

$$CMF_{Combined} = CMF_1 \times CMF_2 \times CMF_3$$

The primary limitation of this method is that it underestimates or overestimates the combined effects of the overall safety improvements, or countermeasures, if their effects are not independent of one another. The multiplicative method assumes that all of the CMFs are independent of one another with no overlap and should only be applied when it is determined that the CMFs are independent of one another (i.e., the conversion of a left-turn phase from permissive to protected along with the installation of an exclusive right-turn lane).

2.4. Highway Safety Manual Predictive Method

Part C of the HSM outlines the Predictive Method, which is used for estimating predicted and expected average crash frequencies for existing and proposed future roadway conditions over a given time period. The HSM Predictive Method provides an 18-step process used to estimate average crash frequencies for a roadway network, facility, or site. The predicted average crash frequency of an individual site is estimated based on traffic volumes, geometric design features, and traffic control type. A roadway network must be divided into individual sites of either homogenous roadway segments or intersections to run the Predictive Method. Predictive models were developed to predict crashes for a variety of facility types using regression models developed from data of similar sites across the country. These regression models, located in the HSM, are known as SPFs. SPFs have been developed for specific facility types under what is called "base conditions" or the most predominant conditions for the similar sites across the country.

Adjustments to crash predictions calculated using SPFs are necessary to account for the differences between base conditions and site-specific conditions for the location being analyzed. A SPF only predicts for base conditions, and CMFs are applied to the site-specific conditions during analysis. It is important to note that there is a difference in the CMFs located in the HSM Part C and CMFs located in the Iowa DOT CFR list and the CMF Clearinghouse. For the CMFs located in the HSM Part C, multiple CMFs can be applied, and do not need to follow the methods for applying multiple CMFs. To eliminate the confusion between CMFs located on the Clearinghouse website and CMFs developed for a specific SPF within the HSM, the Highway Safety Manual 2nd Edition (HSM2) will change SPF-related CMFs to be called Adjustment Factors (AFs).

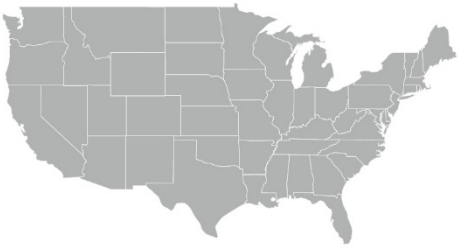
Jurisdiction-specific adjustments to the predicted crash totals can be made using a calibration factor. This accounts for differences between the jurisdiction(s) for which the models were developed and the jurisdiction for which the predictive model is being applied. Iowa has developed calibration factors which are covered in more detail in **Section 2.6**.

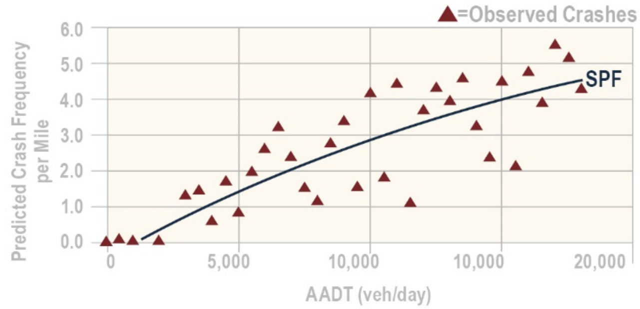
A summary of the HSM Predictive Method is located in **Figure 2.5**.

The HSM has developed predictive models for the following facility types. Additional facility types will be included in HSM2.

- Rural two-lane, two-way roads
- Rural multilane highways
- Urban and suburban arterials
- Freeways and ramps

Safety Performance Function (SPF)





SPF Related Crash Modification Factors (CMFs)

The crash predictions are calculated based on the particular roadway conditions for a homogenous site/segments specified by a SPF. These SPFs have particular CMFs associated with their development and are included in the HSM for that particular roadway type. All of the CMFs associated with a SPF in the HSM may be applied to the crash prediction calculations.

- **CMF =** $\frac{\text{Anticipated crashes with treatment}}{\text{Anticipated crashes without treatment}}$
- **CMF = 1.0 = Anticipated to have no impact on safety**
- **CMF < 1.0 = Anticipated to reduce crashes**
- **CMF > 1.0 = Anticipated increase crashes**

Calibration Factor

A **calibration factor** is applied to adjust the estimated crashes from national data to local conditions by comparing observed crashes for 30 to 50 local sites and the crashes predicted from the national data. If a calibration factor is not available for specific SPF, a calibration factor of 1 should be used.

$$\text{Calibration Factor} = \frac{\sum \text{Observed Crashes (sample sites)}}{\sum \text{Predicted Crashes (sample sites)}}$$

Figure 2.5 – Highway Safety Manual Predictive Method

2.5. Predicted Versus Expected Crashes

The HSM Predictive Method can be used to determine predicted and expected average crash frequencies. **Table 2.4** provides a brief summary of the differences between predicted and expected crashes.

Table 2.4 – Predicted Verses Expected Crashes

Difference	Predicted Crashes (Empirical Bayes Method is Not Applicable)	Expected Crashes (Empirical Bayes Method is Applicable)
Data Used to Calculate?	No Observed Crash Data Used	Observed Crash Data is Used
Accuracy?	Less Accurate	More Accurate
What Does it Mean?	Anticipated Crashes are not Adjusted Based on Observed Crash Data	Anticipated Crashes are Adjusted Based on Observed Crash Data
When Can I Calculate it?	Alternatives Analysis of New Projects, Alternatives Analysis When Alternatives Contain Major Changes (i.e., Signal to Roundabout, Undivided to Divided Roadway)	Existing Crash Data is Available, Alternatives Analysis When There Are Only Minor or No Changes to Existing Conditions
Is Regression-to-the-Mean (RTM) Bias accounted for?	No	Yes

The predicted average crash frequency for an individual site is determined based on traffic volumes, geometric design, and traffic control for the site using the SPF developed for the facility type. Observed crash data are not utilized in the Predictive Method when calculating a predicted average crash frequency.

For an existing site or facility, the observed crash frequency can then be combined with the predicted average crash frequency to improve the reliability of the estimate and determine an expected average crash frequency. This is accomplished through the application of the Empirical Bayes (EB) Method within the Predictive Method to account for the statistical reliability of the SPF and Regression-to-the-Mean (RTM) bias. The EB Method can only be applied when observed crash data are available. The HSM defines the EB Method as the method used to combined observed crash frequency data for a given site with the predicted crash frequency data from many similar sites to estimate its expected crash frequency.

Figure 2.6 demonstrates the relationship between predicted (■), expected (◆), and observed crashes (●) when applying the EB Method.

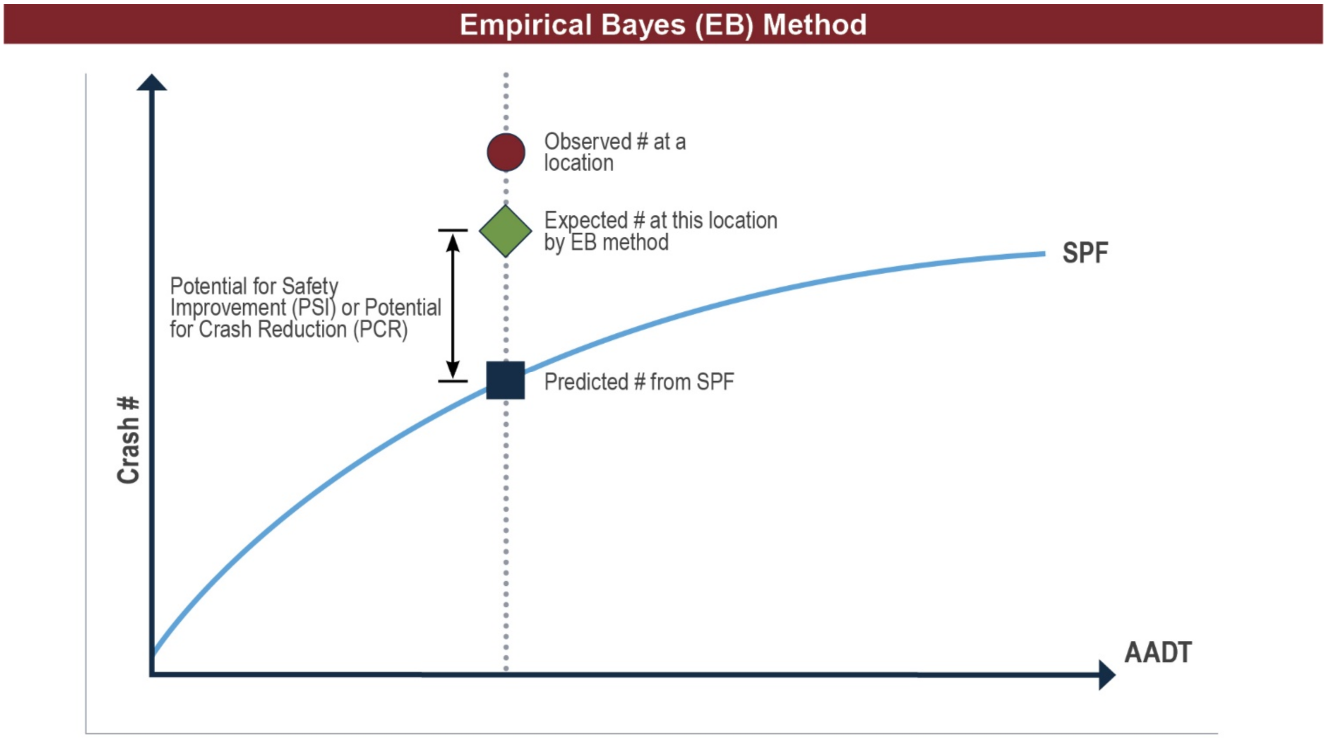


Figure 2.6 – Empirical Bayes Method

The difference between the number of expected and predicted crashes is identified as the potential for safety improvement (PSI) of a particular site. Iowa uses the term Potential for Crash Reduction (PCR) instead of PSI. The term PCR will be used through the remainder of the SAG. PCR is further defined in **Section 4.1.2**.

Because crash totals fluctuate over time it is difficult to know whether changes in the observed crash totals are due to changes in site conditions or are due to natural fluctuations. This means that a time period with a high number of observed crashes is statistically probable to be followed by a time period with a low number of observed crashes. This tendency to regress to the mean or average is known as RTM. The inverse of this tendency also applies to the probability that the time period with low crash totals will be followed by time period with high crash totals. Failure to account for the effects of RTM introduces the potential for RTM bias which is also known as selection bias. RTM bias results in overestimating or underestimating the effectiveness of a treatment. The effects of RTM bias are illustrated in **Figure 2.7**.

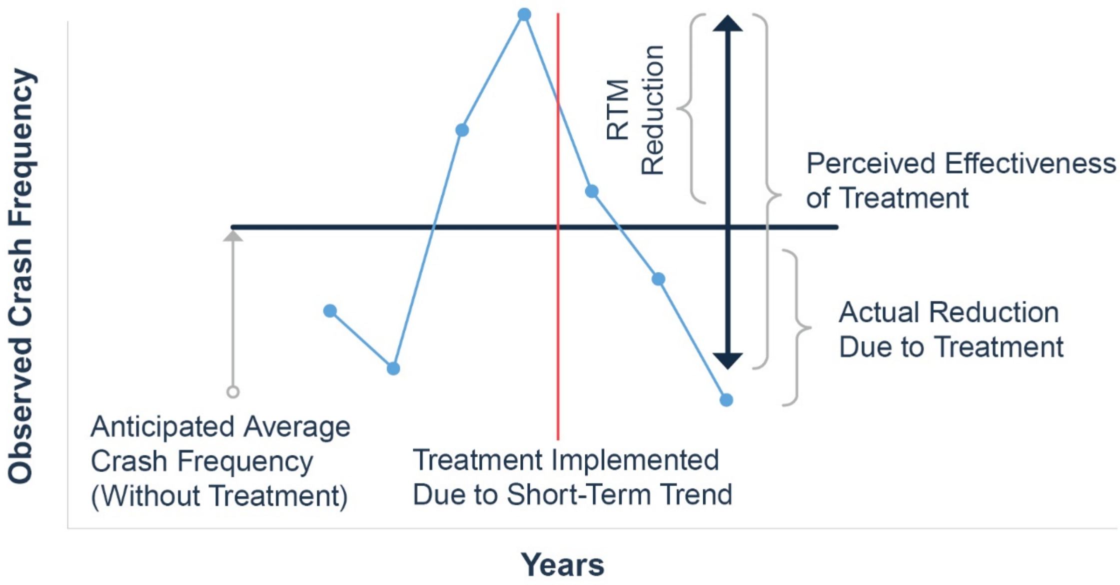


Figure 2.7 – Regression-to-the-Mean Bias

The practitioner must decide if the EB Method is applicable for the type of analysis being performed. **Table 2.5** identifies the scenarios when the EB Method is applicable and not applicable on analyses involving future planned project types as identified in the HSM.

Table 2.5 - Applicability of the Empirical Bayes Method

EB Method is Not Applicable (Predicted Crashes)	EB Method is Applicable (Expected Crashes)
EB method is not applicable for the following types of situations: ▪ new alignments for a substantial proportion of the project length ▪ basic number of intersection legs or traffic control type is changed	EB method is applicable for the following types of situations: ▪ geometrics and traffic control features are not being changed (for example the “do-nothing alternative”) ▪ where the roadway cross section is modified but the basic number of through lanes remains the same ▪ minor changes in alignment are made while still leaving the majority of the alignment intact ▪ a passing lane or short four-lane section is added to a rural two-lane, two-way road ▪ any combination of the above improvements

When comparing results among proposed conditions or alternatives, it is important that all of the results are either predicted crashes or all of the results are expected crashes to ensure that there are consistent results for comparison across alternatives. If the EB Method is not applicable for one alternative, then all of the alternatives should be analyzed for predicted crashes only.

2.6. Iowa Calibration Factors

Iowa-specific calibration factors were derived by comparing crash prediction results using the HSM crash prediction models to statewide observed crashes. These calibration factors adjust the HSM crash prediction model results to account for differences in geography, crash reporting, enforcement policies, and driver behavior between the HSM models and Iowa crash characteristics. Iowa-specific calibration factors for roadway segments and intersections are included in **Table 2.6** and **Table 2.7**, respectively.

Table 2.6 – Iowa Calibration Factors – Segments

Facility Type - Segments		Calibration Factor (Total Crashes)
Rural Two-Lane, Two-Way Roads		
2U	Two-Lane Undivided	*
Rural Multilane Highways		
4U	Four-Lane Undivided	*
4D	Four-Lane Divided	*
Urban and Suburban Arterials		
2U	Two-Lane Undivided	1.63
3T	Three-Lane with Two-Way Left-Turn Lane (TWLTL)	1.53
4U	Four-Lane Undivided	1.70
4D	Four-Lane Divided	2.44
5T	Five-Lane with TWLTL	1.14

** Calibration factor is currently under development*

Table 2.7 – Iowa Calibration Factors – Intersections

Facility Type - Intersection		Calibration Factor (Total Crashes)
Rural Two-Lane, Two-Way Roads		
3ST	Unsignalized Three-Leg, Minor Stop	*
4ST	Unsignalized Four-Leg, Minor Stop	*
4SG	Signalized Four-Leg	*
Rural Multilane Highways		
3ST	Unsignalized Three-Leg, Minor Stop	*
4ST	Unsignalized Four-Leg, Minor Stop	*
4SG	Signalized Four-Leg	*
Urban and Suburban Arterials		
3ST	Unsignalized Three-Leg, Minor Stop	*
3SG	Signalized Three-Leg	*
4ST	Unsignalized Four-Leg, Minor Stop	*
4SG	Signalized Four-Leg	*

** Calibration factor is currently under development*

Additional information on the Iowa-specific calibration factors is available on the Iowa DOT website.

IOWA CALIBRATION FACTORS: LINK TBD

2.6.1. Application Guidance

Iowa-specific calibration factors are to only be used in conjunction with their associated HSM SPFs. This ensures that HSM prediction models account for local conditions in Iowa. The Iowa-specific calibration factors located in this document should not be applied to the Iowa-specific SPFs (**Section 2.7**) as these SPFs were developed using only Iowa-specific data and already take into account the unique aspects of what is occurring on Iowa roadways. Several of the tools developed to help conduct safety analyses using the HSM Predictive Method have features that allow the practitioner to input locally derived calibration factors.

2.7. Iowa Safety Performance Functions

Iowa-specific SPFs have been developed for 11 categories of paved intersections. The 11 intersection categories are presented in **Table 2.8**. These SPFs are used to calculate a PCR for intersections throughout the state and are intended to replace crash rates in safety analyses (**Section 2.7.1**). Additional information related to PCR for intersections is available on the Iowa DOT PCR of Intersections website:

IOWA DOT PCR OF INTERSECTIONS:
https://iowadot.maps.arcgis.com/apps/MapSeries/index.html?appid=6920b9b36fa54caa90c25bd6dcdd0c7e

Table 2.8 – Iowa Safety Performance Function Intersection Categories

Category	Description
1	Divided and Undivided, High-Speed (>45 mph), Traffic Signal Control
2	Divided, High-Speed, Partial Stop Control
3	Divided, Low-Speed (<= 45 mph), Traffic Signal Control
4	Divided, Low-Speed, Partial Stop Control
5	Undivided, High-Speed, Partial Stop Control
6	Undivided, Low-Speed, Traffic Signal Control
7	Undivided, Low-Speed, Partial Stop Control
8	Roundabout
9	All-Way Stop Control
10	Yield Control
11	Uncontrolled

Iowa is currently working on developing Iowa-specific SPFs for roadway segments. That data will be made available online when it is finalized in a similar fashion as the PCR of Intersections website.

2.7.1. Crash Rates

The use of simple crash rates, frequency, or crash rate comparisons is not recommended when performing any type of safety analysis. The Iowa-specific SPFs that have been developed (or are under development) should be used in the place of crash rates for crash analyses. It should also be noted that statewide average crash rate lists are out of date and will not be updated. No safety analysis should include statewide average crash rates and/or a comparison of crash rates as part of the analysis.

2.7.2. Application Guidance

The Iowa-specific SPFs located on the PCR website should be used for safety performance comparison. The PCR website uses the Iowa-specific SPFs to rank facilities throughout the state and allow the practitioner to compare a particular facility with the average of that facility type throughout the state. Based on the PCR, each facility type is ranked into safety tiers with Tier 1 locations being eligible for safety funding. Information that can be obtained from the PCR website includes:

- Number of observed crashes
  - All crashes (KABCO)
  - Injurious crashes (KAB)
- PCR per year
  - All crashes (KABCO)
  - Injurious crashes (KAB)
- Overall rankings
  - All crashes (KABCO)
  - Injurious crashes (KAB)
- Category rankings
  - All crashes (KABCO)
  - Injurious crashes (KAB)
- Safety tier
  - Tier 1 locations are eligible for safety funding

2.8. Safety Valuation

The following section provides an overview of safety valuation information related to Iowa safety analysis in terms of societal crash costs and benefit-cost analysis.

2.8.1. Societal Crash Costs

The societal crash cost for Iowa was determined using the latest guidance documented in the FHWA report Crash Costs for Highway Safety Analysis (Report No. FHWA-SA-17-071). Table 2.9 displays Iowa-specific crash costs that should be used in safety analyses. Crash costs are updated periodically, and it is the practitioner's responsibility to ensure the most up-to-date crash costs are being utilized. Additional Iowa crash cost information is available on the Iowa DOT website.

Table 2.9 – Iowa Crash Costs

Crash Severity	Iowa Crash Cost (2001 Dollars)
Fatal Crash (K)	$3,253,349
Suspected Serious Injury Crash (A)	$3,253,349
Suspected Minor Injury Crash (B)	$217,607
Possible/Unknown Injury Crash (C)	$102,564
Property Damage Only Crash (O)	$12,656

Based on HSM Guidance, apply inflation of 4% annually to calculate current year cost.

IOWA CRASH COSTS: LINK TBD

2.8.2. Safety Benefit-Cost Analysis

The purpose of a safety benefit-cost analysis is to identify the relationship between the anticipated safety benefits of a specific project, countermeasure, or set of countermeasures and the project costs. The safety benefit is calculated based on the number of crashes reduced and the societal crash costs (**Section 2.8.1**). A benefit-cost ratio (BCR) is the ratio of the present value benefits to the cost of implementing the project. **Figure 2.8** displays how a BCR is calculated. Additional guidance on calculating Iowa-specific BCRs is located in **Section 4.3**.

$$BCR = \frac{PV_{\text{BENEFITS}}}{PV_{\text{COSTS}}}$$

PV BENEFITS = Present Value of Project Benefits

PV COSTS = Present Value of Project Costs

Figure 2.8 – Benefit-Cost Ratio Calculation

3. Safety Analysis Requirements

This section includes the safety analysis requirements for conducting safety processes and procedures for the Iowa DOT.

3.1. Identified Safety Processes and Procedures

In order to develop the SAG, known safety processes and procedures were reviewed to identify the requirements for safety analyses. The following safety-related processes and procedures were identified:

- Response to crash data request
- Traffic impact analysis (TIA)
- Road safety audit (RSA)
- Intersection control evaluation (ICE)
- Highway Safety Improvement Program (HSIP) application
- Traffic Safety Improvement Program (TSIP) application
- Design exceptions
- Interchange Justification Report (IJR)
- Interchange Operations Report (IOR)
- Planning and Environmental Linkages (PEL) Study
- Project concept statement
- Alternative analysis
- Corridor study
- Signal warrant study
- Traffic signal evaluation
- Speed zone review
- Lighting warrant
- School crossing study

3.2. Safety Analysis Requirements

The safety analysis requirements for each of the identified safety processes are outlined in **Table 3.1**. An overview of how to perform the various safety analysis types is provided in **Section 4**.

<<<Note: Kimley-Horn would like feedback from the Iowa DOT on how the table is filled out. Additional discussion should take place on items such as ICE and RSAs since there are guides available. Also, discussion on how to represent flexibility (i.e., sometimes for a corridor study observed crashes with CMF adjustments or HSM Predictive Method can be utilized based on the situation), but we would want a practitioner to do at least one or the other. This could be addressed with different icons in the table.>>>

Table 3.1 – Safety Analysis Requirements

Processes and Procedures	Type of Safety Analysis to Include										
	Existing Conditions Safety Analysis				Future Conditions Safety Analysis			Benefit-Cost Analysis		Special Analysis	
	Crash Summary Tables (4.1.1.1)	Crash Figures (4.1.1.2)	Collision Diagrams (4.1.1.3)	PCR Analysis (4.1.2)	Relative CMF Comparison (4.2.1)	Observed Crashes w/ CMF Adjustments (4.2.2)	HSM Predictive Method (4.2.3)	CMF Benefit-Cost (4.3.1)	Predictive Benefit-Cost (4.3.2)	Bike/Ped Analysis (4.4.1)	Systemic Safety (4.4.2)
Response to Crash Data Request	✓	✓									
TIA	✓										
RSA	✓	✓	✓			✓				✓	
ICE	✓	✓					✓				
HSIP Application	✓	✓		✓		✓		✓			
TSIP Application	✓	✓		✓			✓		✓		
Design Exceptions							✓		✓		
IJR	✓	✓	✓			✓	✓				
IOR	✓	✓	✓			✓	✓				
PEL Study	✓	✓		✓		✓					
Project Concept Statement	✓	✓		✓		✓					
Alternatives Analysis	✓	✓			✓		✓		✓		
Corridor Study	✓	✓	✓	✓		✓	✓	✓	✓		

Processes and Procedures	Type of Safety Analysis to Include										
	Existing Conditions Safety Analysis				Future Conditions Safety Analysis			Benefit-Cost Analysis		Special Analysis	
	Crash Summary Tables (4.1.1.1)	Crash Figures (4.1.1.2)	Collision Diagrams (4.1.1.3)	PCR Analysis (4.1.2)	Relative CMF Comparison (4.2.1)	Observed Crashes w/ CMF Adjustments (4.2.2)	HSM Predictive Method (4.2.3)	CMF Benefit-Cost (4.3.1)	Predictive Benefit-Cost (4.3.2)	Bike/Ped Analysis (4.4.1)	Systemic Safety (4.4.2)
Signal Warrant Study	✓										
Traffic Signal Evaluation	✓										
Speed Zone Review	✓										
Lighting Warrant	✓										
School Crossing Study	✓									✓	

4. Safety Analysis Methods

This section of the SAG provides a summary of the various safety analysis methods that are required for the different processes and procedures and identifies the steps required to complete the required safety analyses. Tools that can be used to complete a particular safety analysis are also identified. **Figure 4.1** contains each of the various safety analysis methods covered in this section.

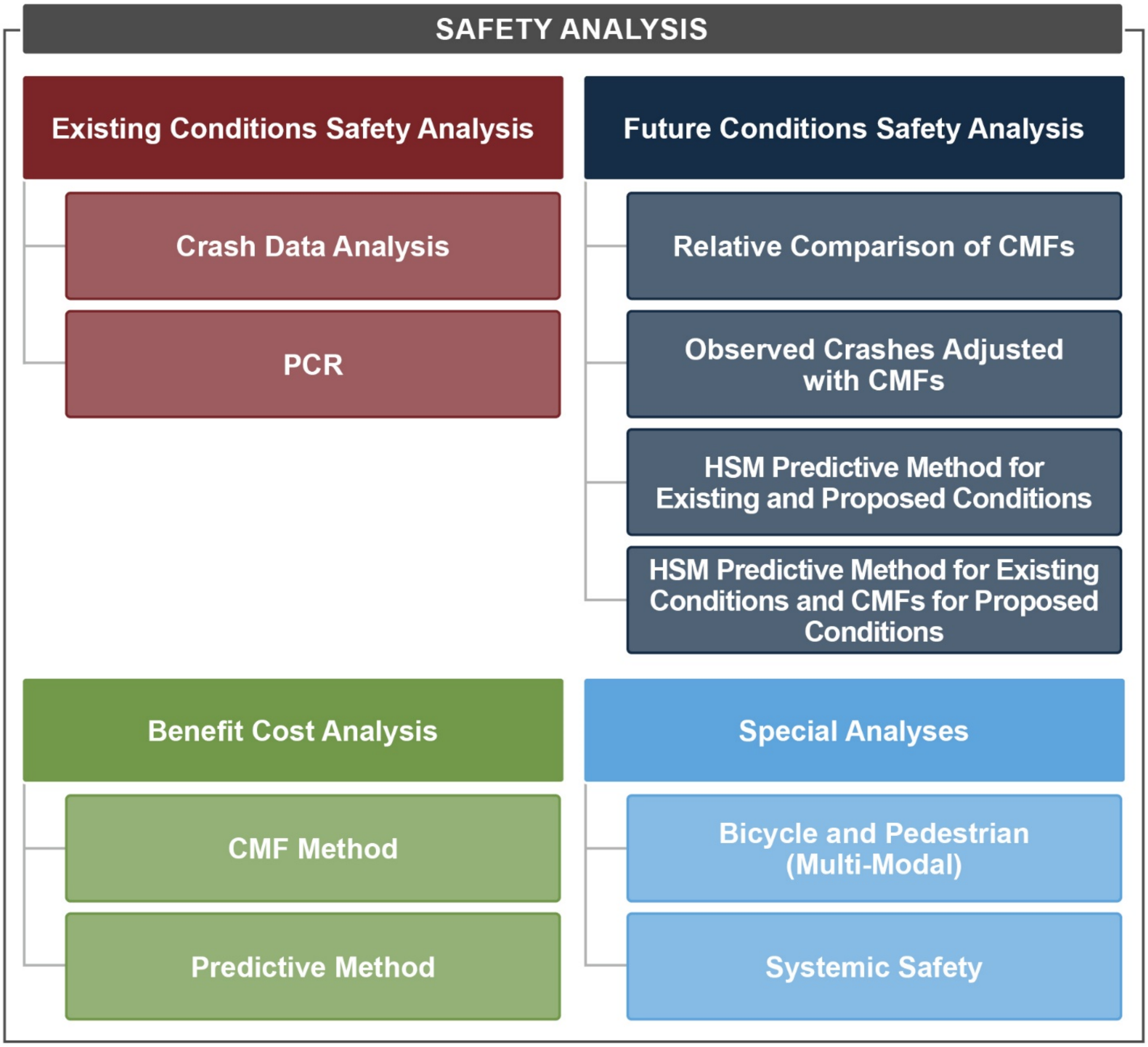


Figure 4.1 – Safety Analysis Methods

4.1. Existing Conditions Safety Analysis

Many safety processes and procedures require that an analysis be performed to analyze the existing conditions. The following sections provide an overview of the requirements to perform an existing conditions safety analysis. Existing conditions safety analyses include crash data analysis and a PCR analysis.

4.1.1. Crash Data Analysis

Crash data analysis is broken into three types of analyses as covered in the following subsections: crash summary tables, crash figures, and collision diagrams. Crash data used in each analysis should be obtained from ICAT. ICAT and associated tutorials can be accessed through the following links.

ICAT: https://icat.iowadot.gov

ICAT TUTORIALS: https://iowadot.gov/traffic/icat-tutorial

4.1.1.1. Crash Summary Tables

Crash summary tables describe crashes numerically and can be used to identify crash patterns. Tables should include a row for each study intersection and/or roadway segment and a column for each category of crashes being summarized. At a minimum, crash summary tables should include five tables summarizing crash severity, manner of crash collision, vehicle action, contributing circumstance (driver), and injury status. Crashes should follow the National Safety Council KABCO crash severity scale:

- Fatal crash (K)
- Suspected serious injury crash (A)
- Suspected minor injury crash (B)
- Possible/unknown injury crash (C)
- Property damage only crash (O)

Summary tables should summarize the total number of injuries by crash with the exception of the injury status summary table, which should summarize the total number of injuries by injury severity. Additional tables may be provided at the practitioner's discretion or at the request of the Iowa DOT reviewer. Additional crash summary tables could include information related to weather, location, time of day, day of week, month of year, year, driver characteristics, first harmful event, etc.

Analysis Steps
- Determine analysis study area
- Determine crash analysis years
- Use ICAT to filter for crash data
- Create required crash summary tables
  - Crash severity
  - Manner of crash collision
  - Vehicle action
  - Contributing circumstance (driver)
  - Injury status
- Create additional crash summary tables (as needed)
- Review crash summary tables and identify crash patterns

Documentation Requirements
At a minimum the following crash summary tables are required:

- Crash severity
- Manner of crash collision
- Vehicle action
- Contributing circumstance (driver)
- Injury status

The years of crash data utilized in developing the tables should be included in the table title or as a footnote to the table. Raw crash data should be provided as an appendix or attachment to the crash analysis documentation. The raw crash data should be in the form of one of the various reports that can be generated in ICAT. Following is the link to access ICAT and associated tutorials.

ICAT: https://icat.iowadot.gov

ICAT TUTORIALS: https://iowadot.gov/traffic/icat-tutorial

Example Crash Summary Tables

Examples of crashes summarized by crash severity and manner of crash collision are located in **Table 4.1** and **Table 4.2**, respectively. **Table 4.2** is not meant to give an exhaustive list of all manner of crash collision types but rather to provide an example of what a possible crash summary table could look like. The example tables do not represent an actual location in Iowa and are meant only to show what a crash summary table could look like.

Table 4.1 – Crash Severity

Intersection / Roadway	Crash Severity					Total
	Fatal (K)	Suspected Serious Injury (A)	Suspected Minor Injury (B)	Possible/ Unknown Injury (C)	Property Damage Only (O)	
Intersection 1	1	1	3	6	8	19
Intersection 2	0	2	0	4	12	18
Intersection 3	2	1	0	5	2	10
Roadway 1	0	0	4	4	6	14
Roadway 2	3	4	3	5	19	34
Total	**6**	**8**	**10**	**24**	**47**	**95**

Source: ICAT, 2016 - 2020

Table 4.2 – Manner of Crash Collision

Intersection / Roadway	Manner of Crash Collision							Total
	Rear-End	Head-On	Non-Collision	Angle	Sideswipe	Broadside	Other	
Intersection 1	8	5	1	1	3	0	1	19
Intersection 2	2	1	0	7	6	1	1	18
Intersection 3	0	2	1	5	0	1	1	10
Roadway 1	1	3	3	4	0	1	2	14
Roadway 2	3	2	5	16	2	3	3	34
Total	**14**	**13**	**10**	**33**	**11**	**6**	**8**	**95**

Source: ICAT, 2016 - 2020

4.1.1.2. Crash Figures

Crash figures, maps, charts, and/or graphs to display crashes graphically or spatially and can be used to identify crash patterns which can be indicative of potential safety issues. Crash figures should accompany the summary tables and are intended to aid in crash analysis by providing supplemental information to what is provided in the crash summary tables. There is no set requirement related to the type of crash figures that should be included. The practitioner should use professional judgment to determine which crash figures would be most helpful based on the type of crashes that have occurred at the analysis location. The visual presentation of crash data analysis can be generated in ICAT or in other programs including geographic information systems (GIS).

Analysis Steps

- Determine analysis study area
- Determine crash analysis years
- Use ICAT to filter for crash data
- Create needed crash figures
- Review figures and identify crash patterns

Documentation Requirements

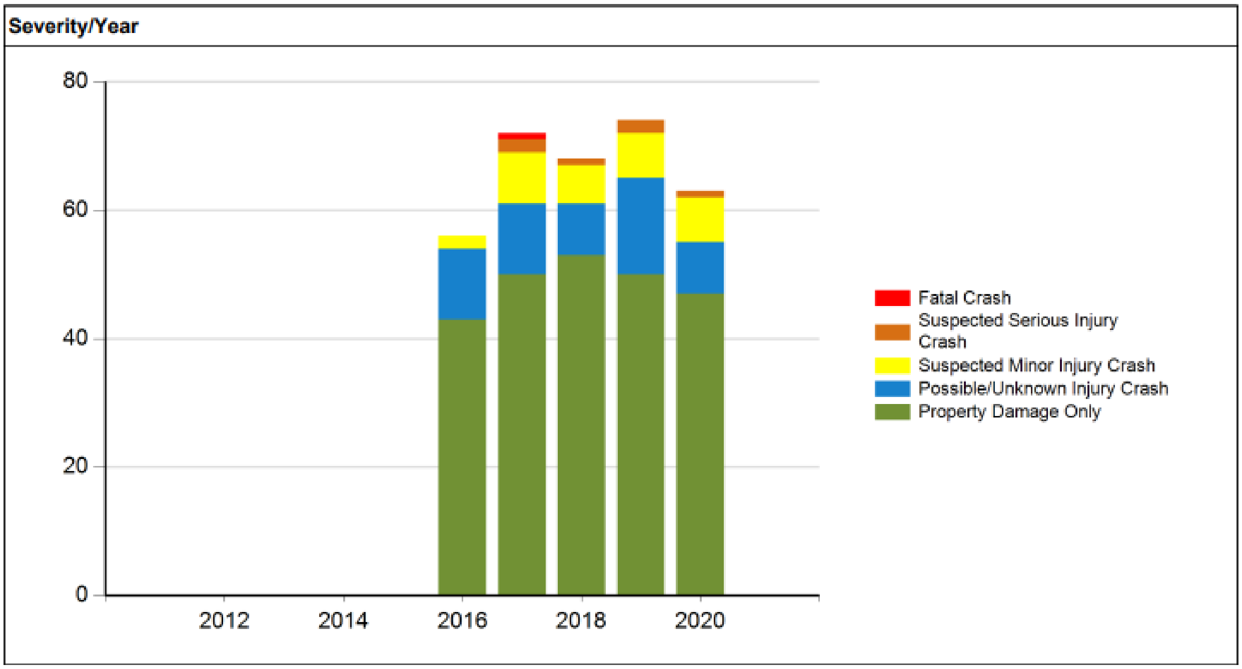
Provide appropriate crash figures. There is no set requirement related to the type of crash figures that should be included. The years of crash data utilized in developing the figures should be included in the figure title or as a footnote to the figure. Crash data used in creating crash figures should be obtained from ICAT. Raw crash data should be provided as an appendix or attachment to the crash analysis documentation. The raw crash data can be in the form of one of the various reports that is generated in ICAT. Following is the link to access ICAT and associated tutorials.

ICAT: https://icat.iowadot.gov

ICAT TUTORIALS: *https://iowadot.gov/traffic/icat-tutorial*

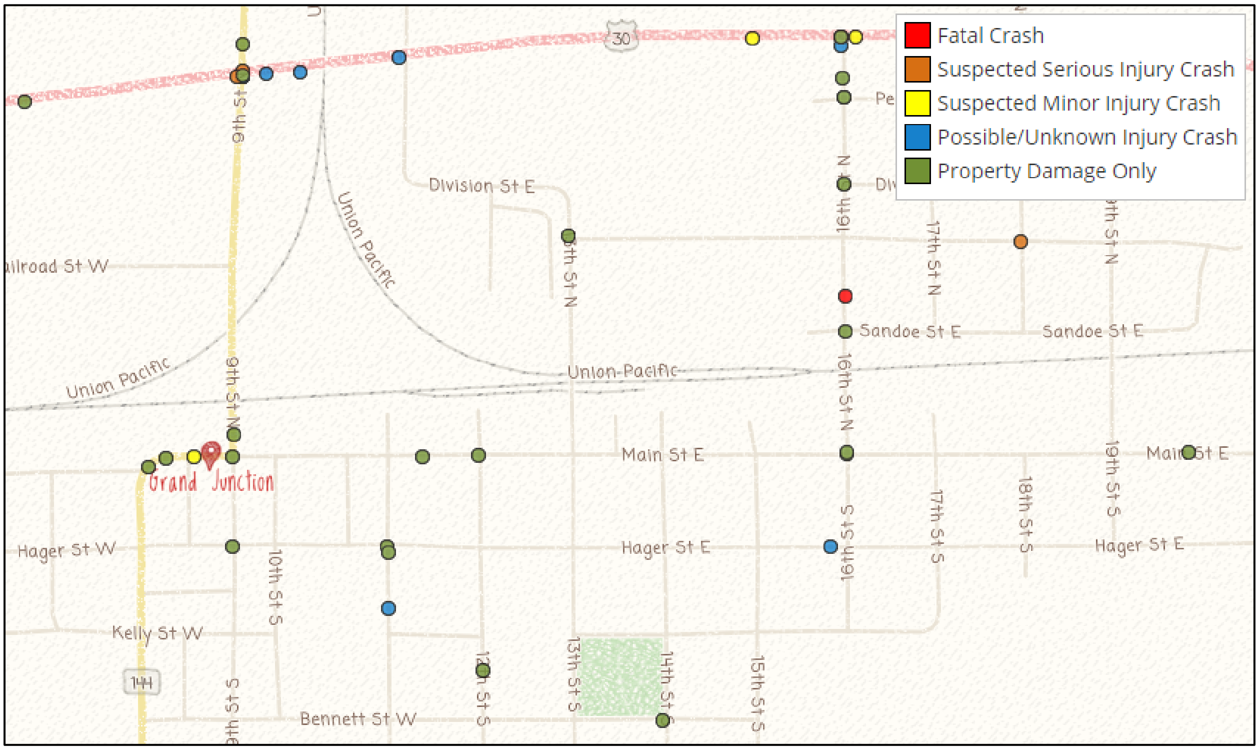
Example Crash Figures

A wide variety of crash figures can be created with ICAT. **Figure 4.2** through **Figure 4.7** are examples of the types of figures that can be created within ICAT to visually present crash data analyses.



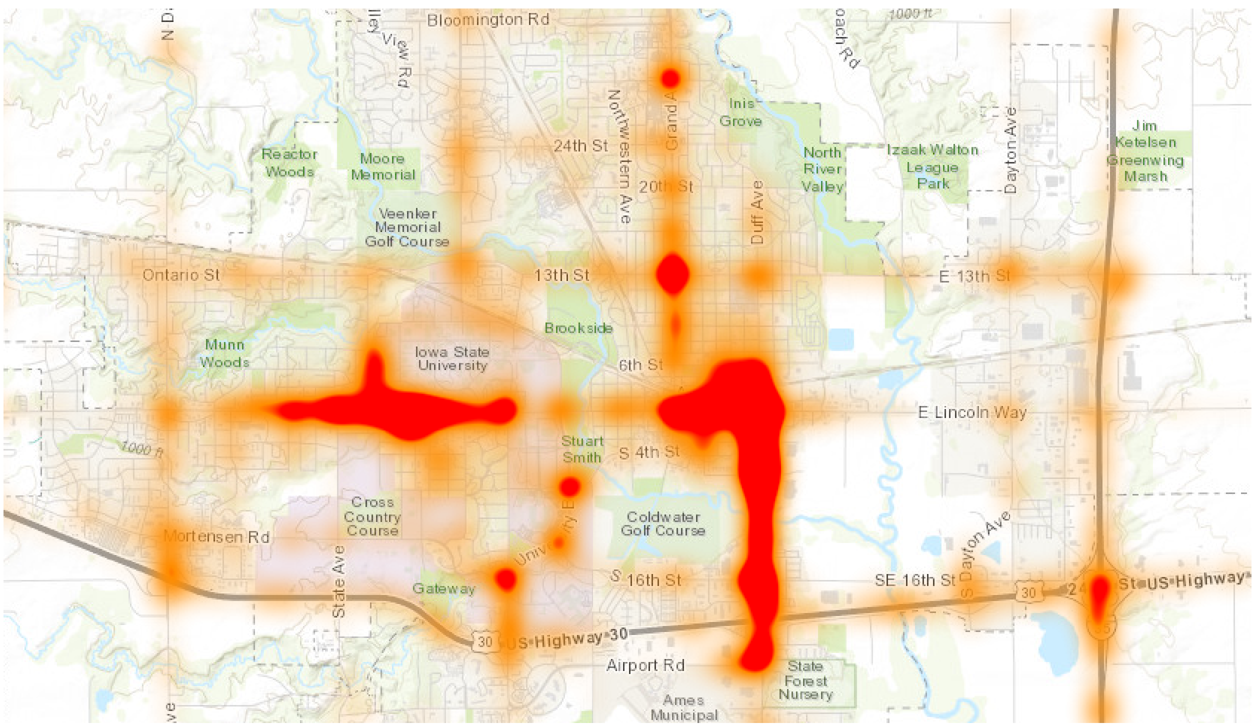
Source: ICAT, 2016 - 2020

Figure 4.2 – Crash Severity by Year



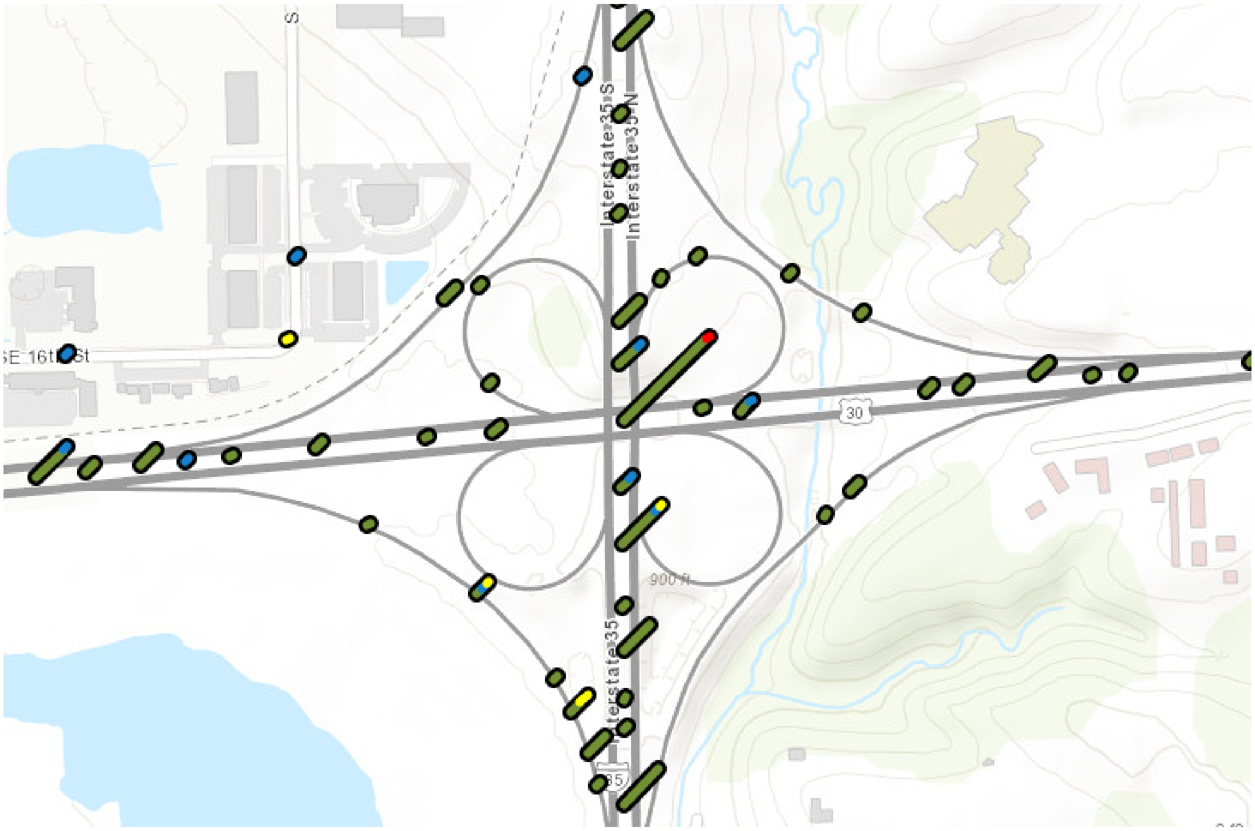
Source: ICAT, 2016 - 2020

Figure 4.3 – Crash Severity Map by Location



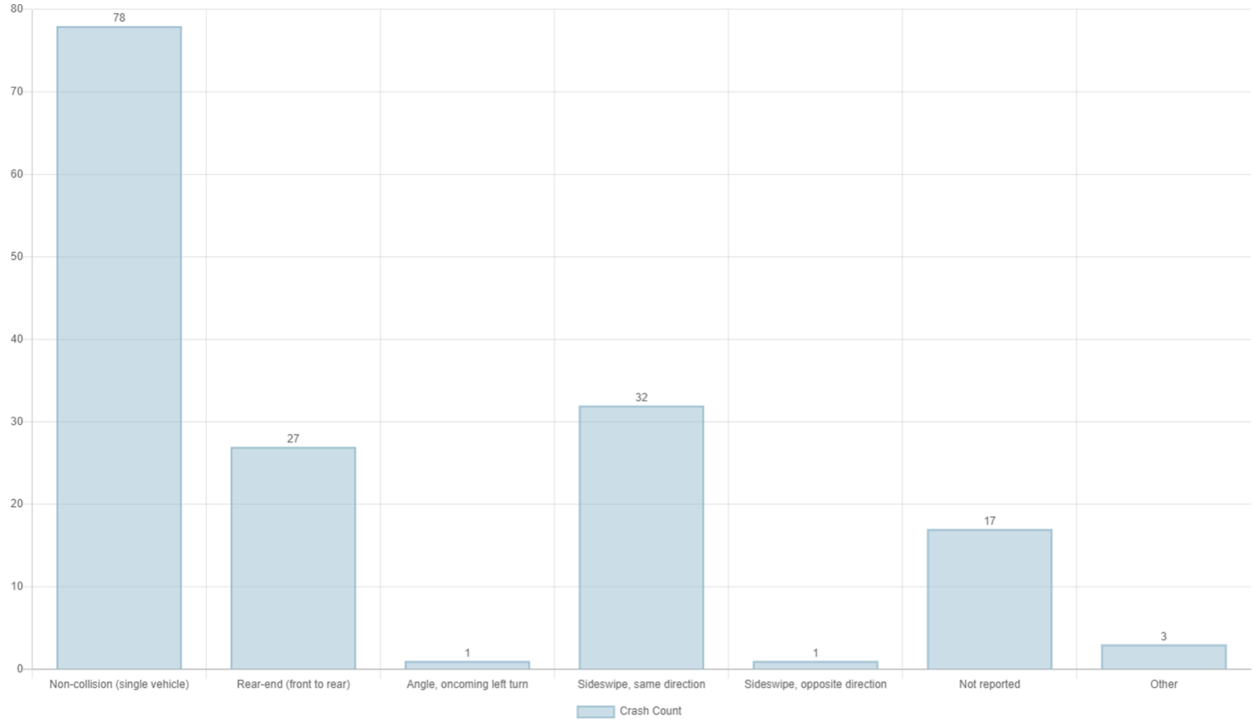
Source: ICAT, 2020-2016

Figure 4.4 – Heat Map



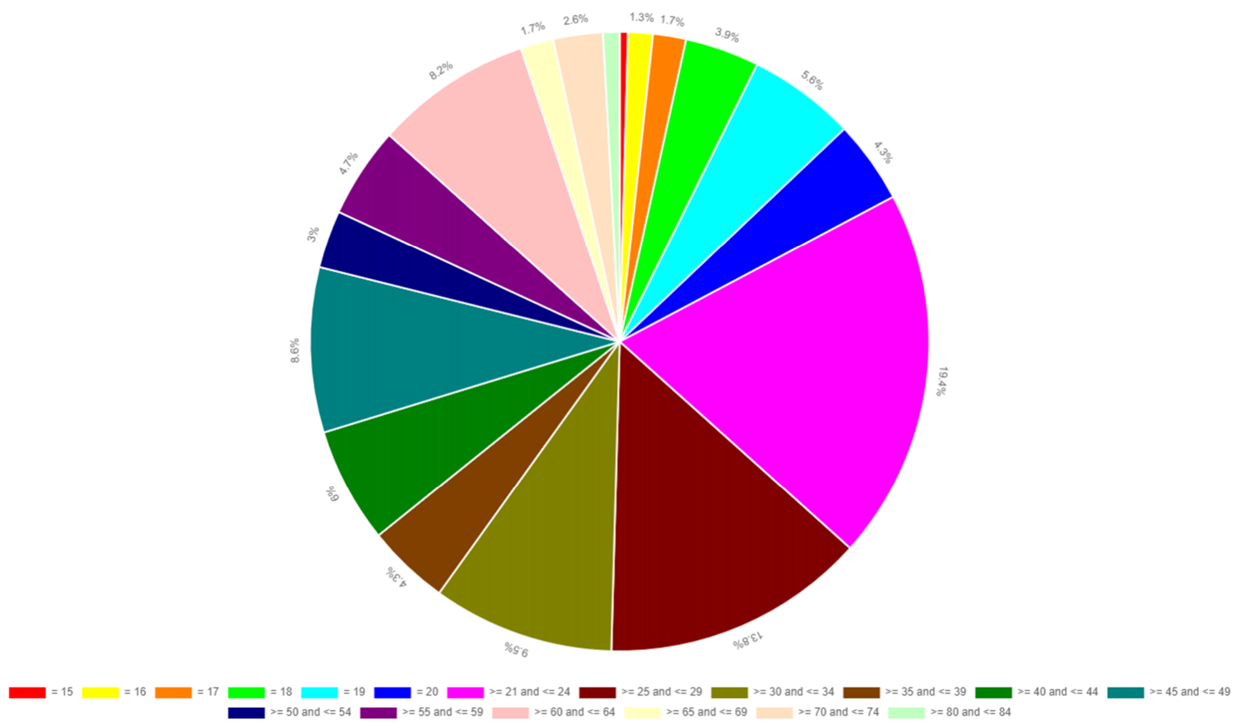
Source: ICAT, 2016-2020

Figure 4.5 – Stacks Crash Map



Source: ICAT, 2020-2016

Figure 4.6 – Manner of Crash Collision



Source: ICAT, 2016-2020

Figure 4.7 – Driver Age

4.1.1.3. Collision Diagrams

A collision diagram is a schematic drawing that has been compiled to show a series of individual crashes relative to a specific location, segment, or intersection. The diagram displays the direction vehicles were traveling prior to the crash occurring, the type and severity of the crash, and the location that the crash occurred. The creation of collision diagrams is intended to provide supplemental information and analysis in addition to what is provided with the crash summary tables and crash figures. Collision diagrams are created within ICAT. Practitioners can upload a KMZ or KML file into ICAT or manually remove crashes to assist in filtering crashes before creating the collision diagram.

Analysis Steps

- Determine intersection functional area
- Determine crash analysis years
- Use ICAT to filter for crash data: Follow guidance in **Section 2.2.3** for intersection-related crashes
- Create collision diagram
- Review collision diagrams and identify crash patterns

Documentation Requirements

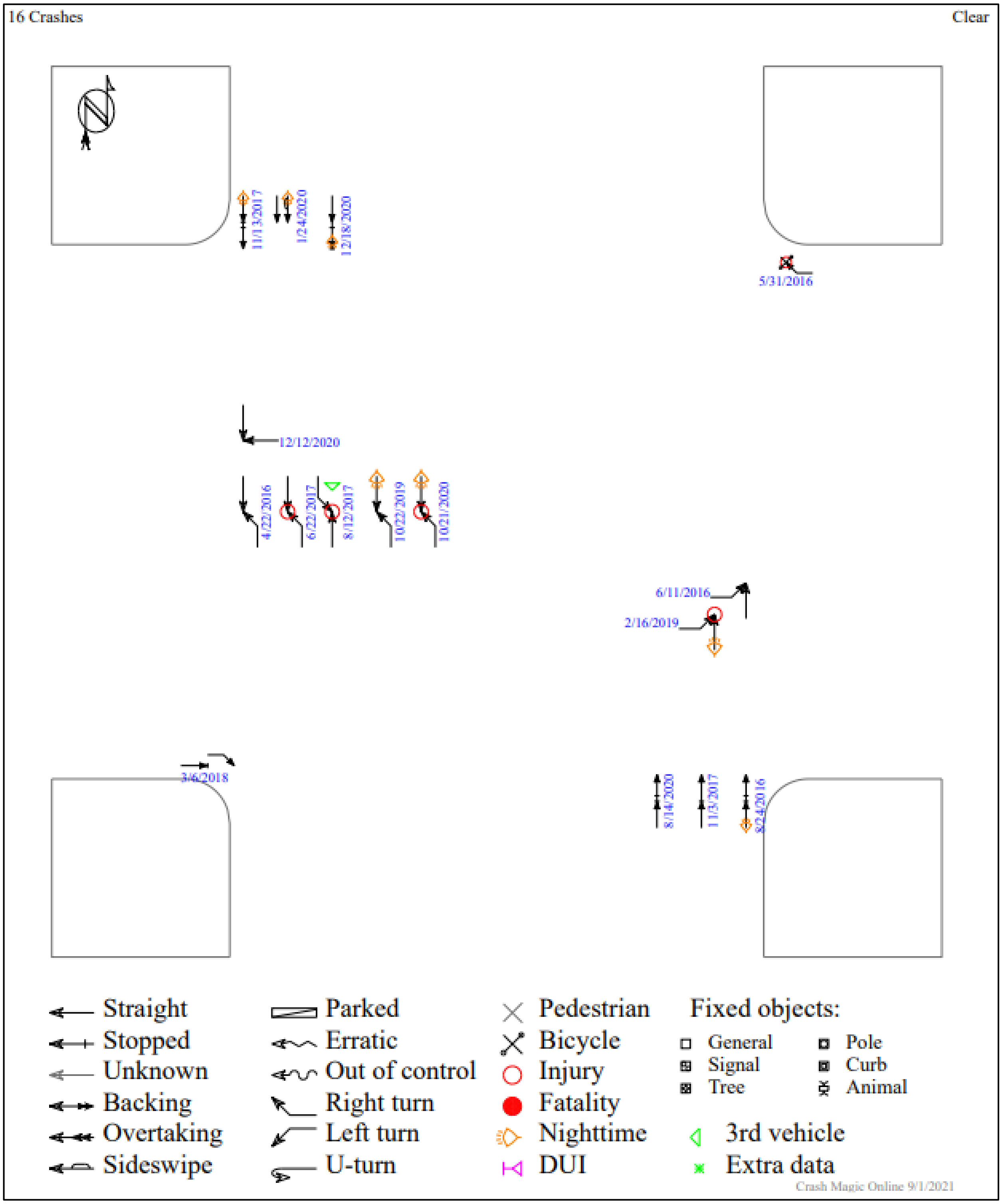
A collision diagram created in ICAT is required as part of the crash analysis documentation. The years of crash data utilized in developing the diagrams should be included in the figure title or as a footnote to the diagram. Crash data used in creating collision diagrams should be obtained from ICAT. Raw crash data should be provided as an appendix or attachment to the crash analysis documentation. This raw crash data can be in the form of one of the various reports that is generated in ICAT. Following is the link to access ICAT and associated tutorials.

ICAT: https://icat.iowadot.gov

ICAT TUTORIALS: https://iowadot.gov/traffic/icat-tutorial

Example Collision Diagram

Figure 4.8 is an example of a collision diagram created in ICAT.



Source: ICAT, 2016-2020

Figure 4.8 – Iowa Crash Analysis Tool Collision Diagram

4.1.2. Potential for Crash Reduction

PCR analysis uses the HSM Predictive Method to analyze existing conditions at a study area to determine the potential to reduce the total number of future crashes at that location. This is accomplished by taking the difference between the expected average crash frequency (using the EB Method) and the predicted average crash frequency (from SPF). The difference between the number of expected crashes and the number of predicted crashes is the potential reduction in crashes for safety improvements when compared to similar facility types.

PCR values for intersections are located on the Iowa DOT website. If a PCR value is not available on the website, then a PCR value can be calculated using one of the HSM Predictive Method tools. PCR analysis can be used to compare multiple sites or to investigate an individual site to determine the potential for improvement based on implementation of countermeasures. **Figure 4.9** demonstrates the relationship between predicted, expected, and observed crashes when performing PCR analysis.

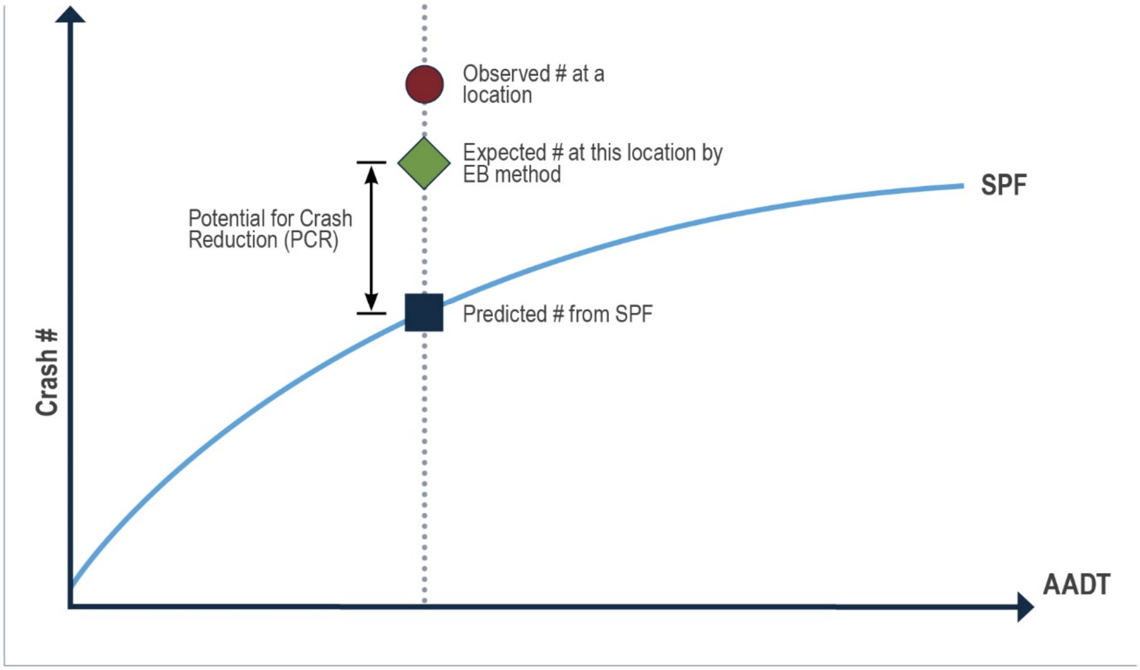


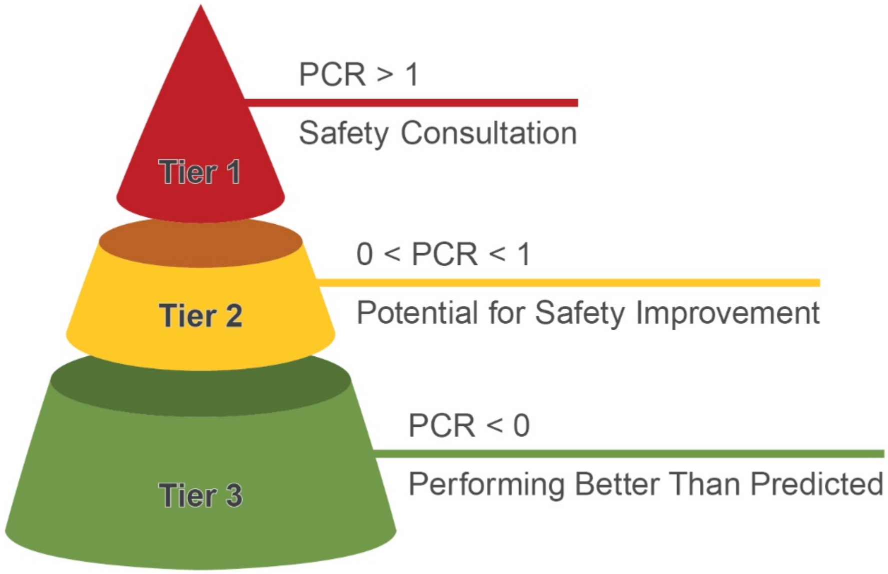
Figure 4.9 – Predicted, Expected, Observed, and Potential for Safety Improvement Relationship

The Iowa DOT PCR website includes an ARC GIS map of all intersections in Iowa categorized by their safety tier along with an attribute table including all the relevant information for each intersection. This attribute table can be download to a CSV file. The website also contains helpful information about PCRs and SPFs, including their definitions, how to use PCR values, and how to interpret the PCR rankings.

For each intersection included on the website, two PCR calculations are provided: all crash severity types (KABCO) and injurious crashes (KAB). Using the calculated PCR values, each intersection is grouped into a safety tier. Per the Iowa DOT PCR website, the safety tiers are defined as follows:

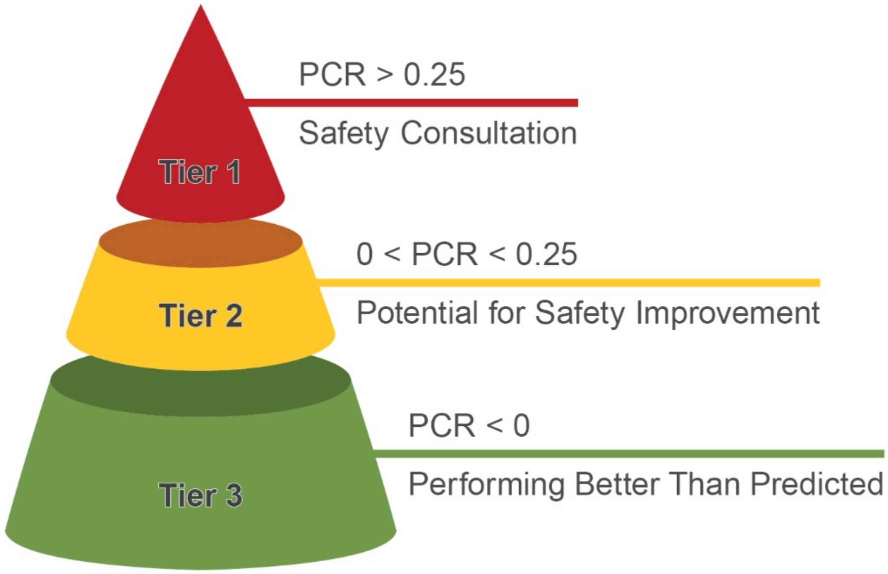
- Tier 1: Intersections will now replace the “above the statewide average” classification. Projects at these intersections may qualify for safety funds and will require a consultation with the Traffic and Safety Bureau to determine potential safety improvements.
- Tier 2: Intersections have room for improvement but may not qualify for safety funds.
- Tier 3: Intersections are performing better than predicted.

Figure 4.10 and **Figure 4.11** display the safety tier breakdown based on PCR values for all crashes and injurious crash, respectively.



Source: Iowa DOT PCR of Intersections Website

Figure 4.10 – Safety Tiers for All Crashes (KABCO)



Source: Iowa DOT PCR of Intersections Website

Figure 4.11 – Safety Tier for Injurious Crashes (KAB)

The Iowa DOT is currently working to develop PCR values for roadway segments. When that information is available it will be published online in a similar format as the Iowa DOT PCR of Intersections website.

IOWA DOT PCR OF INTERSECTIONS:
https://iowadot.maps.arcgis.com/apps/MapSeries/index.html?appid=6920b9b36fa54caa90c25bd6dcdd0c7e

Analysis Steps for Multiple Sites (Comparison)

- Determine the analysis study area and facility types
- If the Iowa-specific PCR is available on the Iowa DOT PCR website, retrieve the PCR data (at the time this document was developed, intersections were available on the PCR website)
- If the Iowa-specific PCR is not available on the Iowa DOT PCR website, calculate the PCR with HSM tools using the following steps:
  - Determine the crash analysis years
  - Use ICAT to obtain observed crash data
  - Calculate the predicted average crash frequency using the appropriate HSM Predictive Method tool (same years as observed crash data)
  - Calculate the expected average crash frequency using the appropriate HSM Predictive Method tool (same years as observed crash data)
  - Determine the difference between the expected and predicted yearly average crash totals
- Compare and display the results across multiple sites
- Rank sites (if needed)

Analysis Steps for Individual Sites (Non-Comparison)

- Determine the analysis study area and facility types
- If the Iowa-specific PCR is available on the Iowa DOT PCR website, retrieve the PCR data (at the time this document was developed, intersections were available on the PCR website)
- If the Iowa-specific PCR is not available on the Iowa DOT PCR website, calculate the PCR with HSM tools using the following steps:
  - Determine the crash analysis years
  - Use ICAT to obtain the observed crash data
  - Calculate the predicted average crash frequency using the appropriate HSM Predictive Method tool (same years as observed crash data)
  - Calculate the expected average crash frequency using the appropriate HSM Predictive Method tool (same years as observed crash data)
  - Determine the difference between the expected and predicted yearly average crash totals
- Display the results for the individual site

Documentation Requirements

- For multiple site comparison analysis: Include results in tabular form
- For individual sites: Include figure showing observed, predicted, expected, and PCR totals

Raw crash data used in the analysis should be provided as an appendix or attachment to the crash analysis documentation. The raw crash data can be in the form of one of the various reports that is generated in ICAT.

Example PCR Figure

There are various forms by which a PCR analysis can be displayed. **Figure 4.12** contains an example of one method to display the results of a PCR analysis for an individual site. Results for comparing multiple sites and ranking the sites would likely be displayed in a tabular format.

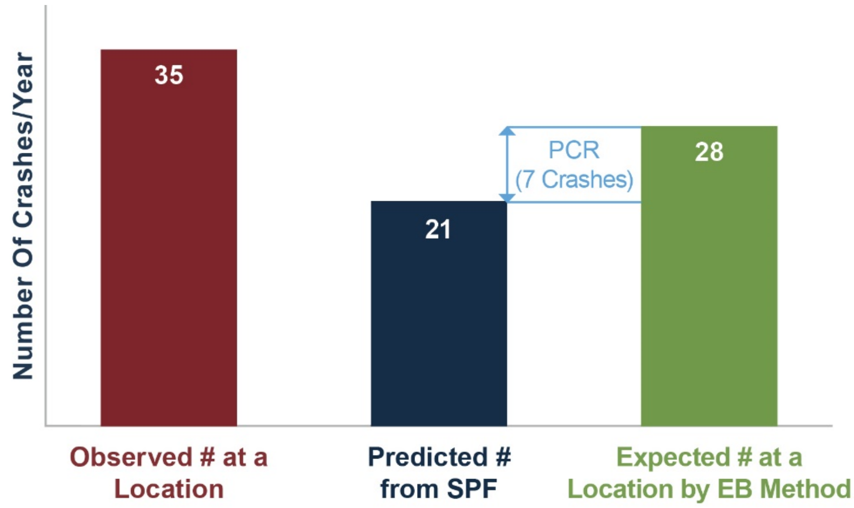


Figure 4.12 – Potential for Crash Reduction Example

Tools Available to Conduct PCR

The following tools are available to help practitioners perform PCR analyses. Additional information about these tools are in **Appendix C**.

- Iowa DOT PCR website
- PCR (HSM Tools)
  - Iowa Crash Prediction Tool
  - Interactive Highway Safety Design Model (IHSDM)
  - Enhanced Interchange Safety Analysis Tool (ISATe)

4.2. Future Conditions Safety Analysis

Future conditions safety analyses can take a variety of different forms. The following types of future conditions safety analyses are covered in this section of the SAG:

- Relative comparison of CMFs
- Observed crashes adjusted with CMFs
- HSM Predictive Method analysis
  - HSM Predictive Method analysis for existing and proposed conditions
  - HSM Predictive Method analysis for existing conditions and CMF application for proposed conditions

4.2.1. Relative Comparison of Crash Modification Factors

The relative comparison of CMFs method is used to compare the relative potential safety impact of proposed countermeasures by comparing the CMF values for each of the proposed treatments or alternatives. This method is generally only used when crash data is not available. While this method is the simplest method to apply, it may lead to unreliable results as it does not provide an estimate of the potential change in crashes. The relative comparison of CMFs method is most suitable for the initial screening of viable alternatives before performing more detailed analysis.

Analysis Steps

- Identify existing conditions and applicable alternative(s) at the study area
- Determine appropriate CRF(s) or CMF(s) for each alternative
- Document results

- Use results to determine next steps for further analysis (if needed)

Documentation Requirements
All CRFs and/or CMFs that were not obtained from the Iowa Planning-Level CRF List must be clearly identified in the analysis documentation. This includes documenting the CMF ID and star rating for all CMFs from the CMF Clearinghouse website along with including a PDF summary of the CMF as an appendix or attachment. A sample document is available on the following website to provide additional guidance as to what is expected for this type of analysis.

RELATIVE COMPARISON OF CMFS AND CRFS – EXAMPLE DOCUMENTATION: LINK TBD

Example CMF Summary Table
Table 4.3 is an example application of the relative comparison of CMFs analysis method. This example includes alternatives for traffic control at an intersection using the Iowa Planning-Level CRF List. Part of the documentation requirements is to include something similar to **Table 4.3**.

Table 4.3 – Relative Comparison of Crash Modification Factors

Alternative	CRF/CMF Description (Source)	CRF Value	CMF Value
Alternative 1 – Left-Turn Lanes	Install Left-Turn Lane on Major Approach(es) when Warranted (Iowa CRF US-41)	35%	0.65
Alternative 2 – Flashing Beacon	Install Flashing Beacon on Existing Stop Signs (Iowa CRF US-01)	5%	0.95
Alternative 3 - TWLTL	Add TWLTL to the Major Approach of an Unsignalized 4-Leg intersection (Clearinghouse CMF ID: 3017)	34%	0.66
Alternative 4 – Roundabout	Install Roundabout (Iowa CRF US-61)	45%	0.55
Alternative 5 – Traffic Signal	Install Traffic Signal when Warranted (Iowa CRF US-33)	0%	1.0

Note: This is an excerpt of the type of summary table that would be prepared as part of the relative comparison of CMFs

4.2.2. Observed Crashes Adjusted with Crash Modification Factors

The observed crashes adjusted with CMFs analysis method is used to adjust observed crashes based on the proposed countermeasures using CMF values. The potential crash reduction is estimated by multiplying the CMF value by the yearly average number of observed crashes. This analysis method can be conducted with a single CMF or multiple CMFs. Reference **Section 2.3.4** when applying multiple CMFs for a proposed countermeasure.

Analysis Steps
- Determine the analysis study area
- Determine the crash analysis years
- Use ICAT to filter for crash data
- Determine the appropriate CRF(s) or CMF(s) for the proposed countermeasure
- Apply the CRF/CMF value to average yearly crash total
- Determine the change in crashes/year
- Document the results

Documentation Requirements
Crash data should be obtained from ICAT. Raw crash data should be provided as an appendix or attachment to the crash analysis documentation. The raw crash data can be in the form of one of the various reports that can be generated in ICAT.

All CRFs and/or CMFs that were not obtained from the Iowa Planning-Level CRF List must be clearly identified in the analysis documentation. This includes documenting the CMF ID and star rating for all CMFs from the CMF Clearinghouse website along with including a PDF summary of the CMF as an appendix or attachment.

A sample document is available on the following website to provide additional guidance as to what is expected for this type of analysis.

OBSERVED CRASHES ADJUSTED WITH CMFS AND CRFS – EXAMPLE DOCUMENTATION: LINK TBD

Example Results Summary Table
Table 4.4 is an example application of the observed crashes adjusted with CMF analysis method. This example is a continuation of the example located in **Table 4.3**. A results summary similar to **Table 4.4** is required as part of the analysis documentation.

Table 4.4 – Observed Crashes Adjusted with Crash Modification Factors Example

Alternative	Average Yearly Crashes	CMF Value	Estimated Yearly Crashes	Change in Crashes	Percent Change
Alternative 1 – Left-Turn Lanes (Iowa CRF US-41)	3.0	0.65	1.95	1.05	35%
Alternative 2 – Flashing Beacon (Iowa CRF US-01)		0.95	2.85	0.15	5%
Alternative 3 – TWLTL (Clearinghouse CMF ID: 3017)		0.66	1.98	1.02	34%
Alternative 4 – Roundabout (Iowa CRF US-61)		0.55	1.65	1.35	45%
Alternative 5 – Traffic Signal (Iowa CRF US-33)		1.0	3.0	0.0	0%

Note: This is an excerpt of the type of summary table that would be prepared as part of the observed crashes adjusted with CMFs

4.2.3. Highway Safety Manual Predictive Method Analysis

An introduction into the HSM Predictive Method is summarized in **Section 2.4**. When practitioners are performing the HSM Predictive Method analysis, it is important to follow the 18-step process contained in **Figure 4.13**. Due to the nature of the HSM Predictive Method, there are multiple variations of the analysis methodology that can be applied. Not all analysis methods have the same order of reliability for the potential safety impact for proposed improvements or alternatives. The different methods are listed as follows in order of reliability. The following subsections provide additional details on how to conduct the first two of these methods.

- Apply the HSM Predictive Method for both existing and proposed conditions (calculate expected crashes whenever possible)
- Apply the HSM Predictive Method for existing conditions and apply appropriate CMFs for proposed conditions

- Apply SPFs developed outside the HSM for existing conditions and apply appropriate CMFs for proposed conditions (Please consult with the Iowa DOT Traffic and Safety Bureau before considering this approach)
- Use observed crash data and apply appropriate CMFs (**Section 4.2.2**)

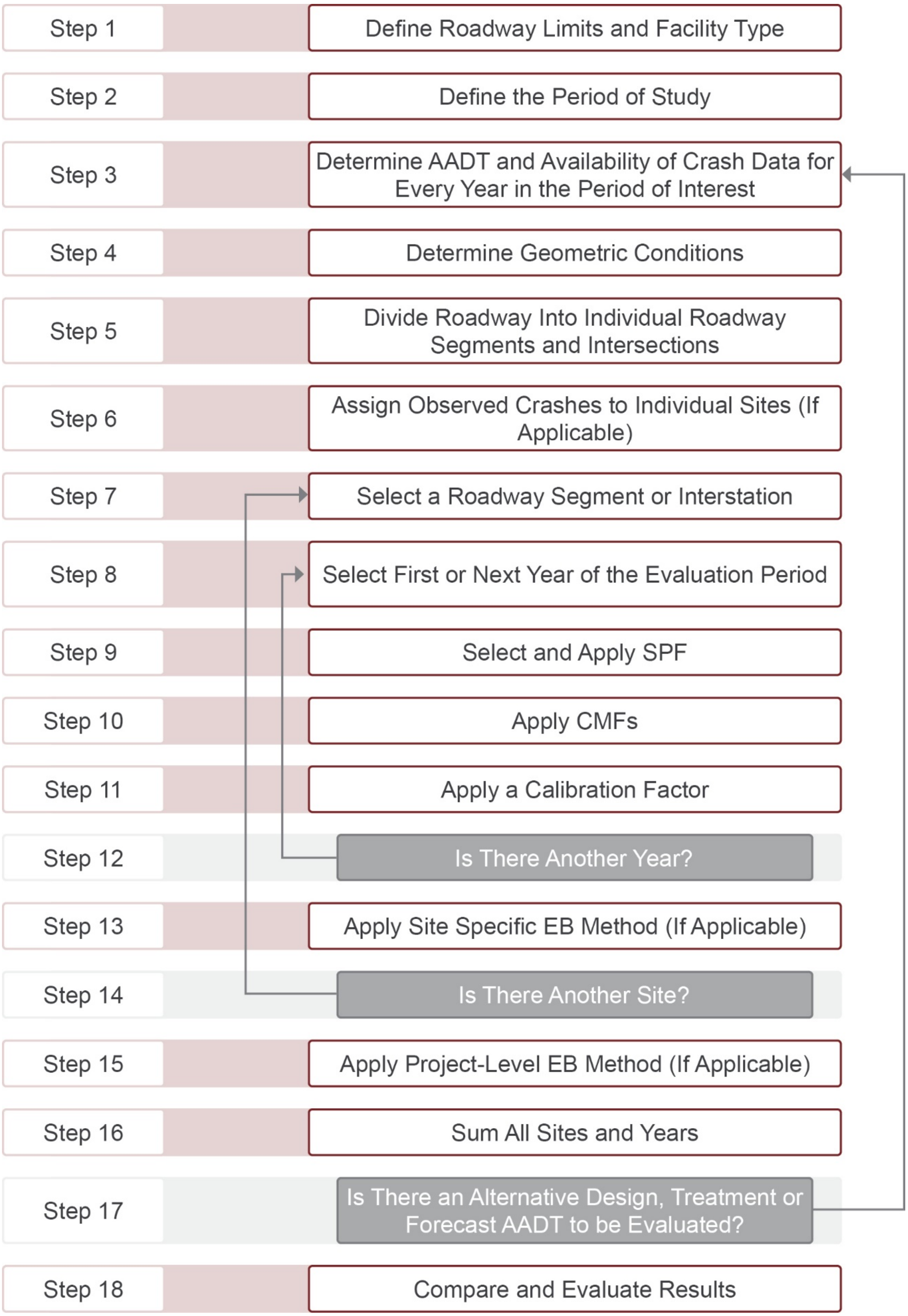


Figure 4.13 – Highway Safety Manual Predictive Method 18-Step Process

Tools Available to Conduct HSM Predictive Method Analysis

The tools identified in **Table 4.5** are available to help practitioners conduct HSM Predictive Method analysis. **Table 4.5** identifies the various facility types each tool is able to analyze. Additional information about these tools is located in **Appendix C**. It is preferred that the Iowa Crash Prediction Tool be used when applicable.

Table 4.5 – Highway Safety Manual Predictive Method Tools

Tool	Application	
	Segments	Intersections
Iowa Crash Prediction Tool	Rural Two-Lane, Two-Way Roads	
	▪ Two-Lane Undivided (2U)	▪ Unsignalized Three-Leg, Minor Stop (3ST) ▪ Unsignalized Four-Leg, Minor Stop (4ST) ▪ Signalized Four-Leg (4SG)
	Rural Multilane Highways	
	▪ Four-Lane Undivided (4U) ▪ Four-Lane Divided (4D)	▪ Unsignalized Three-Leg, Minor Stop (3ST) ▪ Unsignalized Four-Leg, Minor Stop (4ST) ▪ Signalized Four-Leg (4SG)
	Urban and Suburban Arterials	
	▪ Two-Lane Undivided (2U) ▪ Three-Lane with Two-Way Left-Turn Lane (TWLTL) (3T) ▪ Four-Lane Undivided (4U) ▪ Four-Lane Divided (4D) ▪ Five-Lane with TWLTL (5T)	▪ Unsignalized Three-Leg, Minor Stop (3ST) ▪ Signalized Three-Leg (3SG) ▪ Unsignalized Four-Leg, Minor Stop (4ST) ▪ Signalized Four-Leg (4SG)
ISATe	▪ Rural Freeway (4-8 Lanes) ▪ Urban Freeway (4-10 Lanes) ▪ Freeway Speed Change Lanes ▪ Freeway Ramps	▪ Ramp Terminals
IHSDM	▪ All Iowa Crash Prediction Tool Segment Types ▪ All ISATe Segment Types ▪ Additional Segment Types for HSM2	▪ All Iowa Crash Prediction Tool Intersection Types ▪ All ISATe Intersection (Ramp Terminal) Types ▪ Additional Intersection Types for HSM2

4.2.3.1. Highway Safety Manual Predictive Method for Existing and Proposed Conditions

The HSM Predictive Method should be applied to both the existing and proposed conditions whenever possible to determine the potential safety impact of proposed improvements or alternatives. This is the most reliable and accurate application of this analysis method.

Analysis Steps

- Existing conditions
  - Determine the analysis study area and facility types
  - Determine the crash analysis years and obtain observed crash data from ICAT
  - Apply the HSM 18-step process for determining predicted or expected average crash frequency
  - Document the assumptions
  - Document the results
- Proposed conditions
  - Determine the analysis study area and facility types for each alternative
  - Determine the crash analysis years and obtain observed crash data from ICAT (if needed)
  - Apply the HSM 18-step process for determining predicted or expected average crash frequencies for each alternative
  - Document the assumptions
  - Document the results
- Compare the results between the existing and proposed conditions
- Calculate the BCR (if required)

Documentation Requirements

All assumptions required to perform the HSM Predictive Method should be documented along with all data input parameters used in the analysis. These can be included as an appendix or attachment to the analysis documentation. Output summary reports from any tool used to assist in this analysis should also be included as an appendix or attachment

A single summary table should be provided clearly showing the crash prediction results for both the existing conditions and proposed conditions for each alternative analyzed. Additional tables can be provided if needed.

If crash data is used in this method, it should be obtained from ICAT. Raw crash data should be provided as an appendix or attachment to the crash analysis documentation. The raw crash data can be in the form of one of the various reports that can be generated in ICAT.

Example

Examples of applying the HSM Predictive Method for existing and proposed conditions are in the Iowa Crash Prediction Tool User Guide located on the Iowa DOT website.

IOWA CRASH PREDICTION TOOL USER GUIDE: *LINK TBD*

4.2.3.2. Highway Safety Manual Predictive Method for Existing and Crash Modification Factors Application for Proposed Conditions

For this analysis approach, the HSM Predictive Method can only be applied to the existing conditions and cannot be applied to the proposed conditions. Typically, this analysis approach is necessary when analyzing alternatives that do not have an HSM-developed SPF for a particular facility type or are outside the scope of the current edition of the HSM. The practitioner must apply CMFs related to the proposed conditions to the results of the existing conditions analysis.

Analysis Steps

- Existing conditions
  - Determine the analysis study area and facility types
  - Apply the HSM 18-step process for determining predicted or expected average crash frequency
  - Document the assumptions

  - Document the results
- Proposed conditions
  - Determine the analysis study area and facility types for each alternative
  - Determine the appropriate CRF(s) or CMF(s) for the proposed conditions of each alternative
  - Apply the CMF value for each alternative to the existing conditions results
  - Document the assumptions
  - Document results
- Compare results between existing and proposed conditions
- Calculate BCR (if required)

Documentation Requirements
All assumptions required to perform the HSM Predictive Methods should be documented along with all data input parameters used in the analysis. These can be included as an appendix or attachment to the analysis documentation. Output summary reports from any tool used to assist in this analysis should also be included as an appendix or attachment

A single summary table should be provided clearly showing the crash prediction results for both the existing conditions and proposed conditions for each alternative analyzed. Additional tables can be provided if needed.

All CRFs and/or CMFs that were not obtained from the Iowa Planning-Level CRF List must be clearly identified in the analysis documentation. This includes documenting the CMF ID and star rating for all CMFs from the CMF Clearinghouse website along with including a PDF summary of the CMF as an appendix or attachment.

Example
Examples of applying the HSM Predictive Method for the existing conditions is in the Iowa Crash Prediction Tool User Guide located on the Iowa DOT website.

IOWA CRASH PREDICTION TOOL USER GUIDE: *LINK TBD*

4.3. Benefit-Cost Analysis

The following is an overview of how to perform benefit-cost analysis to determine a BCR and the tools available to assist in these types of analyses. A benefit-cost analysis can be performed using the CMF method or the predictive method.

<<<Note: The tools the practitioner will use are not developed yet. This section will be finalized when the tool is finished.>>>

4.3.1. Calculating Benefit-Cost Using Crash Modification Factor Method

When calculating the safety BCR using the CMF method a single CMF or a combined value for multiple CMFs may be used. It is important to follow the guidance located in **Section 2.3** when selecting and applying CMFs in benefit-cost analysis.

Analysis Steps
- Determine and input the following user inputs into the CMF Method BCR Spreadsheet:
  - Project implementation cost
  - Annual maintenance costs
  - Current prime interest rate
  - Percentage of growth
  - Estimated service life

  - Years of crash data
  - Existing crashes by KABCO
  - Expected CRF
- Document the BCR results

Documentation Requirements
<<<Note: The tools the practitioner will use are not developed yet. This section will be finalized when the tool is finished.>>>

Example
<<<Note: The tools the practitioner will use are not developed yet. This section will be finalized when the tool is finished.>>>

4.3.2. Calculating Benefit-Cost Using Predictive Method

This approach for determining a BCR should be used when performing future conditions safety analyses using the HSM Predictive Method (**Section 4.2.3**). When calculating safety BCR using the Predictive Method it is important to follow the guidance outlined in **Section 2.4** and **Section 4.2.3** to conduct the safety analysis.

Analysis Steps
- Determine and input the following user inputs into the Predictive Method BCR Spreadsheet:
  - Project implementation cost
  - Annual maintenance costs
  - Current prime interest rate
  - Percentage of growth
  - Estimated service life
  - Years of crash data
  - Existing conditions predictive crashes
  - Alternative predictive crashes
- Document the BCR results

Documentation Requirements
<<<Note: The tools the practitioner will use are not developed yet. This section will be finalized when the tool is finished.>>>

Example
<<<Note: The tools the practitioner will use are not developed yet. This section will be finalized when the tool is finished.>>>

4.3.3. Tools Available to Conduct Benefit-Cost Ratio Analysis

- TSIP Spreadsheet
- <<<Note: There is currently a project in place to develop new spreadsheets to conduct BCR>>>

4.4. Special Analyses or Processes

Practitioners may run across unique situations requiring special analysis or processes, such as bicycle/pedestrian crash analysis and/or systemic analysis. It is recommended that practitioners reference the latest FHWA guidance when conducting a unique analysis not outlined within the SAG.

- Bicycle/Pedestrian Safety (Multi-Modal): Reference FHWA Pedestrian and Bicycle Safety https://safety.fhwa.dot.gov/ped_bike/

- Systemic Safety: Reference FHWA A Systemic Approach to Safety – Using Risk to Drive Action https://safety.fhwa.dot.gov/systemic/

Appendix A

GLOSSARY

<<<Note: There was discussion among the Technical Advisory Committee as to whether a glossary should be included as an appendix. We welcome any feedback the reviewers have with regards to a glossary and/or the types of items that should be included in a glossary as opposed to what is included in the List of Acronyms.>>>

Appendix B

CMF Clearinghouse – CMF Detail Summary Page

Appendix C

Safety Analysis Resources

Safety Analysis Resources

Following is a list of safety resources referenced within the SAG:

- Iowa Crash Analysis Tool (ICAT)
  - ICAT*:* https://icat.iowadot.gov
  - ICAT Tutorials*:* https://iowadot.gov/traffic/icat-tutorial
- Iowa Access Management Manual*: LINK TBD*
- Iowa Planning-Level CRF List*:* https://iowadot.gov/traffic/pdfs/CRFListVersion.pdf
- CMF Clearinghouse
  - CMF Clearinghouse*:* http://www.cmfclearinghouse.org
  - Star Rating System*:* http://www.cmfclearinghouse.org/sqr.cfm
  - February 2021 Star Rating Changes*:* http://www.cmfclearinghouse.org/changes.cfm
  - Selecting CMFS*:* http://www.cmfclearinghouse.org/userguide_identify.cfm
- Iowa Calibration Factors*: LINK TBD*
- Iowa PCR of Intersections: https://iowadot.maps.arcgis.com/apps/MapSeries/index.html?appid=6920b9b36fa54caa90c25bd6dcdd0c7e
- Iowa Crash Costs*: LINK TBD*
- Iowa Crash Prediction Tool
  - Iowa Crash Prediction Tools: *LINK TBD*
  - Iowa Crash Prediction Tool User Guide*: LINK TBD*
- IHSDM: https://highways.dot.gov/research/safety/interactive-highway-safety-design-model/interactive-highway-safety-design-model-ihsdm-overview
- ISATe: https://safety.fhwa.dot.gov/rsdp/toolbox-content.aspx?toolid=62
- HSM Website: http://www.highwaysafetymanual.org/Pages/default.aspx
- FHWA Pedestrian and Bicycle Safety: https://safety.fhwa.dot.gov/ped_bike/
- FHWA A Systemic Approach to Safety: https://safety.fhwa.dot.gov/systemic/

Following is a list of example documentation resources:

- Relative Comparison of CMFs and CRFs – Example Documentation: *LINK TBD*
- Observed Crashes Adjusted with CMFs and CRFs – Example Documentation: *LINK TBD*
- PCR Calculations using Iowa DOT Website – Example Documentation: *LINK TBD*
- PCR Calculations using HSM Tools – Example Documentation: *LINK TBD*
- HSM Crash Prediction Method Alternatives Analysis – Example Documentation: *LINK TBD*