Washington State Department of Transportation

Safety Analysis Guide

April 2020

Multimodal Development and Delivery
Transportation Safety and Systems Analysis Division
Traffic Operations Division
Development Division

Table of Contents

EXHIBITS

FIGURES

ACRONYMS

Acronym	Description
5Es	engineering, education, enforcement, emergency medical services, and evaluation
AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
ARM	Accumulated Route Mileage – part of WSDOT linear referencing system
B/C or BCR	Benefit Cost ratio
CAC	Collision Analysis Corridor
CAL	Collision Analysis Location
CMF	crash modification factor
CPDM	Capital Program Development and Management
DM	Design Manual
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
TDGMO	Transportation Data, GIS, and Modeling Office (WSDOT)
HFG	NCHRP Report 600: Human Factors Guidelines for Road Systems: 2nd Edition
HSEC	WSDOT Highway Safety Executive Committee (WSDOT)
HSIG	WSDOT Highway Safety Issues Group (WSDOT)
HSM/ HSM1	AASHTO Highway Safety Manual (AASHTO, 2010)
HSM2	2nd Edition of the HSM – currently under development
I2	The sub-program used to manage and track investments in capital transportation projects with a primary need related to improving safety
IAL	Intersection Analysis Location
IHSDM	Interactive Highway Safety Design Model
ISATe	Interchange Safety Analysis Tool enhanced
KABCO	Crash injury severity scale used to describe the most severe injury level sustained in a crash. • K – Fatal injury crash • A – Serious injury crash/suspected serious injury crash • B – Evident injury crash • C – Possible Injury crash • PDO – Property-damage only
LRS	Linear Referencing System
MMUCC	Model Minimum Uniform Crash Criteria
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
PDO	Property Damage Only
PTCR	Police Traffic Collision Report
SHS	WSDOT Sustainable Highway Safety (Executive Order E 1085.00)
SHSP	Strategic Highway Safety Plan
SPF	Safety Performance Function
SRMP	State Route Mile Post – part of WSDOT LRS and is accompanied by an ahead or back indicator (these values can change over time)
TRB	Transportation Research Board
TZ	Target Zero (Washington State Strategic Highway Safety Plan, SHSP) – www.targetzero.com
WSDOT	Washington State Department of Transportation
WSP	Washington State Patrol
WTSC	Washington State Traffic Safety Commission

1. Purpose

The purpose of this guide is to provide guidance to WSDOT staff regarding expectations for safety analysis. This guide defines the focus, scale, and scope of safety analyses across the different WSDOT program areas as well as safety analysis outside the typical program areas. The target audience for the document is staff that have the responsibility for safety analysis as part of program and project development and associated activities. This document is also for those who make a determination on the appropriate scale and scope of the safety analysis for a project. This guide will include current documentation policies related to safety analysis and assumptions considered reasonable to make within the current WSDOT context. The goal of this guide is to support integration of safety performance considerations throughout planning, project development, operations, maintenance, and other WSDOT activities, projects, and programs without creating undue burden, staying practical and focusing on high value for effort. The guide provides guidance in a manner that balances the simplicity of a safety analysis with the thoroughness of a safety analysis that aids in making sound decisions that are data driven and science-based. **The guide is intended to supplement sound engineering judgement and experience based on specific project conditions, context, and modal priorities. Engineering judgement should also be used to address items not covered in this guide.** The guide does not replace the WSDOT Design Manual (DM), rather it supports the DM by clarifying safety analysis components that are not easily described within the DM.

The guide is not inclusive of every condition, nor does it constitute specific requirements for projects. The document is used as guidance and recognizes that individual project analysis aspects will vary as those doing the analysis consider how best to achieve their stated project goals. The guide expects teams to consider how best to achieve the safety analysis goals and objectives, early in the project development process to minimize rework and extraneous analysis efforts.

2. Policy

WSDOT has undergone a number of changes related to how it develops and operates the highway system. The Department has developed strategies to incorporate the practical solutions approach into WSDOT practices. To do so, WSDOT modified its project and program decision-making process through executive orders and Design Manual changes. An important aspect of these policy changes was the incorporation of the AASHTO Highway Safety Manual (HSM) methods into WSDOT practices related to design and operational decision-making. These policies highlight data driven safety analysis in considering how best to approach safety performance related issues on WSDOT highways. The policies also recognize that safety data analysis is a tool, and safety performance considerations are not the only issue that WSDOT deals with in the development of a project or program. The HSM methods do not fit every case (see Appendix A), nor every facility type encountered. The HSM and safety analysis in general continues to evolve and the Department envisions that this guide will evolve as additional information on new methods, procedure and information becomes available. The practitioner is encouraged to make use of multidisciplinary experts in planning, operations, maintenance, design and safety.

2.1 Executive Policies

A number of policies exists related to the use of data driven safety analysis. The policies address the implementation and use of these tools, particularly as it relates to WSDOT's approach to practical solutions. The executive policies include:

- E 1090.00 Moving Washington Forward: Practical Solutions
- E 1085.00 Sustainable Highway Safety Program

The executive policies provide the framework for the development of sustainable safety, practical solutions and the use of the HSM. The policies also provided direction on redevelopment of the WSDOT Design Manual.

2.2 Highway Safety Improvement Program (Federal)

The Highway Safety Improvement Program (HSIP) is a Federal-aid program administered through the Federal Highway Administration (FHWA). The purpose of the program is to reduce fatal and serious crashes on all public roads regardless of ownership. The HSIP requires a data-driven strategic approach with a focus towards performance. HSIP funds are divided between WSDOT and local agencies. WSDOT uses HSIP funds to address I2 safety needs.

23 U.S. Code § 148 provides the legislation to carry out the HSIP, the implementation regulations are found in Part 924 of Title 23, Code of Federal Regulations (23 CFR Part 924). The HSIP consists of three main components, the Strategic Highway Safety Plan, State HSIP or program of highway safety improvement projects, and the Railway-Highway Crossing Program, In addition, Washington also has a High Risk Rural Roads program because of an increasing fatality rate on rural roads. Federal legislation requires each state to have a Strategic Highway Safety Plan. In our state, this is called Target Zero.

2.3 Target Zero

Target Zero, the Washington State Strategic Highway Safety Plan (SHSP), forms the basis for how Washington State measures safety performance and sets priorities and emphasis areas for safety performance investments. This statewide plan is developed and updated in consultation with agencies and safety partners in the state. It is a formal statewide safety planning document approved by the FHWA Division Administrator. MAP-21 and the FAST Act require that WSDOT integrate the SHSP into WSDOT safety business practices and processes and requires states to set performance targets related to fatal and serious injuries. *Target Zero's* intent is to reduce fatal and serious injury crashes and includes emphasis areas with priorities based on the number of fatalities or number of serious injuries. The plan highlights the need for multimodal approaches to safety by including emphasis areas for pedestrians, bicyclists, motorcyclists, heavy trucks, older drivers, and younger drivers.

To address *Target Zero* goals and other WSDOT operational objectives, WSDOT considers the full range of crash types and severity depending on the objectives of the investment. The *Target Zero Implementation Plan* refers to WSDOT's programmatic approach to addressing the emphasis areas within *Target Zero*.

2.4 Design Manual

The Design Manual chapters provide specific policies and guidance, criteria, procedures, and the process of documentation on safety analysis. The safety analysis guidance presented as part of this guideline (referenced in Chapter 321) supplements the Design Manual in an effort to provide additional information on intent, scale and scope of safety analysis aspects for different project types. The primary chapters in the WSDOT Design Manual those performing safety analysis should be aware of are:

Chapter 321: Sustainable Safety
Chapter 1100: Practical Design
Chapter 1101: Need Identification
Chapter 1102: Context Identification
Chapter 1103: Design Control Selection
Chapter 1104: Alternatives Analysis
Chapter 1105: Design Element Selection
Chapter 1106: Design Element Dimensions

These safety analysis guidelines do not supersede the Design Manual. The Design Manual uses the Strategic Highway Safety Plan (Target Zero) and FHWA rules to identify fatal and serious injuries as the focus area for safety performance and use in the priority array methods. It is also important to consider how other crashes, crash injury levels, or crash types might influence design and operational choices.

Safety analysis does not necessarily refer to HSM analysis.

2.5 Priority Programming for Highway Development

In RCW 47.05, the Washington State Legislature recognized that the complexity and diversity of transportation needs were becoming increasingly challenging. The legislature also recognized that the needs of the transportation system outweighed the ability to fund every location. The RCW requires that projects be selected based on a policy of priority programming where objectives are defined within available resources, and that the selection of projects be based on factual need and evaluation of the life cycle costs and benefits.

3. Purpose of Safety Analysis at WSDOT

To address *Target Zero* goals and other WSDOT operational objectives, WSDOT considers the full range of crash types and severity depending on the objectives of the investment.

Through the process of conducting safety analysis, the engineer must frequently weigh the tradeoffs of implementing each change to the roadway. For example, installing a traffic signal may reduce entering at angle crashes but increase rear end crashes. Each time a tradeoff is encountered, consider the whole roadway system including all users/modes and how crash severity might be impacted for all users. Carefully weigh the crash potential of each alternative and discuss the tradeoffs with your design team and project stakeholders.

3.1 Limitations

The HSM predictive methods incorporate geometric configurations and traffic volumes, as well as other factors. Using a predictive method outside of the boundaries for which it is developed brings the validity of the results into question. As such, it is important to understand the limitations of the methods that are used. Some of the application constraints have been summarized in Appendix A. In addition to limitations listed in Appendix A, the HSM predictive methods do not account for some unique roadway configurations such as peak period shoulder driving, toll plazas or reversible lanes. If the highway configuration or traffic volumes are outside the applicable ranges discussed in the HSM, consult your ASDE. Your ASDE will consult with subject matter experts from Design, Traffic, and Transportation Safety and Systems Analysis, to determine if the HSM predictive method(s) can still be used. If the HSM predictive method(s) cannot be used, the crash history (observed crashes) can be used along with crash modification functions and factors (CMFs). When only observed crash histories are used, the discussion of results should include specific reference to the fact that observed crash history was used and indicate the reasoning for not using the HSM predictive methods. Because the HSM predictive methods consider site characteristics and traffic growth they are considered statistically more reliable estimates of future crash potential.

WSDOT recognizes that meeting the goal of zero fatal and serious crashes is aspirational and difficult. Achieving this challenge requires the effective and efficient use of scarce resources. Optimization of the analysis means that not all projects will receive the same level of safety analysis. It is important to recognize that WSDOT methods for programming and project development affect the type of analysis that occurs. As an example, preservation projects will receive less analysis than a targeted safety project, because the focus is not on reducing fatal and serious crashes, but on preservation of the system. Mobility and economic initiative projects require safety analysis in project decision making for performance tradeoff considerations between alternatives.

The I2 Safety Program on the other hand, is focused on reducing fatal and serious crashes. The I2 Program uses a network screening process to identify potential locations for further analysis. The next step in this process requires analysis of the crash contributing factors and crash types resulting in fatal and serious crashes at the list of analysis locations.

Within the I2 Program, safety projects are identified as part of the priority programming process. The priorities for the safety program are developed in accordance with RCW 47.05. This law requires WSDOT to follow a defined process that identifies improvement opportunities, has specific minimum performance requirements, and ultimately leads to a prioritized list of projects that includes the benefit/cost of the project.

Network screening begins with the use of specific criteria that is developed to address the historic crashes, the potential for crashes at a given location, or both. The criteria typically considers crash severity, crash type, contributing factors, historic trends or identified factors that are considered to affect fatal and serious injury crash or injury potential.

To achieve the goals of practical solutions and *Target Zero*, the department is targeted in its approach to reducing fatal and serious crashes and our methods seek optimization in the use of scarce resources. From the safety analysis perspective, this means the Department makes a safety investment through the I2 Program to cost effectively maximize the reduction in fatal and serious crashes using a benefit-cost analysis. Safety analysis helps inform these decisions through careful and reliable science-based evaluation given the project type, need and focus. Not all projects need the same level of analysis because the safety focus or targets may be limited.

It is important to recognize that projects may target mobility, preservation, safety, or other goals. The focus of each project may vary and the WSDOT expectation for the safety analysis component vary significantly based on project type and the intended purpose. Selecting the appropriate scale and scope of analysis is critical in order to optimize value of the safety analysis for decision-making with the technical resources used in completing the analysis. In mobility projects, safety analysis focuses on comparative evaluation of different design decisions for the potential difference in terms of safety performance outcomes or the safety performance of alternatives. In preservation, a review may not occur or be limited because of the scope of those projects and because WSDOT is required to use the priority array process to drive safety investments across the state.

WSDOT approaches safety in several ways:

- During Corridor Sketch development, the *Target Zero* Emphasis Area Summary for each corridor forms the basis for describing the safety performance of the corridor to stakeholders and the public. Safety needs are not identified or analyzed as part of the corridor sketch process. The reason is two-fold. First, this is because of the quick turnaround nature of the I2 Program: projects are programmed and implemented much quicker than a normal planning process allows. Second, this approach allows WSDOT to maintain the integrity of the legislatively required priority programming process for safety.
- Within the I2 Program, the state highway system is screened every two years to identify segments and intersections where the expected number of fatal and serious injury crashes are greater than what would be anticipated at a similar site (given the site conditions using methods defined by the HSM, aka predicted average crash frequency). These locations, called collision analysis locations (or corridors), are then analyzed and evaluated by the regions. When further investigation indicates that engineering countermeasures would reduce the anticipated number of fatal and serious injury crashes at the location for the given context, a report describing contributing factors and a benefit-cost analysis is presented to a panel for recommended investment through the I2 program. Final approval for funding occurs through the Highway Safety Executive Committee (HSEC). Note that these projects are implemented within a short time period.
- As part of the I2 Program, systemic treatments that address a specific crash type or contributing factor are also funded and implemented. Each of these investment types requires a specific priority programming process for identifying suitable locations and prioritizes implementation. These systemic treatments are developed to align with Target Zero emphasis areas. For each investment type, the target crash type/ contributing factor(s) and severity along with the

priority programming process are documented and formally approved by HSEC prior to deployment and implementation.

- During planning studies, the required approach for safety analysis as part of corridor planning studies is outlined in the WSDOT Safety Guidance for Corridor Planning Studies.
- Over a period of 7 years, the state highway system is reviewed through the field operational assessment program. Locations scheduled for pavement preservation drives the program. These teams often identify low cost investments (usually operational in nature) that can be quickly implemented. The low cost enhancement program usually funds these low cost investments. Projects that are funded through the I2 Safety Improvement Program follow the priority programming processes.

As we move from planning to programming in the project development process, the methods outlined in this guide are intend to increase the likelihood that higher level injury crashes will diminish over time where investments have occurred. This desire to make data-driven and science based decisions that have a higher probability of returning on target investment means that additional information on travel, roadway and roadside characteristics are added. The methods presented leverage the HSM predictive methods along with its associated tools to inform decisions.

Given the purpose and need of the project, it is important to determine and agree to the nature, extent, and method for safety analysis upfront. This includes identifying and agreeing to the analysis and evaluation focus within the context of *Target Zero* and practical solutions to achieve the right sized analysis to determine the “right projects at the right location at the right time.”

4. Concepts

This section discusses concepts like performance-based approaches, the units for safety performance analysis, crash severity, and different measures of crash frequency.

4.1 Units of safety performance

WSDOT uses the units of “crashes per year.” Safety analysis also distinguishes between the different levels of crash severity and crash type in an effort to target investments in safety performance to align with *Target Zero* and MAP-21 safety performance metrics for the state.

4.2 Crash severity

Table 1 shows the injury severity levels used by WSDOT along with the KABCO scale and the Model Minimum Uniform Crash Criteria (MMUCC 5.0) severity levels.

Table 1. Person Injury Levels

WSDOT	KABCO	MMUCC 5.0	Description of the injury (from MMUCC 5.0)
Fatality (death)	K	Fatal injury	Any injury that results in death within 30 days after the motor vehicle crash in which the injury occurred.
Suspected serious injury*	A	Suspected serious injury	Any injury other than fatal which results in one or more of the following: • Severe laceration resulting in exposure of underlying tissues/muscle/organs or resulting in significant loss of blood • Broken or distorted extremity (arm or leg) • Crush injuries • Suspected skull, chest or abdominal injury other than bruises or minor lacerations • Significant burns (second and third degree burns over 10% or more of the body) • Unconsciousness when taken from the crash scene • Paralysis
Evident injury	B	Suspected minor injury	Any injury that is evident at the scene of the crash, other than fatal or serious injuries. Examples include lump on the head, abrasions, bruises, minor lacerations (cuts on the skin surface with minimal bleeding and no exposure of deeper tissue/muscle).
Possible Injury	C	Possible injury	Any injury reported or claimed which is not a fatal, suspected serious or suspected minor injury. … Possible injuries are those reported by the person or are indicated by his/her behavior, but no wounds or injuries are readily evident.
Property Damage Only (PDO)	O	No apparent injury	Situation where there is no reason to believe that the person received any bodily harm from the motor vehicle crash. There is no physical evidence of injury and the person does not report any change in normal function.

* Previously known as incapacitating injury or serious injury

The Police Traffic Collision Report (PTCR) and supplemental reports (updates submitted after the original PTCR was submitted) record the injury severity levels of all persons involved in a reportable crash based on the assessment by the reporting officer. These per-person injury severities are used to determine the crash severity. The severity of a crash is based on the most severe injury to any person involved in the crash. For example, if a motor vehicle crash involves four occupants and two have no injury, one has an evident injury, and one has a serious injury, then the crash is a suspected serious injury crash.

The KABCO scale is used in the HSM. Table 2 summarizes references to crash severity in the HSM with respect to WSDOT terminology.

Table 2. HSM Terminology Related to Crash Severity

HSM Terminology (Crash Level)	WSDOT Crash Severity Level(s)	KABCO Crash Level(s)
Fatal and injury crashes (FI)	Fatal, suspected serious injury, evident and possible injury crashes	KABC
Fatal, suspected serious injury, and evident injury crashes	Fatal, suspected serious injury, and evident injury crashes	KAB
Property damage only crashes (PDO)	Property damage only crashes	O

4.3 Crash frequency

The term crash frequency refers to the number of crashes per year. Crash frequency is used to describe:

- **Observed average** crash frequency: the historic average of the number of crashes per year (usually the annual average across five years measured in full calendar years). When the HSM predictive method is used with crash history, the expected average crash frequency replaces the observed average crash frequency as a more reliable value of actual average historic performance.
- **Predicted** average crash frequency is an output from the HSM predictive analysis. It is the average safety performance of similar locations in crashes per year (see Section 6.5.1 for a discussion of the predictive method, and Section 9 for examples of how results can be described as part of documentation).
- **Expected** average crash frequency is a more reliable metric of existing average crash performance, measured in crashes per year. This is the value calculated using the predicted average crash frequency, and observed crash history as input to the empirical Bayes method in the HSM predictive methods. Results from the empirical Bayes method is considered a more reliable metric for determining average site specific crash history and is calculated by weighting the observed crash history against the predicted number of crashes per year. The empirical Bayes analysis reliability comes from its ability to account for regression to the mean (see Section 6.5.1 for a discussion of the predictive method, and Section 9 for examples of how results can be described as part of documentation). Note that analysis results values are averages and should not be interpreted as point values. Values are rounded to one decimal place[1] in the discussion of findings and presentation of final analysis results.

These terms are used in the HSM predictive method (see Section 6.5.1). Note that:

- The expected average crash frequency is a more reliable metric of existing average crash performance. As such, use the HSM predictive method with empirical Bayes where it applies. Relying on observed crash history for decision making is not preferred. Consult with your ASDE before relying on observed crash history for safety investment tradeoff decisions. Your ASDE will consult with subject matter experts from Design, Traffic, and Transportation Safety and Systems Analysis to determine if the observed crash history can be used effectively.
- Safety analysis results are averages crashes per year and should not be interpreted as point (absolute) values. It is important to recognize this aspect in decision-making.
- Predictive method analysis results should be rounded to one decimal place[2] in the discussion of findings and presentation of final analysis results.

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[1] All decimal places are kept throughout analysis calculations and the only the final report results are rounded to one decimal place.

[2] All decimal places are kept throughout analysis calculations and the only the final report results are rounded to one decimal place.

5. Technical Support

Technical assistance with safety analysis is available from a network of subject matter experts from the divisions of the WSDOT: Design, Traffic, and Transportation Safety and Systems Analysis. If you need assistance with safety analysis or have questions on how to conduct safety analysis on your project, contact your ASDE. They will work with you to answer your question or to reach out to the network of subject matter experts for assistance.

6. Common Practice

This section covers specific items of safety analysis that are applicable across all program and subprogram types.

6.1 Data needed for Safety Analyses

Safety analysis uses multiple data sources and the data sources will vary across project types, program types, and the analysis purpose. Based on 23 U.S. Code § 148 and 23 U.S. Code § 409, WSDOT regards any data used as part of safety analysis as safety data and not subject to discovery or admission into in a court of law. The WSDOT uses a disclaimer (see Section 6.2.1) to highlight this fact and it is the intent of the Department to use this disclaimer on any safety related data, spreadsheets, summaries, reports or other documents.

6.2 Handling of Safety Data – 23 USC §148 and 23 USC §409

The United States Congress requires state DOTs to collect safety data for use in the development of the Highway Safety Improvement Program (HSIP). Congress requires states, when considering use of federal funds, to identify locations that experience a higher than expected number of fatal and serious injury crashes (23 USC §148). Congress recognizes that the collection and use of safety data for the purposes of identifying locations had the potential to create significant legal liability for DOTs and exempted safety data from discovery and use as evidence against agencies. Safety data is widely defined as data used in analysis of locations and includes crash, traffic, geometric, roadside and other data used for the purposes of safety analysis. WSDOT recognizes the value of this privilege and has taken steps to inform its staff in aspects related to *23 U.S. Code § 148* *and* *23 U.S. Code § 409* and how it relates to safety data or the development of reports, lists, surveys, analyses, evaluations, or assessment. With respect to these deliverables, care is taken to include the disclaimer described in Section 6.2.1.

6.2.1 Disclaimer language

The WSDOT has developed standard disclaimer language that should be included on any page, table, or graph representing safety data or analysis results and included in emails or discussions of safety data. For safety analysis, this disclaimer must be in the footer and the font size can be adjusted to fit:

> *Under 23 U.S. Code § 148 and 23 U.S. Code § 409, safety data, reports, surveys, schedules, lists compiled or collected for the purpose of identifying, evaluating, or planning the safety enhancement of potential crash sites, hazardous roadway conditions, or railway-highway crossings are not subject to discovery or admitted into evidence in a Federal or State court proceeding or considered for other*

purposes in any action for damages arising from any occurrence at a location mentioned or addressed in such reports, surveys, schedules, lists, or data.

The disclaimer reflects the evidentiary exclusion provided for safety data as part of 23 USC §148 and 23 USC §409, as interpreted by the WSDOT Attorney General's Office. The WSDOT Highway Safety Intranet main page (http://wwwi.wsdot.wa.gov/HighwaySafety/) includes the most up to date version of the disclaimer.

6.2.2 Release of crash data or summaries to entities outside WSDOT

Because of 23 USC §148 and 23 USC §409 and subsequent federal and state court decisions, WSDOT attempts to strike a balance between providing information to the public, while not unduly increasing the liabilities against the state in terms of potential lawsuits. To this end, WSDOT has developed a policy for the release of crash data in Policy Statement Number: P 2021.

> *It is the policy of the Washington State Department of Transportation (WSDOT) to make crash data available to anyone who requests the data through the appropriate and applicable methods outlined below with the requestor's acceptance and acknowledgement of the data constraints per the state and federal laws governing access to the data.*

The official policy requires the release of any crash data or summaries to any individuals outside of WSDOT (e.g., public, consultant, external agencies) occur through an official request process with the Crash Data and Reporting Branch of the WSDOT Transportation Data, GIS and Modeling Office (TDGMO). The TDGMO is the only office at WSDOT who can release crash data to the public, and any other entity requesting crash records. Other HQ or Regional Offices do not have the authority to do so. Denial of these requests is the responsibility of the Director of Risk Management and Legal Services.

In addition, the policy also includes references to federal and state laws governing access to the data, information about the different request methods, a link to the request form, and language for cover letters. These are to be used by the WSDOT Crash Data and Reporting Branch staff who provide crash data to requestors outside WSDOT so this policy is carried out in a consistent manner.

6.2.3 Handling police reports

During the review and analysis of crashes, including motor vehicle crashes with people who walk or bike, WSDOT staff is encouraged to review the Police Traffic Collision Report (PTCR) narratives and sketches to help develop their understanding of the contributing factors, actions and events preceding, during and after a crash. PTCRs are for information only. PTCRs are not to be printed, stored, copied, scanned or emailed[3], or kept as part of project documentation. WSDOT staff may request access to PTCRs by contacting the Crash Data and Reporting Branch at WSDOT's TDGMO.

[3] Note that this discussion is not applicable to the financial recovery process.

6.2.4 Crash data

Locating crashes is not always straightforward and requires an understanding of the WSDOT state route linear referencing system. Staff is strongly encouraged to contact the Crash Data and Reporting Branch of the WSDOT Transportation Data, GIS and Modeling Office for any questions about the linear referencing system. The GIS and Modeling Office can also answer questions or comments about crash data. It is through these questions and discussions that staff develop a working understanding of the data, how to use it, and its limitations. It is important to note that ***collision data*** refers to the Washington State Patrol (WSP) data, and that ***crash data*** refers to the engineering crash data warehouse used at WSDOT for analysis. The WSDOT Engineering Crash Data Warehouse differs from the WSP collision database in that it includes many fields that WSDOT crash coding staff create after review of the PTCR, the narrative of the PTCR, and the sketch on the PTCR. The WSDOT Engineering Crash Data Warehouse is the source for crash data in safety performance analysis at WSDOT and for WSDOT projects.

Querying crash data

WSDOT staff can access the crash data through Cognos™. The steps are as follows:

1. Go to the Data Warehouse intranet website: http://wwwi.wsdot.wa.gov/IT/Data/Warehouse/
   NOTE. Review the status flag: if it is orange or red, review the notes provided by IT. Do not use Cognos™ for crash data queries if there are any issues noted with the Collision Data Warehouse.
2. Click on *Cognos™ Reports*.
3. Select *Team Content* ( ) from the left vertical navigation bar.
4. Select *Reports*, then *Transportation Planning*, then *Collision*. If you do not see *Collision*, you must contact the Crash Data and Reporting Branch to gain access.
5. Three report options are available.
   a. **Standard Crash History**:
      i. Click *View Reports*
      ii. Select *State Route Number* & Enter *Begin SRMP* & Enter *End SRMP* along with the ahead/back indicator
      iii. Enter or select from calendar *Begin Date* & *End Date* (Optional *Collision Type*)
      iv. Select *Standard Diagram Detail Report* or *Summary Report* & Sort Type.
   b. **Standard Crash Row Flat File:** Crash history with all information items in columns.
   c. **STATE ROUTE ONLY Condensed SRFF:** Crash history with a limited number of information items in columns.

Important notes (please contact the Crash Data and Reporting Branch if there are questions):

- Location information in Cognos™ is provided by SRMP and ahead/back indicator (this is different from the ARM values in other systems). The SRMP and ARM are shown for each crash in the data.
- When extracting crash data for freeway mainline segments, review the "Primary Trafficway" column to determine if the crashes were on the freeway, on the ramps, or on the crossroad.

- The Cognos™ reports can be customized by right clicking on 'Standard Crash History' (or any of the other two query options), selecting 'Edit report', selecting 'Save as' (saving it under 'My Content'. Then select the navigation item and select the Report page that you would like to customize, and save it for future use.

Reportable crashes

ANSI D16.1-2017[4] and MMUCC 5.0[5] set the requirements for the reporting of motor vehicle crashes in the U.S. and in Washington State WAC 446-85-010 (accident reporting threshold), RCW 46.52.030 (accident reports), and RCW 46.52.070 adds additional requirements. To meet these reporting criteria, a motor vehicle crash must:

(1) Have property damage of at least $1000 or injury of any individual;
(2) Be on a public roadway;
(3) Involve at least one motorized vehicle; and
(4) Not involve an intentional act, a legal intervention, or be medically caused.

Note that a crash is not recorded if a citizen is able to drive away without the assistance of an officer. Therefore, some locations may experience more crashes than is reported in the WSDOT Engineering Crash Data Warehouse. For uniformity with reporting standards across the state and realizing that WSDOT's focus is on fatal and serious crashes, non-reported crashes should not be included in project specific crash analysis.

The Fatality Analysis Reporting System (FARS) is a national data system for fatal crashes. This data system is used for fatal metrics in the federal required state safety performance reporting and updates to *Target Zero*. The Washington State Traffic Safety Commission (WTSC) manages the FARS database in Washington. WSDOT is continuing efforts to more closely align the data in the WSDOT Engineering Crash Data Warehouse with FARS. Staff should continue to use the crash data in the WSDOT Engineering Crash Data Warehouse as the basis for safety analysis.

6.2.5 Traffic volume data

Safety analyses using the HSM predictive method requires the Average Annual Daily Traffic (AADT) volumes as an input. This data is accessible through Cognos™ as part of the Transportation Planning category where crash data can be found (see Section 6.2.4), through the Washington State Pavement Management System (WSPMS) (see Section 6.2.6), online the interactive Traffic Geoportal map, or by contacting the Transportation Data, GIS & Modeling Office. Except in areas where high traffic growth occurred or where traffic volumes greatly reduced, staff is encouraged to rely on available data without

[4] Manual on Classification of Motor Vehicle Traffic Accidents, 2017. 8th Edition, http://www.atsip.org/ANSI_Ver_2017_D16.pdf.
[5] Model Minimum Uniform Crash Criteria 5th Edition (MMUCC 5.0), https://crashstats.nhtsa.dot.gov/Api/Public/Publication/812433 with more information at https://www.nhtsa.gov/mmucc-1. .

investing in additional traffic counts. Region Traffic Offices may have additional traffic count data on state and non-state route approaches.

6.2.6 Roadway data

A variety of tools at WSDOT provides access to roadway data:

- SRView contains photos, maps, and tabular roadway data. The tool can be accessed via a WSDOT computer as an installed application or via SRweb.
- The State Highway Log summarizes roadway data on an annual basis.
- The Washington State Pavement Management System (WebWSPMS) contains roadway, traffic, and other data. Data can be downloaded, viewed on a map, or printed as strip maps.

6.3 Study Period

Use five full calendar years (January 1st to December 31st) of historic crash data for safety analyses. There may be times where shorter study periods are appropriate. For instance, before and after periods where limited data is available. However, the shorter the period, the more likely it becomes that the crash data might indicate an unusually high or low number of crashes (lower reliability). By including 5 years of historic crash data into HSM predictive methods, the more likely that results from the predictive analysis would represent a reliable metric for actual average performance. A minimum of 2 years is required where major modifications at the site have occurred. In rare cases, when only one year of data will be available, then the use of the predicted average crash frequency from the HSM predictive method is recommended rather than the one-year crash history. The focus of this type of analysis is often the analysis of alternatives.

Document the study period, reasoning behind the selection and any assumptions as noted in Sections 7 and 8 of this guide. For complex cases, consult your ASDE. The ASDE will consult with subject matter experts from Design, Traffic, and Transportation Safety and Systems Analysis.

6.4 Study Area

A study area is the area impacted by the potential project or alternative solutions/strategies. Setting an appropriate study area is important and should occur as early as possible in the safety analysis process. Traffic analyses also use study areas and if there is a traffic analysis associated with the project then the study area would be a good starting point: this area can be modified if the safety impact area is different. Document the study area, reasoning for selection, and any assumptions as noted in Sections 6.9, 7, and 8 of this guide.

When selecting the study area consider how the potential safety performance and operational changes might affect the surrounding road and highway networks, the need to evaluate alternatives, and concerns of key stakeholders and approval authorities.

6.5 Crash Analysis Tools and Methods

This section discusses various crash analysis tools and methods used at WSDOT. The content is not meant to be all-inclusive but provides an overview of the tools, best use applications, and special considerations for use. In all cases, the tools and methods selected for the analysis are best selected early on in the project with the management team. If the HSM predictive methods cannot be used, the observed crash history can be used along with CMFs. Perform a human factors review of the feasible alternative and document a review of the fatal and serious injury crashes, and any crashes involving pedestrians or bicyclists.

6.5.1 HSM Predictive Methods

The HSM predictive methods are based on the fact that similar roadways and intersections with similar roadway and traffic characteristics are likely to experience similar crash frequencies, severities, and crash types.

The HSM predictive methods provides procedures to analyze safety performance in terms of crash severity, crash types, and number of vehicles involved in the crashes. In the first edition of the AASHTO HSM, this is accomplished with default distributions of crash severity level or crash types, or both.

The HSM predictive methods use safety performance functions (SPFs, see later in this section) and predictive method-specific crash modification factors (CMFs, see later in this section). The HSM predictive methods calculate the safety performance of similar facilities or sites (called the *predicted average crash frequency*), and, where applicable, the more reliable metric of existing crash performance (called the *expected average crash frequency*). Note that analysis results are averages and should not be interpreted as point values. The predictive method results are rounded to one decimal place in the discussion of findings and presentation of final analysis results. Note that results denote average values and should be interpreted as such.

Site types

The WSDOT uses tools (see Section 6.5.2) to implement the HSM predictive methods for the following facility types (showing relevant HSM 1st Edition, chapters):

- Rural two-lane, two-way highways (Chapter 10 in HSM)
- Rural multilane highways (Chapter 11 in HSM)
- Urban and suburban arterials (Chapter 12 in HSM)
- Freeways (Chapter 18 in HSM)
- Ramps and ramp terminals (Chapter 19 in HSM).

Each of these chapters cover segments (segment configurations) and intersections (number of legs and control type). A project can consist of a single element (segment or intersection) or several elements (segments and/or intersections) depending on the needs of the analysis.

Safety Performance Functions (SPFs)

Safety Performance Functions (SPFs) are equations that estimate the *predicted average crash frequency* for a specific roadway facility type, as is defined by segment or intersection type with **a specific set of base conditions** for those facilities identified. Each HSM chapter may have slightly different base conditions, facility designations, segment or intersection types, and variables used in the development of a given SPF because data, locations, modeling methods and statistical considerations may differ.

Calibration Factors

Calibration is the process of adjusting the SPF curves up or down in an attempt to account for the differing crash frequencies between different jurisdictions. Because much of the data used to develop the HSM predictive methods were from Washington State, WSDOT uses a calibration factor of 1.00, which is the default calibration factor in the HSM predictive methods.

Crash Modification Factors (CMFs)

There are two types of CMFs (Part C CMF and Countermeasure CMF). These CMFs have slightly different purposes and are often confused as interchangeable. It is true that both adjust the average number of crashes that might be anticipated at a site, but the reasoning as to how this is done is quite different. The following sections, highlight these differences.

a) Part C - CMFs

In the HSM Part C, predicted method-specific CMFs are as adjustment factors to the base condition SPF for the particular HSM predictive method. That is, the CMFs adjust the safety performance for the base condition for the particular method to the site specific condition. For instance, if the base condition for a particular HSM predictive method was 12' lanes and 8' shoulders, and the location being evaluated is 11' lanes and 4' shoulders, the method will use two separate adjustment factors for lane and shoulder widths to adjust the SPF value. In the second edition of the HSM, the CMFs in the predictive models will be referred to as "SPF adjustment factors" to reduce confusion.

The CMFs in the HSM predictive methods are only used with the specific SPF for which they were developed and a set of CMFs are specified for each facility and site type. The CMFs for the predictive methods will differ across facility and site types. For example, in the two-way two-lane rural highway segment analysis, several method-specific CMFs (i.e., SPF adjustment factors) are used with the SPF for the base conditions of the SPF: lane width, shoulder width, horizontal curve, grade, driveway density, etc.

b) Countermeasure CMFs

Countermeasure CMFs are CMFs that are used to estimate the anticipated impact of a countermeasure or mitigation on safety performance. Before selecting a countermeasure CMF, it is important to first identify the target crashes for the countermeasure or mitigation, i.e. the particular crash types, contributing factors and severities addressed by the countermeasure or mitigation for the given context being considered. Target crashes are the most common crash types or grouping of crashes that occur at the site. Note that for countermeasure selection purposes, the focus is on groupings of crash types associated with higher severity crashes.

Countermeasure CMFs are generally developed using multiple sites and statistical methods. The quality of CMFs varies significantly, making it necessary for WSDOT to have requirements in place for the review and approval of CMFs for use in analysis. WSDOT maintains a CMF short list that contains CMFs for various measures and this list is available on the WSDOT intranet. A detailed report for each of these CMFs describes the context and background for the CMFs, allowing the analyst to determine whether the CMF is suitable for the particular application (i.e. it matches the context and specific considerations for use).

When CMFs are not available on the shortlist, contact your ASDE or Headquarters Traffic Office for assistance on selection of the appropriate countermeasure for the given location. The ASDE will consult with subject matter experts from Design, Traffic, and Transportation Safety and Systems Analysis to help select an appropriate CMF. The FHWA CMF clearinghouse does contain numerous CMFs and may serve as a starting point for consideration if a particular countermeasure or context for application of a countermeasure is not available from the shortlist. The FHWA CMF Clearinghouse presents all available CMFs regardless of quality. The approval authority has to approve a CMF if it is not selected from the WSDOT CMF shortlist prior to use in required documentation, and for a particular CMF from the shortlist to be applicable, it has to match the treatment and context of application.

The selection of CMFs requires that:

1) The analysis site or corridor context matches the context of the identified CMF.
2) The quality of the study that developed the CMF is the best available for the identified CMF.
3) The CMF accounts for changes to particular crash types (the more specific the better).
4) The CMF accounts for changes to particular crash severities (the more specific the better).

When multiplying several countermeasure CMFs to a set of target crashes or severity levels, the result is often a combined CMF value implying incorrectly a large reduction in the target crashes. Exercise care when multiplying more than one countermeasure or mitigation CMF. Where more than one CMF applies, the CMFs should each apply to a different subset of target crash types or severity levels; or the analysis should only use one CMF.

There are many types of CMFs, including those that consider all crashes, specific crash types and specific injury severity. Where CMFs on crash types or severity levels exists, they are preferred due to the ability to address the specific crash characteristics and the potential impact of the countermeasure being analyzed.

The quality of CMFs are influenced by a multitude of factors. Assumptions made in the study can greatly impact the outcome of a CMF analysis. The following items represent general considerations for the quality of the CMF study:

- The quality of SPF used in the before-after study can impact the reliability of a CMF.
- Some studies do not isolate the impact of the particular countermeasure or ignore other changes made to the road environment, biasing the results.
- The quality of the SPF used in Empirical Bayes before-after studies impacts the reliability of results in that it biases the estimation of the typical performance of similar sites.
- Some studies suffer from omitted variable bias: changes that can affect the results are not accounted for.

- A countermeasure may have different impacts on safety performance across regions and states, sometimes because of how the measure is implemented, other times because of differences in user behavior.
- The context is sometimes not well defined, mixing distinctly different road environments together and biasing results.
- Some CMFs may be applicable to certain crash severity groupings rather than all the reported crashes.
- Small sample sizes reduce the reliability of results.
- Ignoring whether results of statistical significance during CMF analysis may lead to erroneous conclusions (lack of statistical significance indicates that the analysis does not offer findings that can be used for decision making).
- CMF development with meta-analysis is often challenging because it combines different studies and these studies often represent many different analysis methods, different assumptions, and contexts.
- CMFs showing no effect or an increase in crash types or severities are often not published (publication bias).

6.5.2 Tools for the HSM Predictive Methods

Spreadsheet Tools

There is a set of spreadsheet tools developed to automate the HSM predictive methods. The tools that WSDOT currently uses include:

- Extended spreadsheets: http://safetyperformance.org/tools/
  - Chapter 10: Rural two-way two-lane highways
  - Chapter 11: Rural multilane highways
  - Chapter 12: Urban and suburban arterials
- ISATe spreadsheet: http://wwwi.wsdot.wa.gov/HighwaySafety/SafetyTools.htm
  - Chapter 18: Freeway mainline segments and speed change lanes (Ramp Tapers)
  - Chapter 19: Ramps, ramp terminal intersections, & Collector Distributer (CD) lines).

These tools provide detailed outputs of safety performance in terms of crashes by:

- Crash severity: fatal and all injury, property damage only (PDO) and total crashes.
- Crash type: head-on, sideswipe, rear-end, etc.

The results can also distinguish between the typical safety performance of similar sites (predicted average crash frequency) and the site-specific safety performance (expected average crash frequency).

Use these tools in accordance with the applicable chapter in the HSM predictive methods outlined in Part C of the HSM. Data element definitions for HSM tools may differ between what is customary at WSDOT and what is required as input to the predictive method. These definitions may also vary between chapters. Therefore, the input to the HSM predictive methods is applied as outlined in the specific chapter, based on the facility and site type to reflect the existing and/or future condition(s). The text in the relevant section within Part C of the HSM should be consulted when gathering the input for the predictive analysis. All analysis assumptions need to be documented in the safety analysis and should be detailed enough to allow for replication of analysis results. The safety analysis will be included in the appropriate project or planning documents.

Section 9 of this guide provides examples of how the results from the predictive method can be discussed in reports and project documentation.

IHSDM

The Interactive Highway Safety Design Model (IHSDM) is software developed and maintained by FHWA. IHSDM is a suite of analysis tools and includes the Crash Prediction Module (CPM) to implement the HSM predictive analysis chapters. In 2019 WSDOT is introducing the Crash Prediction Module of the Interactive Highway Safety Design Model (IHSDM) developed by FHWA to the WSDOT analysis toolbox. This software that performs the AASHTO Highway Safety Manual predictive methods. The software is currently funded by FHWA and available for free to any user. In 2018 the IHSDM team made several changes to the software that makes the tool practical for use at WSDOT. The major advantage of IHSDM is that it supports analysis across the different HSM Predictive Chapters. For example, a corridor may require the use of several chapters in the predictive methods of the HSM. The HSM spreadsheets listed above would then require the use of several spreadsheets and the project team/user needs to assemble these sheets to show performance across the corridor. With IHSDM this is no longer necessary because it is included as one tool. The IHSDM training is now part of the Practical Solutions Highway Safety Manual training series for staff and a WSDOT output template for use with IHSDM is also available and required for use with WSDOT projects.

6.6 Societal Cost

The societal cost of a crash is a monetary value that a state agency adopts to quantify the benefits of a change in safety performance as part of a benefit-cost analysis. These values are used department wide and set as a matter of policy by the HSEC. The values used by WSDOT are modified from NHTSA and FHWA values. These FHWA values may be updated to account for inflation, most commonly these changes occur based on federal cost estimates modifications or recommendations. WSDOT incorporates these changes periodically and the most current values can be found online on the WSDOT Highway Safety intranet site.

6.7 Human Factors

The purpose of the human factors review is to evaluate the operation of the proposed configuration. For example, evaluate how information is provided to the user, driver expectation, perception-reaction conditions, potential conflict points, the context and speed of users at the site, and how the users will interact with one another.

Chapter 2 of the HSM (2010) and NCHRP Report 600, Human Factors Guidelines for Road Systems (2nd Edition, 2015) are valuable resources that can be used to perform human factors task analysis and specific human factors considerations during design.

The use of human factors reviews are an emerging practice within WSDOT. WSDOT will incorporate new practices into this document as appropriate.

6.8 Planning, Scoping, and Programming

6.8.1 Relationship between Planning and the I2 Safety Program

The State Highway Strategic Plan (SHSP) is the primary focal point that guides planning, public input and the safety priority programming processes. MAP-21 and the FAST Act, along with federal safety performance rulemaking (April 2016) require states to develop a SHSP, safety performance metrics, and to align their safety programs, policies and processes with the SHSP.

In Washington State, *Target Zero* is the SHSP. This plan is developed and updated every three to five years using a statewide stakeholder and public engagement process, representing agreement among state agencies and safety partners in Washington about the emphasis areas, priorities, and safety performance metrics. *Target Zero* uses data analysis to identify and prioritize leading crash contributing factors and types. Each priority has associated strategies in education, enforcement, engineering, emergency services, and evaluation (e.g., the 5Es). WSDOT uses *Target Zero* to provide direction in the development and approach to highway safety by organizing its safety improvement program consistent with the priorities and emphasis areas of *Target Zero*. In this manner, WSDOT is coordinated with other agencies in carrying out its responsibilities. WSDOT has developed a Public Crash Data Portal and is incorporating SHSP emphasis areas into the AASHTOWare SafetyAnalyst™ tool to provide the *Target Zero* emphasis area crash summary information for a given location.

Figure 1 shows how Target Zero is developed with statewide stakeholder input and public engagement, and how it serves as the foundation for the development of projects that make up WSDOT's Target Zero Implementation Plan. This implementation plan relies upon the priority programming processes in the development and programming of capital safety projects. The figure shows how this process; along with planning, community engagement, and field operational assessments, may lead to non-capital actions to reduce crash potential including Low Cost Enhancements, maintenance activities, policy or operational activities.

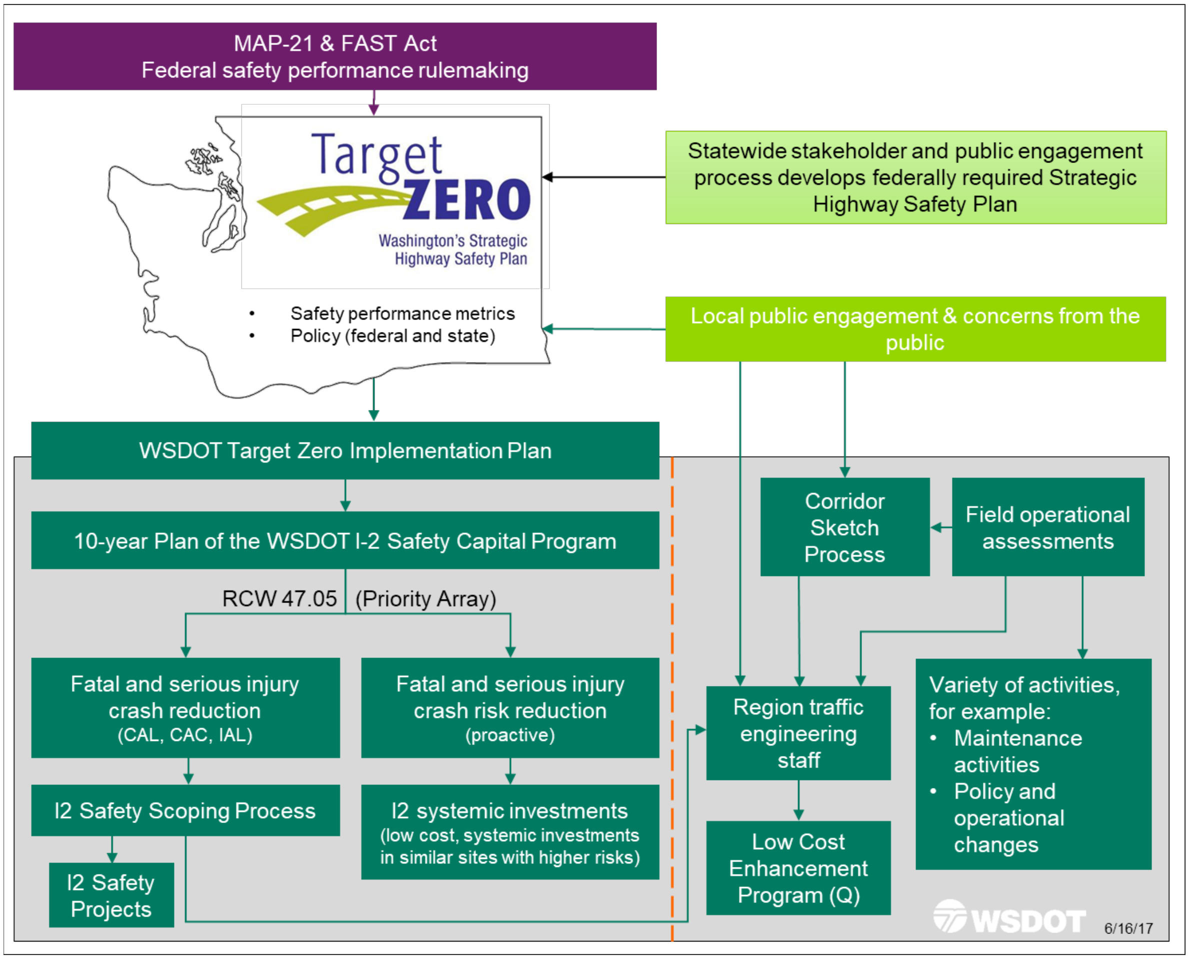

Figure 1. Safety Priority Programming and Public Processes
(For questions about the process, please contact the Director of Transportation Safety and Systems Analysis for more information.)

6.8.2 I2 Safety Project Identification and Community Engagement

WSDOT uses three approaches to identify potential projects. The most restrictive approach is through the WSDOT safety priority array. For a project to be identified as a location funded by the I2 Safety Program, it must be identified, analyzed and programmed through the priority programming based on observed and expected future crashes; and only after it is ranked in comparison to other like locations throughout the state.

When a location is not identified in the priority array, the WSDOT's Traffic Operations Low Cost Enhancement Program may be used to identify quick turnaround and lower cost solutions. With this approach, public comments are sometimes provided to region traffic staff for consideration. The demand for low cost enhancement funding exceeds the amount available and therefore it undergoes a prioritization process lead by the Region Traffic Engineer.

Based on the particular public input or comments, and the ability to identify a lower cost investment, a small project may be considered. Engineers may deem it necessary to continue to monitor the location, or identify the need to gather more data before determining next steps. In some cases, no action will be taken because a lower cost solution is not available or the analysis indicates that the potential solution(s) are unlikely to provide a return on the investment. As mentioned, both the Safety Improvement program and the Low Cost Enhancement Program are limited in the type, scale and costs of the projects they were developed to address. Some comments from the public may request actions that are outside of WSDOT's ability to respond. For instance, a project outside of WSDOT safety priority array, or outside of the scope of Low Cost Enhancement projects. Although less common, the comments may result in future planning efforts, local investments, or other legislative actions.

6.8.3 Expectations for Corridor Sketch Activities and Safety

The *Target Zero* Emphasis Area summaries for each corridor are available for use in the documentation of the safety performance of a corridor. This information is presented as observed crash history based on a five-year period and is presented as factual information for use in communication with the public. A key part of this message is that the I2 safety program is driven by a statewide plan, *Target Zero*, and that multiple partners across the state are working together towards the *Target Zero* Goal.

The expectation for safety in corridor sketches is to identify opportunities that address system performance within the corridor. This activity is conducted prior to any decisions that are made regarding sources of funds to implement solutions.

It is important to inform the public that the I2 Safety Improvement Program has specific required actions outlined as part of its priority programming process.

6.8.4 WSDOT's I2 Safety Improvement Program Overview

WSDOT's highway safety program has been developed to reduce fatal and serious crashes across the state in the most economical and efficient manner. WSDOT works with its partners in developing and implementing a strategic approach to highway safety. This strategic approach is highlighted in *Target Zero*. Using *Target Zero* as its guide, WSDOT uses a priority programming system to identify and determine what locations have the highest potential for the reduction of fatal and serious injury crashes, and return the greatest benefit for the cost of the project.

In this manner, projects are identified through data driven safety analysis, which is a key point to emphasize. This approach is required by Federal regulations and makes good business sense. This is because projects are more likely to return on investment because the deliberate and science-based approach is based on crash data, science, and risk. The opinion or perceptions of drivers and other road users is very important to WSDOT as it provides information not available to WSDOT, but it is supplemental to the priority programming.

The Safety Improvement Program has been developed to address both the occurrence and potential for crashes. These two categories are referred to as *Crash Reduction* and *Crash Prevention* categories.

Crash Reduction

The Crash Reduction category focuses on locations that experience fatal and injury crashes that meet the Collision Analysis Location/Collision Analysis Corridor (CAL/CAC) or Intersection Analysis Location (IAL) criteria. CAL/CAC and IAL locations are screened and ranked on a statewide basis. These ranked lists are provided for further analysis to the Region Offices responsible for safety scoping.

The Region identifies countermeasures and conducts cost/benefit analysis. Based on this process, proposed countermeasures are documented in a Crash Analysis Report (CAR – see Section 8.4). This information is presented to an I2 safety panel to evaluate and recommends the project for programming or additional analysis and evaluation. Of primary importance is that the potential project is consistent with *Target Zero* and WSDOT policies and processes.

This process is formalized under the Safety Scoping Process for State Routes.

Crash Prevention

The *Crash Prevention* program identifies engineering countermeasures that can be applied on statewide, corridor or localized basis to address particular contributing factors, crash types or countermeasures. The selection of project approaches within the Crash Prevention program considers the characteristics and context of a given facility. Systemic treatments and roadside features are commonly considered and implemented. Each of these investment types requires specific priority programming processes for identifying suitable locations and prioritizes implementation. This includes development and documentation of a method for ranking, scoping and determining benefits and costs in prioritizing projects.

Program Approval

Together these two categories (*Crash Reduction* and *Crash Prevention*) form the WSDOT Safety Improvement (I2) Program. However, not all projects that are analyzed by the regions are programmed within the safety program because the contributing factors to the crashes may not be effectively reduced through engineering countermeasures. For instance, behavioral issues, such as impaired driving related crashes. In addition, some projects may be driven by multiple performance requirements, including mobility, economic vitality, or preservation. These types of projects are typically higher costs and are addressed within other program areas. In some cases, WSDOT will implement lower cost projects through its Low Cost Enhancement Program. These projects typically have multiple factors driving their selection. These types of projects are limited in scale, scope and cost.

The I2 Safety program is divided into two investment categories: Crash Reduction and Crash Prevention. These categories are sub-divided by safety activities (sub-categories). For example, Crash Prevention is currently divided into new rumble strip installation, mitigation of redirectional landforms, cable median barriers and other prevention strategies. The Division of Transportation Safety and System Analysis leads a joint effort with the Divisions of Traffic Operations, Development, and CPDM to develop a 10-Year Capital Investment Plan. This 10-Year plan is then presented to HSEC for agreement. Finally, the list of categories, sub-categories and the projects contained within the 10-year Program Plan of WSDOT's I2

Safety Program is approved annually as part of the FHWA Highway Safety Improvement Program (HSIP) submittal. The HSIP report is submitted by the Director of Transportation and Systems Analysis. The submittal outlines WSDOT's approach to reducing fatal and serious crashes consistent with its Strategic Highway Safety Plan, *Target Zero.* Further, as required by federal regulations, WSDOT may also be required to submit a *Target Zero Implementation Plan* when the state safety performance targets are not met.

6.8.5 Design Analysis

The purpose of safety analysis in a design analysis is to quantify the safety performance impacts of the alternatives to inform the tradeoff decisions and/or determine the potential mitigation measures. In some cases, safety performance may be impacted while in other cases it will have no or a negligible impact.

Safety analysis is contained in the options analysis section of the design analysis template. The safety analysis should focus on the number of fatal and serious injury crashes per year and crashes involving pedestrians or bicyclists. Lower severity crashes may be taken into consideration on projects where safety is a contextual need. Compare the alternatives being considered and discuss the tradeoffs with respect to safety.

Trigger	Design selection or alternative selection outside DM ranges and may impact safety performance.
Study Area	The location of the elements being analyzed in the design analysis.
Study Period	Five calendar years unless there has been a significant change that justifies a reduction in the number of years (2 years minimum).
Scope	The elements for which the design analysis is being written.
Methodology	Follow the methodology detailed in Section 6.9.
Tools	See Section 6.5
Goals	1. Evaluate existing safety performance to identify safety improvement opportunities and inform design decisions. 2. Analyze the safety performance of all identified alternatives to provide safety performance measures to help inform the tradeoff decisions during the preferred alternative selection 3. To reduce crashes for users, with an emphasis on fatal and serious crash reduction
Documentation	Discuss the safety performance results and tradeoffs in the "Options Analysis" section of the design analysis template.

6.9 Safety Analysis Scope and Methodology for Non-Preservation Projects

NOTE: This section details the methodology for I1, I2, I3, ARR, EIS, or TIA projects/processes. Only utilize this section when directed to by the table in Section 7 or 8 that relates to your project funding or process

The following five steps describe the general safety analysis scope and methodology for non-preservation projects and processes. Consult your ASDE for assistance in interpreting these steps and the applicability of each step to the particular project. As the analyst go through these steps, document all assumptions, results, and conclusions.

STEP 1. Consult the table from Section 7 or 8 that relates to your project funding or process. Work with your ASDE to reach agreement on an appropriate scale and scope of the safety analysis. The agreement on scale and scope is critical to assuring the appropriate analysis is conducted. The ASDE will consult with subject matter experts from Design, Traffic, and Transportation Safety and Systems Analysis to determine if steps 2 thru 4 of this process may be skipped or modified.

STEP 2. If the project will be making significant changes to the existing facility, it may skip steps 2 through 4 and go directly to step 5. An example of a significant change is converting a diamond interchange into a diverging diamond or replacing a two-way stop with a roundabout. In both of these significant changes, the history of what happened may not be directly applicable to what may happen in the future. If a crash history is beneficial, pull the crash data (Section 6.2.4) for the applicable study period and study area. The items listed below are ways to summarize this data to get a better understanding of the existing facility.

- If an HSM predictive method is available for the existing conditions, you can calculate the predicted crash frequency within the study area and determine if the location is performing better or worse than predicted.
- Create charts and/or tables of the data to help visualize patterns. The charts can depict many things such as injury severity, driver age, mode, crash type, contributing factors, time of day, or day of the week.
- Map the crash data. Mapping is commonly done as summary level data to assist in visualizing the data in relationship to the geometrics, roadside conditions, or development. This may be done in GIS, Excel, MicroStation, or simply on an aerial photo. Visualization of crash data can be beneficial in public forums.
- If the study area includes an intersection, it may be helpful to draw an intersection crash diagram for each intersection. See Chapter 5.2 of the HSM for guidance.
- A human factors review of the project area and crash history may provide a better understanding of crash patterns in the study area. See Section 6.7 for more information on human factors.

STEP 3. As part of *Target Zero* (see Section 2.3), review all fatal and serious injury crashes and any crashes involving people who walk or bike. Consider the items listed in STEP 2 and determine if any of these tools will help in the review. Identify mitigation to reduce these crash types through infrastructure investments that are cost effective. These investments will not be excessive in cost to such an extent that it is outside the available budget for the mobility, preservation, or economic vitality project. Be aware that improving a roadway for one user may have impacts on another mode of transportation.

STEP 4. Analyze the data from Step 2 and 3 to determine if there are any patterns to the crashes or if there are concentrations of crashes at a particular location(s). If there are no patterns or concentrations of crashes, document there is no pattern and end this process. Otherwise, determine the target crash types, severities, and their contributing factors. It may be necessary to develop condition diagrams for the locations with crash patterns or concentrations to better understand the contributing factors (see HSM Chapter 5.2 for guidance). During this step, the Police Traffic Collision Reports may be helpful to understand the contributing factors.

NOTE: The patterns and target crashes you identify in this STEP are a factual representation of the data and cannot be identified as “safety projects”. The sub-program I2 Safety contains the only projects that are referenced to as “safety projects”. Projects may have safety components that influence safety performance, but these projects are driven by other baseline needs such as traffic operations, preservation, mobility, economic initiatives or environmental retrofit (Q, P, M, I1, I3, I4 respectively).

STEP 5. The purpose of this step is to conduct a safety performance analysis of each reasonable alternative to assist in the selection of a preferred alternative. If the roadway is not being significantly modified, it may be beneficial to compare the alternatives to the no-build. It is important to document the safety analysis done on each alternative and how safety analysis was considered when selecting the preferred alternative.

a. If the alternatives can be analyzed using the HSM predictive method(s) (See HSM Chapters 10, 11, 12, 18, or 19), follow the HSM procedure. Use the results in the alternatives comparison process to help select the preferred alternative. Document all assumptions.

b. If there is no HSM predictive method available to assess the safety performance for a particular alternative, but there is a CMF that represent the particular alternative, apply the CMF to the observed crashes per year. Follow Section 6.5.1 on how to select a CMF. This will determine an average number of anticipated crashes per year for that alternative. It may be necessary to repeat this process for each countermeasure that is employed in an alternative. Compare the anticipated crashes per year for each alternative. Use this information in the alternatives comparison process to help select the preferred alternative.

c. If there are no CMFs for a countermeasure, consult your ASDE or Headquarter Traffic Office. WSDOT requires a consistent scientific basis for CMF development and acceptance for use. Therefore, your ASDE will consult with subject matter experts from Design, Traffic, and Transportation Safety and Systems Analysis for assistance on how to proceed with determination of a CMF. The subject matter experts may have additional knowledge of research that may be used for the CMF. They may also ask if similar countermeasures have been deployed for use in developing a new or interim CMF. In some cases it may be necessary to track the performance of the countermeasure as a series of pilot projects and report back on the countermeasure’s effectiveness.

7. Safety Analysis by Program Type

This section of the guide steps through the primary funding mechanisms and discusses safety analysis for each sub-program for the Preservation (P), Investment (I), and Traffic Operations (Q), programs. The Project Definition contains the primary need, solution, and purpose for a project and is used to determine the program and sub-program for a project. Final determination of the appropriate program and sub-program for a project is the responsibility of CPDM.

In each sub-section, there is a table with the following rows: Trigger, Study Area, Study Period, Scope, Scale, Methodology, Tools, Goals, and Documentation. Each table is intended to summarize the safety analysis that is needed for a project in the particular program type. **The guide does not take away the responsibility of the user to apply sound engineering judgement based on specific project conditions or to address items not covered in this guide**.

7.1 Preservation (P)

7.1.1 Pavement Preservation (P1)

Projects funded from P1 are to preserve pavements at the lowest life cycle cost[6] and safety is not a baseline need, but can be a contextual need. Designers should contact their region's Field Assessment program to determine whether there are low/no cost contextual safety elements that have been identified for the corridor and can be incorporated into the project. Documentation for these improvements has to follow the requirements of the Field Assessment program, will include a traffic basis of design (QBOD), and need to be incorporated into the Project Development Approval.

Trigger	If the lane width or shoulder width is reduced, see Section 7.1.2. If Field Assessment or Traffic Operations programs identify items to incorporate into the project through a QBOD, see Section 7.3
Study Area	N/A
Study Period	N/A
Scope	N/A
Scale	N/A
Methodology	N/A
Tools	N/A
Goals	N/A
Documentation	The Field Assessment program will provide a QBOD that is appropriate for their program. QBODs are approved by the Region Traffic Engineer. Include the QBOD in the Project Design Documentation Package (DDP).

7.1.2 Bridge Preservation Program (P2)

The bridge preservation program addresses the overall preservation of bridges and structures on the state highway system[7]. This program includes vehicular bridges, culverts longer than 20 feet, pedestrian bridges, tunnels, lids, and deck overlays.

Bridge preservation projects preserve the state's bridge network through cost effective actions. There are numerous types of bridge preservation actions including: deck rehabilitation, seismic retrofit, painting steel bridges, and scour repair. The type of bridge preservation work that effects safety is where the lane or shoulder widths change. If the bridge is widened so that the lane and/or shoulder widths will end up larger and neither are narrowed, then no safety analysis is needed.

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[6] WSDOT 2017-2019 Capital Improvement and Preservation Program, September 2016, page II2
[7] WSDOT 2017-2019 Capital Improvement and Preservation Program, September 2016, page II-5

Trigger	If the lane or shoulder width is changed. If a Field Assessment or Traffic Operations programs identifies items to incorporate into the project, follow Section 7.3. If a bridge is being replaced, follow Section 7.2.1.
Study Area	Field Assessment limits or where the lane width or shoulder width is changed.
Study Period	Crash history is not used in this analysis because the analysis only compares the predicted average annual crash frequencies across alternatives.
Scope	Analyze the lane and shoulder widths being considered. Analyze the crash data for crashes that can be attributed to lane and shoulder width and their contributing factors.
Methodology	Use the applicable CMF tables/equations for the roadway type with respect to lane and shoulder width. Compare the CMFs of the lane/shoulder widths being considered.
Tools	For the appropriate roadway type, use the following items from the HSM: • Rural Two-Lane, Two-Way Roads: o Lanes: Table 10-8 o Shoulders: Table 10-9 • Undivided Roadway Segment o Lanes: Table 11-11 o Shoulders: Table 11-12 • Divided Roadway Segment o Lanes: Table 11-16 o Shoulders: Table 11-17 • Freeway Segments: See HSM Chapter 18.7.1 o Lane Width: Equation 18-25 o Inside Shoulder Width: Equation 18-26 o Outside Shoulder Width: Equation 18-35
Goals	Assess the safety performance of the alternatives being considered.
Documentation	Include safety performance as a contextual need in the BOD. Include CMF discussion in the alternatives comparison section of the BOD. Summarize the findings of the contributing factors analysis in the BOD. If Field Assessment or Traffic Operations request the change, then complete a QBOD and include it in the project's DDP.

7.1.3 Other Highway Facilities Preservation Program (P3)

Preservation of other facilities includes basic safety guardrail and signing, major drainage, major electrical, unstable slopes and other project types. P3 signal rehabilitation projects require a safety analysis as part of the Intersection Control Evaluation (ICE). If the signal is being replaced with a single lane roundabout, no safety analysis is needed. If another P3 project type impacts lane and shoulder width, follow the safety analysis requirements for the Bridge Preservation Program described in Section 7.1.2.

Trigger	Refurbishing an existing signal or modifying lane/shoulder width. For projects that only modify lane/shoulder width, follow the directions provided in Section 7.1.2. If the existing signal is being replaced by a single lane roundabout, a safety analysis is not required.
Study Area	The intersection with the signal and any roadway segments that are changed.

Study Period	Use five calendar years of crash history as part of the input into the analysis unless there has been a significant change that justifies a reduction in the number of years (2 years minimum).
Scope	The scope of the safety analysis is limited, focusing on the characteristics and contributing factors of the intersection and intersection-related target crashes (rear-end, right-angle and sideswipe crashes) that can be addressed within the scope of the P3 signal replacement activities. For example, signal related installation, signal timing, lane markings, and signage. Recommendations should be general in nature and presented as suggestions for consideration during the installation and implementation of the signal replacement system.
Methodology	Compare the portion of fatal and all injury crashes for intersection and intersection related crashes of the following types: rear-end, right-angled and sideswipe crashes to the typical proportions of these crashes in the applicable HSM Part C chapter and section. If the HSM Predictive methods cannot be used, the crash history can be used along with CMFs. Perform a human factors review of the feasible alternatives and document a review of the fatal and serious injury crashes, and any crashes involving pedestrians or bicyclists. Define mitigation strategies to address changes in safety performance.
Tools	Use the following HSM tables: • Rural Two-Lane Two-Way Intersections (all crashes): Table 10-6 • Rural Multilane Intersections (all crashes): Table 11-9 • Urban/Suburban Intersections o Multiple-Vehicle Crashes (3 leg & 4 leg signals) - Table 12-11 o Single-Vehicle Crashes (3 leg & 4 leg signals) - Table 12-12 • Ramp Terminal Intersections (all crashes) - Table 19-16
Goals	Compare the crashes to determine if there is benefit to switching the signal to another method of intersection control.
Documentation	Include documentation of the results of the safety analysis in the ICE. Briefly summarize the findings from the investigation done in the scope and methodology sections of this table. If there is an over-representation of particular crash types when reviewing the portion fatal and serious injury crashes, review and discuss the contributing factors to these higher severity crashes at the location based on a human factors and crash characteristics review. Also, review and discuss the factors that contributed to any cashes involving people walking or biking. Where appropriate, recommend additional analysis related to modification of signal operations and/or lane markings.

7.2 Highway Improvement (I)

7.2.1 Mobility Improvement (I1)

The purpose of the I1 Mobility Improvement Program is to make “investments to move people, goods, and reduce congestion, by managing demand effectively, operating transportation systems efficiently, improving local network, changing policies when necessary before considering adding infrastructure capacity[8]."

Safety performance is integral to these projects and WSDOT's practical design approach is committed to multimodal safety as identified in WSDOT's *Target Zero*. To meet this commitment, projects are required to include a baseline performance metric for evaluating the number of fatal and serious injury crashes in **safety**, **mobility,** and **economic vitality** category projects[9]." Note: Analysis of the safety performance of mobility alternatives is required regardless of whether any fatal or serious injury crashes occurred within the study area.

The size and scope of many I1 project requires flexibility in the safety analysis approach. Getting agreement on the specific scope and scale of the given project by the respective Region and Headquarters teams should occur early in the project development.

Crashes may increase with an I1 project because of the increase of exposure created by increased VMT. Crashes may reduce the mobility performance of a given network. Consider potential strategies to address these crash impacts.

Trigger	Safety performance in terms of fatal and serious injury crashes is a baseline need (per DM Chapter 1101.02(1)). Safety performance of alternatives is required. The scope is flexible as noted below and in Section 6.9.
Study Area	Begin by matching the study area of the traffic analysis. Adjust the study area as necessary and as agreed to by your stakeholders. If no traffic analysis is completed for the project consult Section 6.4.
Study Period	Use five calendar years of crash history unless there has been a significant change that justifies a reduction in the number of years (2 years minimum).
Scope and Methodology	Follow the Safety Analysis Scope and Methodology detailed in Section 6.9.
Tools	For freeway segments, ramps, and ramp terminals, use the Interchange Safety Analysis Tool enhanced (ISATe). For other facility types, use the extended HSM spreadsheets. The analysis tools can be found online at: http://www.wsdot.wa.gov/Design/Support.htm
Goals	The goals are achieved by following the scope and methodology detailed in Section 6.9.
Documentation	Document the steps from Section 6.9 that were completed. Document the assumptions, what was discovered in each step, and the conclusions. This document will be the safety analysis that is required for Design Approval.

7.2.2 Safety Improvement (I2)

The safety improvement program is a targeted program developed to reduce fatal and serious crashes on the state highway system. The program is derived through *Target Zero*, and further developed through WSDOT's *Target Zero* Implementation Plan, where WSDOT highlights the sub-categories of the

[8] WSDOT 2017-2019 Capital Improvement and Preservation Program, September 2016, page II-9
[9] Design Manual, July 2017, Chapter 1101.02(1)

safety program and the intended performance objectives of each. The safety program is structured into Crash Reduction and Crash Prevention Categories, and sub-categories are defined with a focus on specific crash types, contributing circumstances, historical data or systemic treatments. These categories may change based on performance over time (See Figure *2*). Priority array analysis is used to determine a ranked list of projects where countermeasures are evaluated and priorities are determined using a benefit cost analysis.

Section 6.8 discusses the priority array process, legislative requirements, and approach for the I2 Program.

I2 projects that fall within the CAL, CAC, and IAL sub-categories will require a Crash Analysis Report (CAR). The CAR is a standard document that is typically reviewed by the Region Traffic Engineer and ASDE then provided to the State Safety Engineer for review and presentation to the I2 Panel. The I2 Panel may require technical modification and adjustments before the project moves forward in the programming process.

Trigger	See Figure *2*. If a CAR is required, see Section 8.4. For I-2 crash prevention projects that require a safety analysis per Figure *2*, follow the guidance in this section.
Study Area	Begin with the project limits as defined in the project documentation. The study area can be adjusted as needed to reflect the area of impact.
Study Period	Use five calendar years of crash history as part of the input into the analysis unless there has been a significant change that justifies a reduction in the number of years (2 years minimum).
Scope and Methodology	Follow the Safety Analysis Scope and Methodology detailed in Section 6.9.
Tools	• CAR template. • For freeway segments, ramps, and ramp terminals, use the Interchange Safety Analysis Tool enhanced (ISATe). For other facility types, use the applicable extended HSM predictive method spreadsheet. These tools can be found online at: http://www.wsdot.wa.gov/Design/Support.htm. • Benefit/cost spreadsheet provided with the I2 scoping instructions.
Goals	The goals are achieved by following the scope and methodology detailed in Section 6.9.
Documentation	Document what was done as Section 6.9 was followed. Document the assumptions, what was discovered in each step, and the conclusions. This document will be the safety analysis that is required for Design Approval.

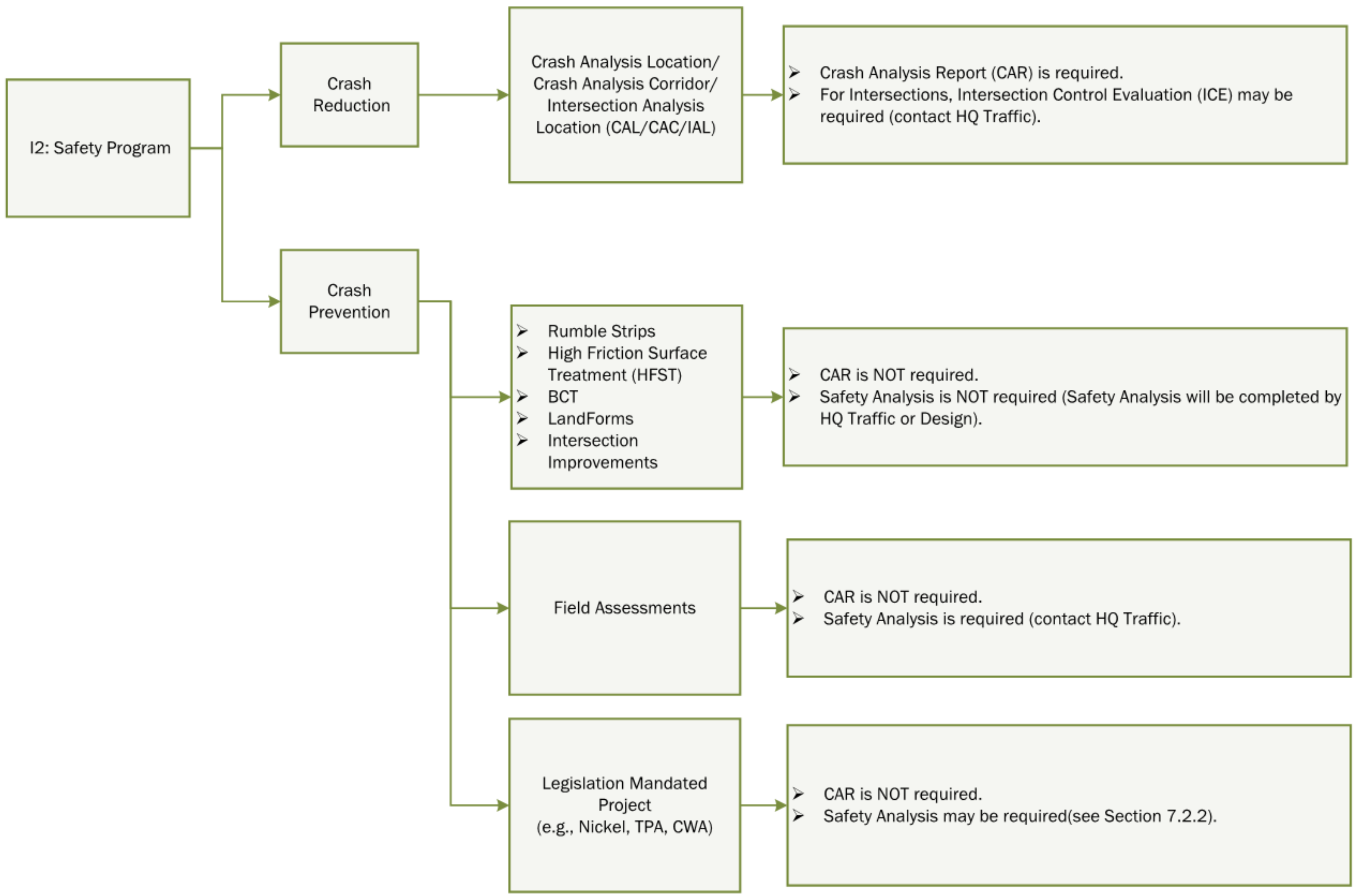

Figure 2. I2 Safety Analysis for Collision Reduction and Prevention Programs

7.2.3 Economic Initiatives (I3)

I3 Economic Initiatives projects includes promoting and developing "transportation systems that stimulate, support, and enhance the movement of people and goods to ensure a prosperous economy. Economic Initiatives support freight movement and tourism development through the construction of new rest areas and bicycle touring facilities along scenic and recreational highways. To achieve the program goals, the Economic Initiatives program is subdivided into the following subcategories: 1. Freight (upgrading all-weather pavements and bridges with restricted vertical clearance). 2. Community Livability and Economic Vitality. 3. Scenic and Recreational Highways.[10]"

The Chapter 1101.02(1) of the Design Manual requires a baseline metric for evaluating the number of fatal and serious injury crashes for all I3 projects.

Safety analysis for all I3 project is the same as for I1 Mobility projects. As a result, follow the process outlined for I1 Mobility projects (Section 7.2.1.).

7.2.4 Environmental Retrofit (I4)

I4 environmental retrofit projects enhances "Washington's quality of life through transportation investments that promote energy conservation, enhance healthy communities, and protect the environment. Environmental retrofit projects reduce or eliminate environmental impacts of existing highway systems to meet environmental requirements that have emerged since the highways were built.[11]" Environmental retrofit projects includes fish passage barriers, chronic environmental deficiency, plant management, stormwater runoff, noise reduction, and wildlife connectivity. Generally, these projects do not change the characteristics of the roadway, but do have the ability to impact clear zones and side slopes. Clear zones should be evaluated or treated per DM Chapter 1600.

Trigger	If the lane width or shoulder width is reduced. If a bridge is replacing a culvert, follow Section 7.2.1.
Study Area	Where the lane width or shoulder width is reduced.
Study Period	Crash history is not used in this analysis because the analysis only compares the predicted average annual crash frequencies across alternatives.
Scope	Analyze the lane and shoulder widths being considered.
Methodology	Use the applicable CMF tables/equations for the roadway type in terms of lane and shoulder width. Compare the CMFs of the lane/shoulder widths being considered.
Tools	For the appropriate roadway type, use the following items from the HSM: • Rural Two-Lane, Two-Way Roads: o Lanes: Table 10-8 o Shoulders: Table 10-9 • Undivided Roadway Segment o Lanes: Table 11-11 o Shoulders: Table 11-12 • Divided Roadway Segment

[10] WSDOT 2017-2019 Capital Improvement and Preservation Program, September 2016, page II-17
[11] WSDOT 2017-2019 Capital Improvement and Preservation Program, September 2016, page II-17

	o Lanes: Table 11-16 o Shoulders: Table 11-17 • Freeway Segments: See HSM Chapter 18.7.1 o Lane Width: Equation 18-25 o Inside Shoulder Width: Equation 18-26 o Outside Shoulder Width: Equation 18-35
Goals	Assess the safety performance of the alternatives being considered.
Documentation	Include safety performance as a contextual need on the BOD. Include CMF discussion in the alternatives comparison section of the BOD.

7.3 Traffic Operations (Q)

"Low Cost Enhancements (LCE) are projects that can be quickly implemented to improve operational performance on state highways. The Washington State Department of Transportation's (WSDOT) six regions use LCEs strategically to improve the operational safety and efficiency of the highway system, and to respond quickly to emergent roadway safety issues. LCE projects are implemented through WSDOT's Traffic Operations Program[12]."

LCE projects can be standalone projects or incorporated into capital projects. All LCE projects must be documented per HQ Traffic Office direction and approved by the Region Traffic Engineer. If an LCE project is incorporated into another capital project, the documentation (QBOD) is completed by the Region Traffic Office and provided to the project office. The project office will incorporate the LCE documentation into the Design Approval or Project Development Approval as appropriate. LCE projects that are incorporated into other capital projects have a safety analysis included in the documentation provided by the Region Traffic Office per the following table.

Trigger	If the lane width or shoulder width is reduced. Addition of turn lanes.
Study Area	Where the lane width or shoulder width is reduced.
Study Period	Crash history is not used in this analysis because the analysis only compares the predicted average annual crash frequencies across alternatives.
Scope	Analyze the lane and shoulder widths being considered.
Methodology	Use the applicable CMF tables/equations for the roadway type with respect to lane and shoulder width. Compare the CMFs of the lane/shoulder widths being considered. Include a discussion on countermeasures as need to mitigate for increased crash potential.
Tools	For the appropriate roadway type, use the following items from the HSM: • Rural Two-Lane, Two-Way Roads: o Lanes: Table 10-8 o Shoulders: Table 10-9 • Undivided Roadway Segment o Lanes: Table 11-11 o Shoulders: Table 11-12 • Divided Roadway Segment o Lanes: Table 11-16

[12] WSDOT Traffic Operations Low Cost Enhancement 2013-15 Biennium Interim Report, page 2

	o Shoulders: Table 11-17 • Freeway Segments: See HSM Chapter 18.7.1 o Lane Width: Equation 18-25 o Inside Shoulder Width: Equation 18-26 o Outside Shoulder Width: Equation 18-35
Goals	Assess the safety performance of the alternatives being considered.
Documentation	Include safety performance as a baseline or contextual need on the QBOD. Include CMF discussion in the alternatives comparison section of the QBOD. If the preferred alternative is not the best performing from a safety perspective, document your reasoning. Include documentation on treatment of targeted crashes.

8. Miscellaneous Activities

This section introduces different activities that provide opportunities for different scales of analysis. Note that the goal is to optimize the value of safety analysis for the particular activity.

8.1 Access Revision Reports

The access revision process consist of two steps: *Non-Access Feasibility Study* and *Access Revision Report* (ARR). Safety analysis is used in the feasibility study phase to understand the safety performance of the existing network and help compare non-access alternatives. Then, if applicable, safety analysis is used again in the ARR phase to inform the tradeoff decision in selecting a preferred alternative that modifies access. The details of the two phases are addressed in Chapter 550 of the Design Manual.

The safety analysis methodology and scope of the feasibility study are discussed, agreed upon, and documented in the Methods and Assumptions (M&A) document. The M&A is reevaluated for the ARR phase. The table titled 'Non-Access Feasibility Study Safety Analysis' (below) details the scale and scope of the safety analysis part of a Non-Access Feasibility Study. The table titled 'Access Revision Report Safety Analysis' (below) details the scale and scope of the safety analysis part of an ARR.

Non-Access Feasibility Study Safety Analysis

Trigger	A Non-Access Feasibility Studies requires a safety analysis.
Study Area	Match the study area of the operational analysis. If necessary, adjust the study area to the safety impact area as agreed to by the ARR technical support team. The safety analysis needs to focus on the non-access network. Safety analysis of the freeway mainline is not required.
Study Period	Use the feasibility study periods/years as documented in the Non-Access Feasibility Study M&A.
Scope and Methodology	Follow the Safety Analysis Scope and Methodology detailed in Section 6.9.
Tools	For freeway ramps, and ramp terminals, use the Interchange Safety Analysis Tool enhanced (ISATe). For other facility types, use the applicable extended HSM predictive method spreadsheet. The tools can be found online at: http://www.wsdot.wa.gov/Design/Support.htm

Goals	1. Determine the safety performance of the existing conditions to understand any safety performance issues within the study area. 2. Compare the safety performance of the no-build and all reasonable non-access alternatives to help determine the preferred alternative. 3. Determine if the preferred alternative will significantly increase crashes. If so, determine and document what countermeasure(s) will mitigate crashes.
Documentation	A separate safety analysis document is not required. The safety analysis is incorporated into the Non-Access Feasibility Study as follows: Method and Assumptions: In the "Safety Performance Analysis" section, discuss the study area, study period, study years, methodology, tools, and measures of effectiveness. Non-Access Feasibility Study: the safety analysis section of the Non-Access Feasibility Study should contain a summary of the safety analysis and the details should be contained in an appendix. The write-up should explain how the goals listed above were addressed as well as contrast and compare all feasible alternatives and the no-build.

Access Revision Report Safety Analysis

Trigger	An Access Revision Report requires a safety analysis.
Study Area	Start with the feasibility study area and add needed freeway segments, ramps, and other roadway segments and intersections to model the expanded access point alternatives agreed to by the ARR technical support team.
Study Period	Use the feasibility study periods/years as documented in the ARR M&A.
Scope and Methodology	Follow the Safety Analysis Scope and Methodology detailed in Section 6.9.
Tools	For freeway segments, ramps, and ramp terminals, use the Interchange Safety Analysis Tool enhanced (ISATe). For other facility types, use the applicable extended HSM predictive method spreadsheet. The tools can be found online at: http://www.wsdot.wa.gov/Design/Support.htm
Goals	1. Determine the safety performance of the existing conditions to understand any safety performance issues within the study area. 2. Compare the safety performance of the no-build and all reasonable alternatives to help determine the preferred alternative. 3. Determine if the preferred alternative will significantly increase crashes. If so, determine and document what countermeasure(s) will mitigate crashes.
Documentation	A separate safety analysis document is not required. The safety analysis is incorporated into the Access Revision Report (ARR) as follows: • Method and Assumptions: In the "Safety Performance Analysis" section, discuss any changes to the study area, study period, study years, methodology, tools, and measures of effectiveness from the Non-Access Feasibility Study. • Access Revision Report: the safety analysis section of the Non-Access Feasibility Study should contain a summary of the safety analysis and the details should be contained in an appendix. The write-up should explain how the goals listed above were addressed as well as contrast and compare all feasible alternatives and the no-build.

8.2 Environmental Impact Statement/Environmental Assessment

Environmental Impact Statements (EIS) or Environmental Assessment (EA) use crash analysis to help inform the tradeoff decisions during the preferred alternatives selection process. If the EIS has a corresponding IJR, the safety analysis requirements below are applicable to both processes and documents. The Transportation Discipline Report will contain the safety analysis and the following table details the scale and scope:

Trigger	An EIS/EA with a Transportation Discipline Report and the technical advisory committee agrees a safety analysis is needed.
Study Area	Begin by matching the Study Area of the Traffic Analysis. Adjust the Study area as necessary and as agreed to by your Stakeholders.
Study Period	The study period must align with other documents related to the EIS. If the other documents do not set a study period, reference Section 6.3.
Scope and Methodology	Analyze no-build and all feasible alternatives that are analyzed in the EIS. Analyze all locations where there has been a physical change to the infrastructure and/or a greater than 10% change in volumes. Follow the Safety Analysis Scope and Methodology detailed in Section 6.9.
Tools	For freeway segments, ramps, and ramp terminals, use the Interchange Safety Analysis Tool enhanced (ISATe). For other facility types, use the applicable extended HSM predictive method spreadsheet. The tools can be found online at: http://www.wsdot.wa.gov/Design/Support.htm
Goal	1. Determine the safety performance of the existing conditions to understand any safety performance issues within the study area. 2. Compare the safety performance of the no-build and all feasible alternatives to help determine the preferred alternative. 3. Determine if the preferred alternative will significantly increase crashes with particular emphasis on fatal and serious injury crashes. If so, identify and assess mitigation for the crashes.
Documentation	Transportation Discipline Report: Begin by discuss the study area, study period, scope, methodology, and tools (refer to the above sections of this table for more detail). Then summarize the crash analysis details in the Transportation Discipline Report. The crash analysis write-up should quantitatively contrast and compare all feasible alternatives. If the preferred alternative does not have the highest benefit-cost ratio or has a higher number of fatal and serious injury crashes than the alternatives, document your reasoning and mitigation strategy for the chosen approach. Include the outputs of the tools as an appendix to the safety analysis.

8.3 Developer Reviews – Traffic Impact Analysis

Developer reviews are where a developer is proposing a modification to the state highway system and has been requested to analyze the impacts of that development. Depending on the scope of the development, a Traffic Impact Analysis (TIA) may be requested (See DM Chapter 320.05). Safety analysis is a component of a TIA. The safety analysis for a TIA should follow the scope and scale as detailed in the following table:

Trigger	A TIA that has a safety analysis component.
Study Area	The study area should match that of the TIA as detailed in DM Chapter 320.06(1).
Study Period	The study period must align with other documents related to the EIS. If the other documents do not set a study period, reference Section 6.3.
Scope and Methodology	Analyze no-build and all feasible alternatives to match the TIA traffic analysis scenarios as detailed in DM Chapter 320.06(2). Follow the Safety Analysis Scope and Methodology detailed in Section 6.9.
Methodology	Follow the Safety Analysis Scope and Methodology detailed in Section 6.9.
Tools	For freeway segments, ramps, and ramp terminals, use the Interchange Safety Analysis Tool enhanced (ISATe). For other facility types, use the applicable extended HSM predictive method spreadsheet. The tools can be found online at: http://www.wsdot.wa.gov/Design/Support.htm
Goal	Provide quantitative safety performance metrics to inform the tradeoff decision in preferred alternative selection. This can be supplemented with discussion of engineering reasoning in selecting a recommended alternative.
Documentation	TIA Method and Assumptions: In the "Crash Analysis" section, discuss the study area, study period, scope, methodology, and tools. Refer to the above sections of this table for more detail. TIA: The crash analysis for a TIA is contained in Traffic Analysis section (see DM Chapter 320.10). The crash analysis write-up should quantitatively contrast and compare all feasible alternatives. If the preferred alternative is not the best performing from a crash analysis perspective, document your reasoning in this section.

8.4 Crash Analysis Report

A Crash Analysis Report (CAR) is a specific report used only for the I2 Collision Reduction program. The CAR is written during the scoping phase of the project and is required before funding for design is released. As a result, the CAR will provide sufficient safety analysis for a project and no further safety analysis is required during the design phase. When a CAR is needed, the following template must be followed: http://www.wsdot.wa.gov/publications/fulltext/design/ASDE/CARTemplate.docx.

8.5 Intersection Control Evaluation

An Intersection Control Evaluation (ICE) conducts both an operation and safety analysis of a potential change to an intersection. For the safety analysis portion, follow the scope and scale as detailed in the following table:

Trigger	An ICE has safety as a project need as noted in DM Chapter 1300.05(1).
Study Area	If the ICE is a standalone document, the study area should be the intersection of interest corresponding to the study area of the ICE. If the ICE is part of a larger project, follow the guidance associated with that funding source.
Study Period	Select the study period in accordance with Section 6.3 of this document.
Scope and Methodology	Analyze the no-build and all feasible alternatives to match the alternatives analyzed in the operational analysis section of the ICE. Follow the Safety Analysis Scope and Methodology detailed in Section 6.9.

Tools	For freeway ramp terminals, use the Interchange Safety Analysis Tool enhanced (ISATe). For other facility types, use the applicable extended HSM predictive method spreadsheet The tools can be found online at: http://www.wsdot.wa.gov/Design/Support.htm
Goal	To have a quantitative analysis supplemented with a qualitative discussion that can help select a preferred alternative.
Documentation	Incorporate the safety analysis into the ICE. The safety analysis write-up should quantitatively contrast and compare all feasible alternatives. If the selected alternative does not have the lowest total number of crashes, document your reasoning in the ICE. Include the details of the safety analysis in an appendix.

8.6 Work Zones

Properly designed work zones are important to worker safety as well as to the safety of the traveling public. While the HSM methodologies cannot analyze how a work zone will effect worker safety, it can help in the selection of lane and shoulder widths and how this will affect the safety of the traveling public.

Trigger	Safety analysis in not required as part of the design of a work zone. However, HSM methodologies can be beneficial when selecting lane and shoulder width that will be implemented on long duration work zones.
Study Area	Length of work zone.
Study Period	Use only the typical performance of the proposed work zone alternatives (predicted average crash frequencies) to compare work zone alternatives. Assessment of contributing factors to fatal and serious injury crashes, and crashes involving bicyclists and pedestrians can be helpful to support work zone alternative identification and assessment.
Scope	Analyze the lane and shoulder widths being considered.
Methodology	Use the applicable CMF tables/equations for the roadway type with respect to lane and shoulder width from the HSM as per the tools section below. Compare the CMFs of the lane/shoulder widths being considered.

Tools	For the appropriate roadway type, use the following items from the HSM:
	• Rural Two-Lane, Two-Way Roads:
	    o Lanes: Table 10-8
	    o Shoulders: Table 10-9
	• Undivided Roadway Segment
	    o Lanes: Table 11-11
	    o Shoulders: Table 11-12
	• Divided Roadway Segment
	    o Lanes: Table 11-16
	    o Shoulders: Table 11-17
	• Freeway Segments: See HSM Chapter 18.7.1
	    o Lane Width: Equation 18-25
	    o Inside Shoulder Width: Equation 18-26
	    o Outside Shoulder Width: Equation 18-35

Goal	Quantify and understand the safety performance of different alternatives to assist in the selection of a preferred alternative.

Documentation	No documentation is necessary. You may include a summary of the analysis in the Transportation Management Plan if it helped select the preferred alternative.

9. Example language for the HSM Predictive Method

This section contains example language for a report that discusses the existing safety performance of different intersections or segments in comparison to similar facilities. There are three scenarios: location with similar crash performance, location with more crashes than similar locations, and location with fewer crashes than similar locations. Use the text below in reports that discuss the comparison of the facility being analyzed with the HSM predictive method results.

9.1 Scenario 1: Location with similar crash performance

Use the following text and table for locations where the safety performance of the location being analyzed is similar to the HSM predictive method results. The reference to "Appendix XX" is an appendix to the safety analysis report that contains the outputs of the HSM models used in the analysis:

> *Table 3 summarizes the results of the predictive analysis for Intersection A. The worksheets for the analysis are included as part of Appendix XX. Based on the analysis, it is anticipated that the intersection will have a safety performance similar to other intersections that have the same roadway characteristics and traffic volumes. On average, the analysis indicates the potential for two fatal and all injury crashes per year at the intersection compared to 2.1 fatal and all injury crashes per year; for similar intersections with the same traffic volume. In other words, Intersection A is performing as expected.*

Table 3. Predictive Analysis Results for Intersection A

Safety performance metric	Typical performance of similar intersections: Predicted average crash frequency (crashes/year)	Average performance of the intersection: Expected average crash frequency (crashes/year)	Potential for improvement: Excess average crash frequency (crashes/ year)
Fatal and injury crashes	2.1	2.0	0.0
Total crashes	5.6	5.5	0.0

9.2 Scenario 2: Location with more crashes than similar locations

Use the following text and table for locations where the safety performance of the location being analyzed is experiencing more crashes than the HSM predictive method results. The reference to "Appendix XX" is an appendix to the safety analysis report that contains the outputs of the HSM models used in the analysis:

> *Table 4 summarizes the results of the predictive analysis for Intersection B. The worksheets for the analysis are included as part of Appendix XX. Based on the analysis, it is anticipated that the intersection will experience more crashes than intersections with similar roadway characteristics and traffic volumes. On average, the analysis indicates the potential for 2.8 fatal and all injury crashes per year at Intersection B compared to 2.3 fatal and all injury crashes per year for similar intersections with the same traffic volume.*

Table 4. Predictive Analysis Results for Intersection B

Safety performance metric	Typical performance of similar intersections: Predicted average crash frequency (crashes/year)	Average performance of the intersection: Expected average crash frequency (crashes/year)	Potential for improvement: Excess average crash frequency (crashes/ year)
Fatal and injury crashes	2.3	2.8	0.5
Total crashes	7.2	8.8	1.5

9.3 Scenario 3: Location with fewer crashes than similar locations

Use the following text and table for locations where the safety performance of the location being analyzed is experiencing more crashes than the HSM predictive method results. The reference to "Appendix XX" is an appendix to the safety analysis report that contains the outputs of the HSM models used in the analysis:

> *Table 5 summarizes the results of the predictive analysis for Intersection C. The worksheets for the analysis are included as part of Appendix XX. Based on the analysis, it is anticipated that the intersection will experience fewer crashes than intersections with similar roadway characteristics and traffic volumes. On average, the analysis indicates the potential for 1.3 fatal and all injury crashes per year compared to two fatal and all injury crashes per year for similar intersections with the same traffic volume.*

Table 5. Predictive Analysis Results for Intersection C

Safety performance metric	Typical performance of similar segments: Predicted average crash frequency (crashes/year)	Average performance of the segment: Expected average crash frequency (crashes/year)	Potential for improvement: Excess average crash frequency (crashes/ year)
Fatal and injury crashes	2.0	1.3	0.0
Total crashes	6.8	4.3	0.0

APPENDIX A

Roadway Elements Covered by the HSM, 1st Edition, predictive methods

Design Elements Covered in the HSM1 Predictive methods

Design Elements **Directly** Covered by the HSM Chapters 10-12,18, 19

Design Elements **Indirectly** Covered by the HSM Chapters 10-12,18, 19

Design Elements **NOT** Covered by the HSM1 Predictive Method
There may be a Crash Modification Factor (CMF) that covers this Design Element for your specific need and context.

Updated 08/01/16

Rural Two-Lane Highways (Chapter 10 of HSM1)	**Roadway**													**Bridges**			**Intersections**			**Barriers**			**Other Elements Covered**	**Limitations**	**Designs Not Covered**
Roadway Segments	**Horiz. Align.** Curve Radius & Superelevation. **Not Super Transitions**	**Vert. Align.** (Grade. Not Vertical curves)	**Lane Width**	**Shldr Width** & Surface Type	Lane Tran-sition	Median Width	Cross Slope Lane	Cross Slope Shldr	**Fill/ Ditch Slopes** (Roadside Hazard Rating)	**Access** (Driveway Density)	**Clear Zone** (Roadside Hazard Rating)	**Sign, Del. & Illumin.** (Illumin. only)	Bike & Ped.	**Lane Width**	**Shldr Width**	Structural Capacity				Term & Trans. Section	Std. Run (Roadside Hazard Rating)	Bridge Rail (Roadside Hazard Rating)	**- Shoulder Surface Type - Centerline Rumble Strips - Passing Lanes - Two-Way Left-Turn Lane - Auto Speed Enforcement**	• Shoulder Rumble Strips not Included	Auxillary Lanes
Intersections												**Sign, Del. & Illumin.** (Illumin. only)	Bike & Ped.				Turn Radii	**Angle** (Skew from 90°)	I/S Sight Distance				**Intersection Control Types + 3ST - 3 Leg Side Street Stop Controlled + 4ST - 4 Leg 2-Way Stop Controlled + 4SG - 4 Leg Signal Controlled - Left Turn Lanes - Right Turn Lanes**	• I/S Sight Distance not included	• Roundabouts: A CMF is available on the WSDOT CMF short list (Intranet: Sustainable Safety) • 4-way Stop Intersections
Rural Multilane Highways (Chapter 11 of HSM1)	**Roadway**													**Bridges**			**Intersections**			**Barriers**			**Other Elements Covered**	**Limitations**	**Designs Not Covered**
Roadway Segments	Horiz. Align.	Vert. Align.	**Lane Width**	**Shldr Width** & Surface Type (Right Shoulder)	Lane Tran-sition	**Median Width**	Cross Slope Lane	Cross Slope Shldr	**Fill/ Ditch Slopes** (Divided Only)	Access	Clear Zone	**Sign, Del. & Illumin.** (Illumin. only)	Bike & Ped.	Lane Width	Shldr Width	Structural Capacity				Term & Trans. Section	Std. Run	Bridge Rail	**Roadway Segment Types + Divided + Undivided - Shoulder Surface Type - Auto Speed Enforcement**	• Cannot divide NB From SB So, Clear Zone is assumed to be the same on both sides. • Assumes Roadway Section is the same on both sides. • Shoulder Rumble Strips not Included.	Auxilery Lanes
Intersections												**Sign, Del. & Illumin.** (Illumin. only)	Bike & Ped.				Turn Radii	**Angle** (Skew from 90°)	I/S Sight Distance				**Intersection Control Types + 3ST - 3 Leg Side Street Stop Controlled + 4ST - 4 Leg 2-Way Stop Controlled + 4SG - 4 Leg Signal Controlled - Left Turn Lanes - Right Turn Lanes**	• I/S Sight Distance not included	Most of these intersections can be addressed with a combination of this model and CMFs. • Roundabouts • 4-way Stop Intersections • The "Alternative Intersections" From DM (July 2014),1300.04(7)
Urban & Sub-urban Arterials (Chapter 12 of HSM1)	**Roadway**													**Bridges**			**Intersections**			**Barriers**			**Other Elements Covered**	**Limitations**	**Designs Not Covered**
Roadway Segments	Horiz. Align.	Vert. Align.	Lane Width	Shldr Width	Lane Tran-sition	**Median Width** (Divided Only)	Cross Slope Lane	Cross Slope Shldr	Fill/ Ditch Slopes	**Access** Commercial Industrial Residential Other	**Clear Zone** (Fixed Object Density)	**Sign, Del. & Illumin.** (Illumin. only)	Bike & Ped.	Lane Width	Shldr Width	Structural Capacity				Term & Trans. Section	Std. Run	Bridge Rail	**Roadway Segment Types + 2U - 2 lane Undivided + 3T - 3 lane with Left-turn Lane + 4U - 4 Lane Undivided + 4D - 4 Lane Divided + 5T - 5 lane with Left-turn Lane - Type of On-street Parking - % of Curb Length w/On-street Parking - Auto Speed Enforcement - Speed Less or More than 30mph**	• Cannot divide NB From SB • Assumes Roadway Section is the same on both sides.	• Auxilery Lanes • 6 or more lanes total • One way roads
Intersections												**Sign, Del. & Illumin.** (Illumin. only)	**Bike & Ped.** Pedestrian Crossing Volumes/day & Ped. Lanes Crossed (signal Only)				Turn Radii	Angle	I/S Sight Distance				**Intersection Control Types + 3ST - 3 Leg Side Street Stop Control + 4ST - 4 Leg 2-Way Stop Controlled + 3SG - 3 Leg Signal Controlled + 4SG - 4 Leg Signal Controlled Not Signalized: - Left Turn Lanes (Mainline Approaches) - Right Turn Lanes (Mainline Approaches) Signalized: - Approaches w/Left-Turn Phasing - Type of Left-Turn Phasing - Right-Turn on Red Prohibited - Red Light Cameras - Bus Stops Within 1,000 ft. of I/S - Schools Within 1,000 ft. of I/S - Alcohol Sales Within 1,000 ft. of I/S**	• I/S Sight Distance not included	Most of these intersections can be addressed with a combination of this model and CMFs. • Roundabouts • 4-way Stop Intersections • Yield Control Intersections • Uncontrolled Intersections • The "Alternative Intersections" From DM (July 2014),1300.04(7)
Freeways & Interchanges (Chapter 18 and 19 of HSM1)	**Roadway**													**Bridges**			**Intersections**			**Barriers**			**Other Elements Covered**	**Limitations**	**Designs Not Covered**
Freeway Segments & Speed Change Lanes	**Horiz. Align.** Only Curve Radius. (Not Superelevation or Super Transitions)	Vert. Align.	**Lane Width** Through Lanes	**Shldr Width**	Lane Tran-sition	**Median Width**	Cross Slope Lane	Cross Slope Shldr	Fill/ Ditch Slopes	**Access** Distance Between Ramps	**Clear Zone**	Sign, Del. & Illumin.	Bike & Ped.	**Lane Width**	**Shldr Width**	Structural Capacity				Term & Trans. Section	**Std. Run**	**Bridge Rail**	**- Number of Through Lanes - Rumble Strips - Median Barrier - Type "B" Weave**	• Cannot divide NB From SB So, Clear Zone is assumed to be the same on both sides. • Assumes Roadway Section is the same on both sides.	• High Occupancy Vehicle (HOV) Lanes • High Occupancy Toll (HOT) Lanes • Tunnels (The best we can do is barrier on both sides but cannot cover the light/dark difference) • Freeway along another roadway without barrier between them
Ramps & Collector Distributor Lanes	**Horiz. Align.** Only Curve Radius. (Not Superelevation or Super Transitions)	Vert. Align.	**Lane Width**	**Shldr Width**	**Lane Tran-sition**	Median Width	Cross Slope Lane	Cross Slope Shldr	Fill/ Ditch Slopes	**Access** Roadways attached to ramp	**Clear Zone**	Sign, Del. & Illumin.	Bike & Ped.	**Lane Width**	**Shldr Width**	Structural Capacity				Term & Trans. Section	**Std. Run**	**Bridge Rail**	**- Number of Through Lanes -Freeway Speed**	• Two-way CD lines need to be coded as a highway.	• Ramps along roadways • Single Point Urban Interchange
Ramp Terminal Intersections						**Median Width** Crossroad				**Access** Roadways close to Intersection & Distance to other ramp terminal		Sign, Del. & Illumin.	Bike & Ped.				Turn Radii	**Angle** Exit ramp only	I/S Sight Distance				**- Intersection Control Type - Number of Through Lanes - Right & Left Turn Channelization - Right & Left Turn Lanes**	• I/S Sight Distance not included	• Roundabouts • Single Point Urban Interchange • Diverging Diamond Intersections