Florida Department of TRANSPORTATION

Safety Analysis Guidebook

for Project Development and Environment (PD&E) Studies

DRIVING DOWN FATALITIES

Office of Environmental Management
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1 Introduction

Safety is always a consideration in every phase of the transportation project development process. Traditionally, safety evaluation for Project Development and Environment (PD&E) studies has relied on absolute safety (nominal safety) from standards-based design alone which does not provide inference about quantitative differences in safety performance between improvement alternatives with different design features. Recently, data driven safety analysis (descriptive and predictive methods) has been used by practitioners to evaluate performance-based (substantive) safety effects resulting from the combination of different design features, traffic operating conditions, and the context. The ***National Cooperative Highway Research Program (NCHRP) Report Number 480, A Guide to Best Practices for Achieving Context Sensitive Solutions***, differentiates substantive safety from nominal safety by its ability to measure crash risk in a continuum function.

Predictive crash methods offer a scientific and objective approach for predicting quantitative safety differences of project alternatives, and thus allow practitioners to make sound engineering decisions regarding substantive safety on all road users. Unlike nominal safety analysis which involves straight forward design criteria and standard checks, crash predictive method requires detailed analysis to identify the estimated change in crash frequency or severity associated with potential project decisions. The detailed analysis tools for predicting crash safety include Safety Analyst software, Interchange Safety Analysis Tool-enhanced (ISATe), Interactive Highway Safety Design Model (IHSDM) software, and spreadsheet tools that have been developed to deploy Highway Safety Manual (HSM) procedures. In addition, the Safety Analyst software is a tool to support identifying safety as a component of a Purpose and Need for a project.

Application of HSM methods and tools in a PD&E study can allow the Florida Department of Transportation (FDOT) to:

- Incorporate historical safety performance of existing roads when developing of the Purpose and Need of a project;
- Identify alternatives that address the Purpose and Need;
- Evaluate and compare safety performance of different alternatives; and
- Identify mitigation strategies to improve safety performance of a preferred alternative.

1.1 Purpose

The purpose of this guidance is to provide:

- Directions for integrating quantitative[1] safety analysis into the PD&E process commensurate with the project complexity and utilizing the best available data and methods.
- Analysis examples demonstrating application of quantitative safety analysis and interpretation of results in the PD&E studies.
- Consistency and uniform format for completing safety analyses for PD&E studies throughout the state, and thus expediting analysis, documentation and review.

[1] *Quantitative safety analysis is synonymous with HSM methods, crash predictive methods, data driven methods. These terms are used interchangeably throughout this guidebook.*

The FDOT's ***Highway Safety Manual Implementation Policy, Topic Number 000-500-001***, adopted in May 2016, underscores FDOT's commitment to safety analysis in all phases of the project development process. This policy encourages use of HSM methods, where applicable. The information in this guidebook is intended to implement this policy in PD&E Studies by helping PD&E practitioners apply HSM methods to quantify safety performance and compare safety with other performance measures such as traffic operations, environmental impacts and costs in the PD&E's alternatives evaluation process.

The guidebook is consistent with the requirements of safety analyses documented in ***Part 2, Chapter 2 of the PD&E Manual***. It is also generally consistent with other FDOT and Federal Highway Administration (FHWA) safety analysis guidance documents.

1.2 Goals

This guidebook is a resource to use when scoping, conducting and reviewing safety analyses for PD&E studies as it:

- Defines the expectations for the scope of quantitative safety analysis in PD&E studies;
- Facilitates consistent application of quantitative safety analysis tools and procedures;
- Identifies factors contributing to crashes and associated potential countermeasures to address the project's Purpose and Need;
- Estimates the effect of various design alternatives on crash frequency and severity; and
- Improves documentation and interpretation of safety analysis results.

1.3 Intended Use

The guidebook should be used by practitioners (FDOT staff and consultants) who scope, prepare or review safety analyses for PD&E studies. The guidebook assumes the practitioner has basic knowledge and experience with HSM methods and tools.

This guidebook only references (and does not reproduce) HSM framework, methods and tools. Users of this guidebook are encouraged to consult HSM procedures when performing safety analyses.

Although the guidance is aimed at PD&E studies, it can also be a resource for safety analyses on a wide variety of projects such as planning, corridor, feasibility, and safety studies.

1.4 Safety Analysis in the Project Development Process

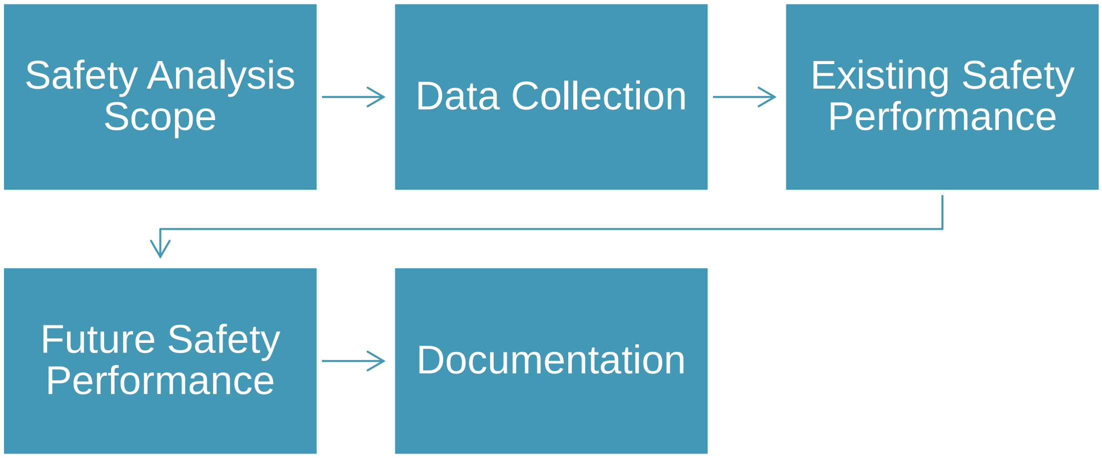
During the PD&E phase, practitioners answer various questions to make decisions about location and design concepts for transportation projects. Related to safety, some of these questions may include:

- Are there any locations with safety deficiencies (higher than statewide averages for similar locations) within the project limits?
- What are safety improvement opportunities (crash countermeasures) in the project limits?
- How do proposed alternatives compare with each other regarding safety performance?

- How can safety goals be balanced against other environmental, economic, or mobility goals for a project?

Figure 1-1 presents an outline of the quantitative safety analysis process that can be used to answer such questions for a PD&E study. The details of these steps are presented in the remainder of this guidebook.

Figure 1-1: Quantitative Safety Analysis Process



1.4.1 Safety Analysis Methodology

Data driven safety analysis (e.g., analyzing historic crash data and applying HSM methods) should be used to the extent practicable to quantitatively assess safety performance of project alternatives. The level of safety analysis should be scoped and scaled to the complexity of the project and documented in the traffic analysis methodology.

HSM predictive methods can also be used to support justification and documentation of the quantitative safety effects of a Design Exception or Design Variation. This guidebook does not supersede the FDOT Design Manual procedure for Design Exception or Design Variation. See ***Part 1 Section 122 of the FDOT Design Manual*** for more guidance.

The methodology for a PD&E safety analysis is typically developed by the consultant project manager as part of the traffic analysis methodology, with FDOT District staff providing guidance, review and approval. Development of the scope for safety analysis for PD&E studies on the interstate highways must be coordinated with District Interchange Review Coordinator, State Interchange Review Coordinator, and FHWA as applicable according to the ***FDOT's New or Modified Interchanges Procedure*** Topic No. 525-030-160 FDOT's Interchange Access Request User's Guide is a resource for safety analysis in interchange access requests.

1.4.2 Purpose and Need for a Project

The project's Purpose and Need is essential in evaluating and selecting a preferred alternative for a PD&E study. Incorporating safety into the project's Purpose and Need involves several considerations, such as:

- Reviewing safety planning documents to identify projects or sections of the projects that are listed in the Florida Strategic Highway Safety Plan (SHSP) or long-range transportation plan (LRTP). Safety-focused projects (projects with safety identified as a primary purpose and need) should directly support specific strategies listed in the FHSP. A PD&E study should reference any safety analysis conducted (to support development of FHSP) to demonstrate if safety improvements may provide benefits in the project area (e.g., results of network screening to identify high-crash locations).

- Evaluating safety conditions using crash history, field observations or road safety audits (RSAs). Analysis of observed crashes, field observations and considerations of human factor should be done to support establishment of the Purpose and Need by identifying locations with potential for safety improvement (existing or proposed conditions) and how the proposed project may change the crash frequency or severity. Typically, descriptive analysis of observed crashes and qualitative analysis of information obtained from field observations can reveal safety conditions in the project area.

- Calculating crash rates for segments or intersections in the project area and then comparing them to the average crash rates for similar facilities either in the same FDOT district or statewide. The procedure for calculating crash rates is discussed in Section 4.1.3. The procedure for comparing the actual observed rate to an average rate involves determining the level of confidence that the observed rate exceeds the average rate. Procedures for this work are available from various sources, including the Crash Analysis and Reporting (CAR) User Manual.

- Applying HSM methods and tools to diagnose safety conditions and thus inform the development and refinement of the Purpose and Need. Safety performance functions (SPFs), where available, can be used to determine whether the observed safety performance at a given location is higher or lower than the average safety performance of other locations with similar roadway characteristics and exposure. Locations with higher than average safety performance may have the greatest safety need or high potential for safety improvement (PSI). The PSI, which can be used when observed crash data, SPFs and calibration factors are available, is the difference between the expected crash frequency (calculated using the Empirical Bayes (EB) method) and the predicted crash experience (based on the SPF) for a given traffic volume.

- Applying human factors fundamentals (using HSM Chapter 2 and ***NCHRP 600: Human Factors Guidelines for Road Systems – Second Edition***) when evaluating the existing safety performance of a project by identifying possible human factor issues that may have contributed to observed crashes, their patterns or contributing factors. Both the HSM and the Human Factors Guidelines for Road Systems include a substantive presentation and discussion of human factor principles and concepts that could be used by practitioners to evaluate safety conditions and propose relevant design features or treatments when developing and evaluating alternatives.

- Incorporating safety issues for all modes of travel and all road users, particularly those likely to be more vulnerable in crashes, such as the elderly, children, disabled, motorcyclists, pedestrians, and bicyclists as appropriate to project context.

1.4.3 Alternatives Development and Evaluation

Estimated safety performance should be included when developing and evaluating all project alternatives in all PD&E studies. CMFs and predictive methods, or other methods as applicable, should be used to quantify safety impacts in the analysis of alternatives process. Safety is only one factor to consider in the project development process. The estimated safety impacts, along with other factors such as operational efficiency, cost-effectiveness, and environmental impacts can be used in the multi-criteria evaluation to select the preferred alternative.

For projects where safety is a primary Purpose and Need, improvement alternatives should be developed with a clear understanding of the safety issue to be addressed, and evaluated to determine if the alternative achieved the desired safety improvement goal. Proposed alternatives should consider both engineering and operational improvements that benefit safety. Operational improvements may require consideration of integrating Transportation Systems Management and Operations (TSMO) strategies as part of the selection of crash countermeasures (safety treatments) without impacting the project scope, schedule, or cost of the project. Coordination with the District TSMO Program Engineers is required to facilitate integration of TSMO strategies in the PD&E's alternative evaluation.

The following should be considered when performing safety analysis in PD&E studies:

- The results from safety diagnostic analyses (HSM Chapter 5 through 7) can be used to develop concepts and alternatives, and crash modification factors (HSM Part D and the FHWA CMF Clearinghouse) can be used to estimate changes in crash frequency or severity between different design options.
- The HSM predictive method (Part C) can be used to estimate magnitude of the changes in crash frequency or severity associated with a change in traffic volume, traffic control or roadway characteristics. The results of the HSM predictive method can be used to estimate the change in safety performance of a preferred alternative compared to a no-build alternative.
- If safety is not part of the project's Purpose and Need, safety analysis may be used to identify design features with proven safety benefits that can be added in the alternatives. A concept level RSA may also supplement safety analysis by uncovering design elements on the alternatives that may present a safety concern or opportunities to mitigate those concerns.

Additional traffic analyses or traffic studies may be necessary to supplement or support safety analysis or evaluation of potential crash countermeasures on proposed improvements. These analyses include but are not limited to capacity analysis, signal warrant studies, and roadway lighting justification studies.

Human factors should be considered when developing alternatives by addressing human factor issues that may have contributed to existing safety conditions and associated countermeasures.

1.5 Resources to Support Safety Analysis

The following tools and resources may support data driven safety analysis during PD&E and therefore a project safety analyst should be aware of:

- ***Highway Safety Manual, First Edition, with 2014 Supplement*** contains a synthesis of validated highway research, procedures for including safety in project decisions, and analytical tools for predicting impact on road safety. The 2nd Edition of the Highway Safety Manual is currently under development.
- ***Manual on Uniform Traffic Studies*** establishes minimum standards for conducting traffic engineering studies on roads under the FDOT jurisdiction.
- ***Interactive Highway Safety Design Model (IHSDM) Software*** supports implementation of the HSM Part C Predictive Method.
- The ***FHWA Crash Modification Factors (CMF) Clearinghouse*** supports the use of HSM Part B (Roadway Safety Management Process) and Part D (Crash Modification Factors).
- ***Interchange Safety Analysis Tool-enhanced (ISATe)*** contains User's Manual and spreadsheets that use HSM Part C predictive method to support evaluation of the safety performance for freeways and interchanges.
- ***Interchange Safety Analysis Tool-enhanced (ISATe) Users Manual*** documents a safety prediction method for freeways segments and freeway speed-change lanes, ramps and ramp terminals.
- ***Safety Analyst Software*** uses HSM Part B to identify safety improvement needs and develop a systemwide program of site-specific improvement projects.
- ***FHWA Road Safety Audits*** supports safety performance examination of existing or future roadway elements.
- ***FHWA Scale and Scope of Safety Assessment Methods in the Project Development Process*** supports identification and application of suitable methods for quantitatively assessing the safety performance impacts of project development decisions such as comparing various design alternatives.
- ***FHWA Integrating Road Safety into NEPA Analysis, A Practitioner's Primer*** highlights the opportunity and benefits of linking safety planning to the environmental analysis at every stage of the National Environmental Policy Act (NEPA) process.
- ***FDOT Interchange Access Request Users Guide (IARUG)*** provides guidance on performing safety analysis on the interstate system.
- The ***Human Factors Guidelines (HFG) for Road Systems*** provides guidance on integrating human factors into safety analysis. The 3rd Edition of the HFG is currently under development.
- ***Primer on the Joint Use of the Highway Safety Manual for Road Systems***[2] describes a general process, tools and examples that explain the combined use of the HSM and HFG to improve safety evaluation and countermeasure identification based on the best available data during planning and development of roadway projects.

[2] The *Primer* was developed by Battelle under NCHRP 20-07(334). A copy of this document can be provided by FDOT Safety Office upon request.

2 Scope of Safety Analysis

The safety analysis methodology for a PD&E study is typically not prescriptive as the scale and scope of analysis effort depends on:

- Selected performance measures to address the purpose and need,
- Project type,
- Project location, context, and existing issues, and
- Complexity or scope of alternatives being evaluated.

Figure 2-1 contains process that should be considered when determining the appropriate scope of safety analysis for a PD&E study. These items are scalable based on the type, context, and complexity of the project.

The safety analysis scope should be developed concurrently with the traffic operational analysis scope since the same analysis years and data (traffic volume, traffic control, and roadway characteristics) are used for both analyses.

Figure 2-1: Safety Analysis Scoping Process

Project Need and Performance Measures	•Define the project •Understand the project needs with regards to safety •Identify safety goals and performance measures
Identify the Analysis Area	•Match operational analysis in most cases •Consider traffic volume changes
Select Analysis Years	•Match operational analysis
Select Analysis Methods	•Define a method for identifying and analyzing existing crashes •Define a method for analyzing and mitigating existing, predicted and expected crashes
Documentation	•Explain how safety analysis results will be documented either in the project traffic study report or a separate report (for large or complex projects)

2.1 Purpose and Need and Performance Measures

Understanding of the project description, Purpose and Need, funding sources, required project approvals, and project schedule is one of the first steps when developing the scope of safety analysis.

2.1.1 Purpose and Need

The Purpose and Need for a project should come from transportation planning documents or processes such as the long-range transportation plan (LRTP), Highway Safety Improvement Plan (HSIP), Florida Strategic Highway Safety Plan (SHSP), planning studies, and the Efficient Transportation Decision Making (ETDM) screening process. The project manager should review the project description and Purpose and Need to determine if safety is identified as the primary need. Additionally, the project manager should review project location and available project information to determine if the project:

- Affects intersections or roadway segments identified by FDOT as priority safety improvement locations.
- Includes locations with safety concerns or potential for safety improvements in the project area as identified in previously completed planning studies, safety studies or by the public.
- Affects a location that is known or anticipated to have potential for safety improvement—i.e., high crash location.
- Involves pedestrian, bicycle, transit, and commercial vehicles that require special considerations in the project area.
- Involves geometric elements that are crash-contributing factors and need to be addressed in the project.
- Involves special features of the proposed project and its surrounding environment that might have safety implications.

If safety is the primary need for a project, the primary Purpose and Need should include results of a safety analysis to define the problem, summarize existing conditions, reference applicable safety plans, incorporate the results of public involvement related to safety (if any), and address the safety need of all road users on the project area.

If safety is included in the Purpose and Need without sufficient data or analysis to define the problem, the Purpose and Need should be refined in the PD&E phase by evaluating, as appropriate:

- Existing safety conditions to identify existing project-site crash patterns, contributing factors, and trends to substantiate the problem.
- Excess expected crash average frequency on the proposed improvements using the PSI method.

Table 2-1 shows information that can be used to identify if the project Purpose and Need statement should include safety. **Figure 2-2** shows an example of a safety focused Purpose and Need statement.

Table 2-1: Safety Information to Include in the Purpose and Need for Projects

Type of Information	Example Information to Consider for Inclusion in the Purpose and Need
Roadway safety performance	Comparison of crash rates with statewide average rates for similar facilities. Comparison of crash rates to expected crashes for similar facilities given traffic volumes. Comparison of existing and expected (observed modified) average crash frequencies for future conditions.
Contributing crash factors	Analysis of crash history to indicate predominance of certain crash types and contributing factors.
Multimodal safety issues	Safety issues for specific types of road users, including pedestrians, bicyclists, freight vehicles, and transit vehicles.
Stakeholders or public input	Safety issues raised by the public as being of concern.
Road safety audit issues	Existing conditions RSA results indicating any findings regarding deficiencies or opportunities for improving safety performance.

Source: *Modified from* ***FHWA Integrating Road Safety into NEPA Analysis, A Practitioner's Primer***

Figure 2-2: Example of a Safety Focused Purpose and Need Statement

The purpose of this PD&E study is to evaluate safety conditions and to identify potential crash countermeasures along a one-mile segment of SR-200 between 10th and 21th street. This corridor is a priority for the City, and has been included in the current MPO's LRTP. Additionally, the intersection of SR 200 and CR 20, 0.5-mile from 10th Street has been identified as a high crash location. This segment also lacks provisions to accommodate non-motorized users.

The need for the project is based on capacity and safety.

Safety

A review of crash data provided by the Department showed a total of 320 crashes were reported for the five-year period (January 1st, 2012 through December 31st, 2016), of which five were fatal crashes and 170 were injury crashes. The crash rate is 6.9 crashes per Million-Miles of Travel which is higher than the average statewide crash rate for similar facilities. Analysis of crash revealed the following notable characteristics:

- The number of reported crashes per year were distributed as follows: 55 crashes in 2012; 62 crashes in 2014; 57 crashes in 2015; 66 crashes in 2016; 80 crashes in 2017
- Rear-end crash (52 percent) was the predominant crash type, followed by angle crashes (19 percent).
- Rear-end crashes occurred along the entire length of the corridor and were most concentrated at CR 20, 15th Street and 20th Street intersections.
- A combination of high traffic volumes and speed differentials appear to be contributing to the angle, rear end and left turn crashes.

- Most crashes occurred during the day on dry pavement under no adverse weather conditions, so weather, pavement condition and lighting do not appear to be a factor in the crashes
- A combination of high traffic volumes and high speeds appear to be contributing to the angle, rear end and left turn crashes.
- All fatal crashes occur during the weekend; and three fatal crashes were attributed to driving under the influence of alcohol.

Field observations revealed some intersections have poor lane configurations which leads to poor lane utilization and long queues extending beyond the adjacent intersections. This supported the assertion that many crashes were attributed to speed differentials.

The PSI for this segment was 15 crashes per year, which is a reduction of 28% compared to the expected crash frequency. This means that the long-term average crash frequency at this roadway segment is greater than for comparable roadways (See Figure 4-2, for calculations).

Capacity

Current daily traffic volumes on SR 200 range between 23000 and 27500 vehicles per day with 6 percent daily truck traffic. Current daily traffic volumes on SR 20 range between 16000 and 19500 vehicles per day with 5 percent trucks. Daily travel demands on these facilities exceed the capacities which indicate level of service F operations. Additionally, the future traffic demand along SR 200 is projected to grow to 40000 vehicles per day.

2.1.2 Performance Measures

The project safety goals and performance measures are established based on the Purpose and Need for a project and the FSHSP. The project safety goals could address topics such as:

- Identifying any safety performance issues within the study area by evaluating safety performance of existing conditions;
- Identifying the alternative that best meets the purpose and need for the project by comparing safety performance of the no-build and viable build alternatives; or
- Identifying crash countermeasures that would mitigate potential build alternative crashes.

Number of crashes (or crash frequency) and crash severity level are the basic indicators of the quantitative safety performance of a roadway. These indicators can be estimated from historical crash records or predicted from statistical analyses such as those provided by HSM methods and tools.

Safety performance measures that can be selected include:

- Number of fatalities;
- Rate of fatalities per 100 million Vehicle Miles Traveled (VMT);
- Number of serious injuries;
- Rate of serious injuries per 100 million VMT;

- Total annual crashes;
- Annual crashes by severity;
- Number of crashes by crash type;
- Number of non-motorized fatalities and non-motorized Serious Injuries;
- Predicted crash rates (motorized or non-motorized); and
- Benefit-cost ratio.

In addition to the above safety performance measures, measures such as number of incidents, emergency response times, and public perceptions of safety for the relevant transportation modes may be used to assess safety of operations.

Since data collection efforts may be prohibitively expensive, availability of existing data (and quality of data) to support the measures and how the measures will be estimated should be considered when selecting performance measures.

2.2 Analysis Area

The safety analysis area should include all roadway elements (segments, intersections, and interchanges) with physical or operational changes resulting from the proposed improvements. Intersections should include a distance up to 250 feet on each approach. HSM contains guidance for determining if crashes are intersection-related or roadway segment-related. It is critical that the study area boundaries are the same for all alternatives to ensure consistency and comparability of the analysis results. The methodology should identify any locations within the analysis area that cannot be analyzed using HSM procedures as they will influence the analysis methods.

The safety analysis area will typically be the same as the traffic operational analysis area unless there is a compelling reason to expand or reduce the area. Roadways where the proposed project increases or decreases the traffic volume substantially should also be identified and included in the analysis area. For example, if a major widening project is expected to reduce the traffic on a parallel roadway, the parallel roadway should be considered in the safety analysis because a large change in exposure on a roadway may likely result in a change in crashes.

2.3 Analysis Years

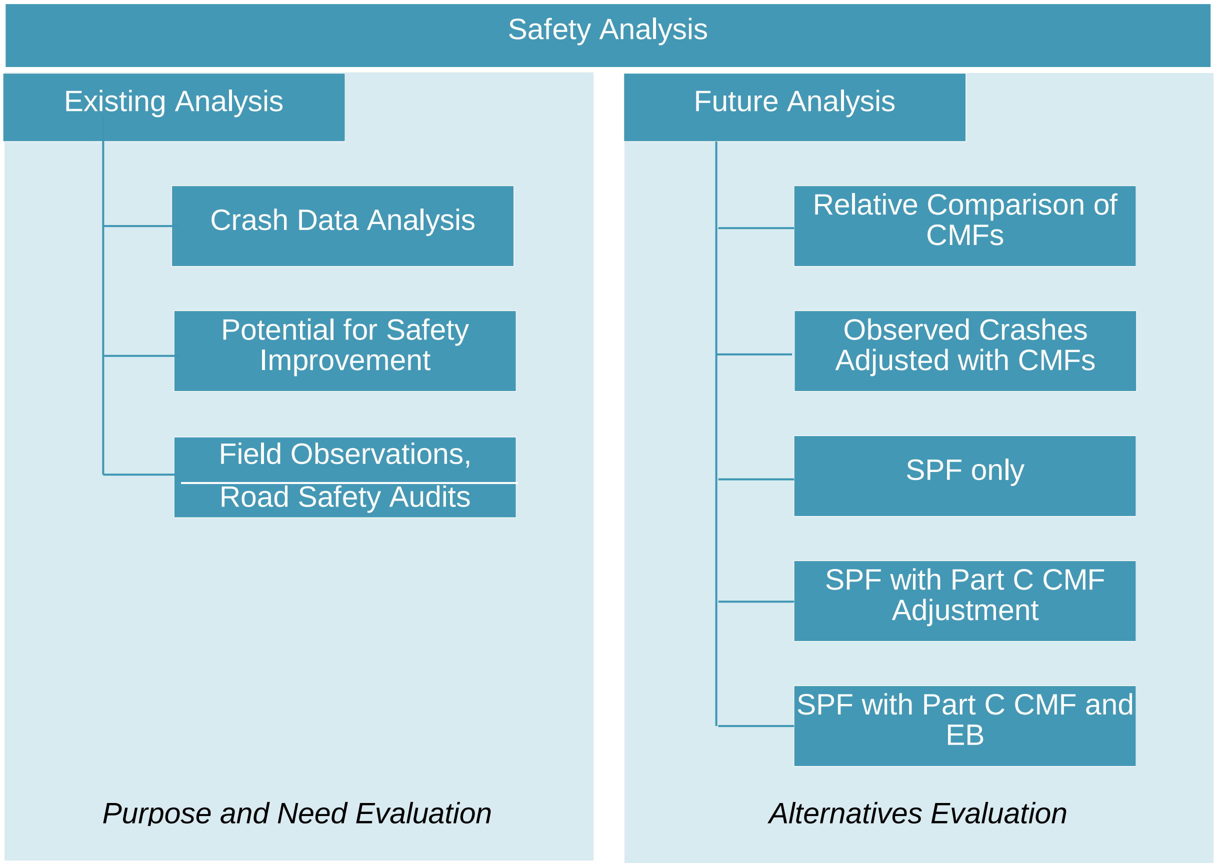
Safety analysis years should be the same as the traffic operations analysis years. This is important because traffic volumes and proposed improvements are inputs to the predictive safety analysis and are used to calculate crash rate. Typical analysis years are existing year, opening year, and design year.

During scoping of safety analysis, it is important to determine if annual crash predictions over many years are needed (e.g., for a benefit-cost analysis). Not all HSM tools automatically report crashes for every year in the analysis period, as such extra effort may be required to produce annualized crashes. Straight-line (simple interpolation) between the existing and design year crashes should be used with caution as most SPFs are nonlinear. However, IHSDM or ISATe can produce crashes in each year over the analysis period.

2.4 Analysis Methods

Existing and future year analysis methods (shown in **Figure 2-3**) depend on the type and context of project, complexity of design alternatives under consideration, and data required by the method. Coordination between the project team and FDOT staff is required to ensure appropriate analysis methods are selected.

Figure 2-3: Quantitative Safety Analysis Methods



2.4.1 Existing Conditions Safety Analysis

The purpose of safety analysis for existing conditions is to identify safety issues and provide information for establishing the project's Purpose and Need and developing alternative improvements that address those issues. Existing conditions safety analysis methods may include:

- Historical crash analysis
- Potential for safety improvements (PSI)
- Road Safety Audit (RSA)
- Field observations

Existing conditions safety analysis must use five years of historical crash data along with field observations, stakeholder input, and other information on the existing traffic operating conditions (e.g., volumes and congestion levels).

Existing conditions safety analysis should also consider whether the project area includes any facilities that are identified on the FDOT high-crash locations list. This information can be obtained from the District Safety Program Engineer.

Where applicable, PSI analysis can be used to evaluate existing conditions utilizing the HSM predictive method and existing crashes to estimate the expected average crash frequency.

2.4.2 Future Conditions Safety Analysis

The future conditions safety analysis is conducted to assess the potential safety benefits of proposed alternatives in comparison to a no-action condition using crash modification factors (CMFs) or the HSM predictive method. The HSM predictive method uses SPFs and CMFs to estimate safety performance in terms of average crash frequency, and where applicable, expected average crash frequency.

There is no single correct method for estimating future safety performance. The most appropriate method depends on many issues including the type of project proposed, safety issues, availability of calibration factors and data, and timelines for the project.

Figure 2-4: Diverging Diamond Interchange (DDI) or Single Point Urban Interchange (SPUI)?

Diverging Diamond Interchange (DDI) and Single Point Urban Interchange (SPUI) are being evaluated to replace a tight diamond interchange. The following approach was followed to discuss the limitations of the HSM methods:

Existing Interchange - Use the HSM predictive method to estimate average crash frequency for the existing interchange and future No-Build interchange (including appropriate adjustment factors).

Select appropriate CMFs for the DDI from the CMF Clearinghouse.

Apply the appropriate CMF to the future No-Build crashes to estimate future crashes under the build alternative.

Since, there are no CMFs for SPUI in the HSM or the CMF Clearinghouse, conduct a literature review to identify available CMFs from current research. If CMFs are found, discuss with the Department Project Manager prior to using them in analysis.

It is likely that some parts of the project may not be consistent with the HSM predictive method. As a result, a combination of analysis methods—for instance applying the predictive method for one portion of the facility and applying a CMF for a different part may be necessary. When establishing the analysis methodology, it is important to document limitations of the HSM predictive method and assumptions on how they will be addressed in the analysis. Some of the limitations of the predictive method include:

- The number of lanes being studied is outside the range of the model (e.g., HSM freeway method cannot address urban freeways with more than 10 lanes).
- Traffic volume on the facility is outside the range of the SPF. Additionally, the SPF does not consider the effects of traffic volume variation during the day.
- The interchange, freeway, street or intersection type does not have an SPF in the HSM (e.g., five-legged intersections, streets with three lanes in one direction and a single lane in the

reverse direction, reversible managed lanes, and Collector-Distributor roads with more than three lanes, or system ramps).

- HSM predictive method does not address the effects of physical characteristics other than those used to develop SPF or CMFs.
- HSM predictive method is based on nationwide or statewide data and does not account for site-specific variation of driving behaviors or characteristics.
- HSM method treats the effects of individual geometric features and traffic control features independently and does not account for interactions between the features.

2.5 Data Needs

After the analysis methods are selected, data needs to analyze safety are identified from multiple sources.

Pursuant to Section 148 and Section 409 of Title 23 of the United States Code (USC), any data collected or compiled for safety analysis on projects is prohibited from use in any litigation against state, tribal or local government that involves the location(s) mentioned in the data. This data can include documents such as crash reports, reports of property damage, high-crash rankings, charts or graphs showing data analysis, or traffic counts.

Table 2-2: Data Needs for Safety Analysis Methods

Safety Analysis Method	Data Needs				
	Roadway Functional Classification	Roadway Data	Traffic Volume	Observed Crashes	Calibration Factor
Road Safety Audit	✓	✓		*	
Historical Crash Analysis	*	*	✓	✓	
CMF Applied to Observed Crashes	✓	✓		✓	
CMF Relative Comparison	✓	✓			
AADT-Only SPF	✓		✓		
SPF with CMF Adjustment	✓	✓	✓		
SPF with CMF Adjustment Weighted with Observed Crashes	✓	✓	✓	✓	✓

Note: ✓ = required data.
* = recommended data

*Adapted and Modified from **FHWA Scale and Scope of Safety Assessment Methods in the Project Development Process***

2.5.1 Crash Data

The most recent five years (January 1st through December 31st) of complete, historic crash data should be used for crash analysis. If a shorter study period is necessary due to discrepancies in data, it should be discussed with District project manager and District Safety Office. Before proposing to use a shorter study period (less than 5 years), the analyst should be aware that because crashes are rare and random events, a shorter period may indicate an unusually low or high number of crashes. More than 5 years of data may need to be used if a detailed pedestrian, bicycle, or commercial vehicle crash analysis is being performed due to the lower frequency of these events.

When the study period is less than five years, in addition to other data documentation, the safety analysis methodology should highlight the study period and reasoning and assumptions for selecting such period.

The geographic extent of the crash data should cover the entire study area defined in the scope of work. At intersections, this will also include up to 250 feet on each intersection approach (HSM, 2010).

2.5.2 Roadway and Traffic Data

Safety analyses using the HSM predictive method requires the roadway and traffic volumes as input. These data should be the same as the one used for traffic operational analysis.

2.6 Documentation

Safety analysis results could be documented as follows, depending on the specific project needs and goals.

- Safety analysis results should be integrated into the Project Traffic Analysis Report in a safety analysis chapter. The chapter should have subsections for each major portion of the safety analysis. See ***Part 2, Chapter 2 Traffic Analysis of the PD&E Manual*** for more details, or
- For large or complex projects, it may be necessary to prepare a separate safety analysis report and technical memorandum that can be incorporated by reference into the Project Traffic Analysis Report.

3 Data Collection

Data is the basis for analyzing safety performance of existing conditions and proposed improvements, and determining mitigation measures to reduce potential crashes in the project area. Data types critical to a safety analysis are crash data, roadway characteristics, traffic volume and traffic operational characteristics. Since HSM methods are driven by data, the scale of these data types depends on the project scope and safety analysis methods.

The accuracy of safety analysis depends on the availability and quality of underlying crash and associated roadway and traffic data. Historical crash data may be incomplete (e.g., lack of complete crash records for property damage only crashes or crashes occurring in rural areas and locally maintained roads). Additionally, crash record databases may contain coding and data entry errors. Therefore, data collection should include examination to determine the reasonableness of historical crash records.

3.1 Crash Data

Crash data is essential for both historical crash analysis and predictive analysis. A thorough evaluation of the crash data provides the foundation for a safety analysis, and is critical to identifying existing safety problems that are included in the project's Purpose and Need.

Minimum data requirements to include:

- Crash type,
- Facility type,
- Physical crash location description (e.g., tangent vs. curve),
- Description of location (e.g., segment/intersection elements),
- Crash severity level, and
- Crash contributing factors.

3.1.1 Crash Data Sources

There are three main sources of crash data (Table 3-1):

1. **Crash Analysis and Reporting System (CARS)** data can be obtained from the ***FDOT Safety Office***. The data can be requested from the District or State Safety Office, or accessed directly from the FDOT mainframe if credentials are granted. CARS database includes crashes on all public roads that have been reported using a long-form report. These data are detailed, with over 300 variables from the long-form crash report, excluding the narrative and diagram. It includes geolocation and roadway data. FDOT checks the location data before publishing it, which typically results in a data entry lag. CARS database provides a good foundation for a project-specific safety analysis.
2. ***State Safety Office Geographic Information System (SSOGis)*** provides a publicly available crash database in a web-based map which can be viewed on the State Safety Office's Traffic Safety Web Portal. This database covers both state and local highways and can be used to supplement CAR data. A limitation of SSOGis is that it does not include all of the detailed long-form crash data fields that are included in the CARS database. However,

for certain projects, data from SSOGis may be the best to use due to their expanded coverage. The SSOGis data has an entry lag issue due to the need to check thousands of records.

3. University of Florida's ***Signal Four Analytics*** tool is a statewide interactive web-based geospatial crash analytical tool. Access to this tool requires permission from the Geoplan Center of the University of Florida. The tool provides up-to-date crash data as it is reported by law enforcement to the Department of Highway Safety and Motor Vehicles (DHSMV). The tool has various crash analysis functions to evaluate the data spatially.

Table 3-1: FDOT Crash Data Summary

Source	Data Available	Key Considerations
CARS	Long-form crash data for all public roads	• Locations have been checked. • Contains a data lag due to data checking. • Does not include short-form reports. •
SSOGis	Subset of long-form crash data for state and local highways	• Locations have been checked. • Contains a data lag due to data checking. • Does not include short-form reports.
Signal 4 Analytics	All currently available short- and long-form crash data	• Locations have not been checked to the same manner of detail as the other two data sets. • Data more current than other two sources.

It is recommended that all three sources be consulted on a typical project. In all cases, the collection of crash data should be coordinated with FDOT District Safety Office.

3.1.2 Crash Data Fields and Relationships

Summary data on the people and vehicles involved is appended to the basic crash data record. The data can be grouped into two sets: crash event and vehicle-driver-passenger. Crash event includes attributes such as date, time, location, severity, manner of collision, first harmful event, contributing circumstances. Vehicle-driver-passenger includes attributes for each vehicle, driver, and passenger involved in the crash.

The complete details regarding Florida crash report data entry and field codes can be found in the ***Uniform Traffic Crash Report Manual***. The data dictionary for both data sets is provided in the Appendix along with a copy of a blank long-form crash report for reference.

3.1.3 Crash Severity

Consistent with the Model Minimum Uniform Crash Criteria (MMUCC), FDOT classifies crash severities using the KABCO injury classification scale as shown in **Table 3-2**. Crash costs by severity can be found in Chapter 122 of the Florida Design Manual.

Table 3-2: Summary of Crash Injury Categorization

KABCO Category	Injury Category	Explanation
K	Fatal Injury	Injury resulting in death within 30 days of the crash occurring.
A	Incapacitating Injury	Injuries that are disabling such as: broken bones, severed limbs, etc. These injuries usually require hospitalization and transport to medical facilities.
B	Non-Incapacitating Injury	Injuries that are not disabling such as lacerations, scrapes, bruises.
C	Possible Injury	Undetermined injury or potential for injury. More difficult to define as it may not be clear at the time of the incident.
O	No Injury	No injury present; a crash resulting in property damage only.

3.2 Roadway Characteristics

Roadway and intersection data are essential to support both historical crash analysis and predictive safety analysis. This data includes attributes for cross section, profile, horizontal alignment, roadway context classification, access density, and functional classification as they define the roadway environment that vehicles and other users are facing as they use the road.

Roadway data also includes intersection features such as intersection type and control, number of approaches, number of approach lanes, proximity to railroad crossing, presence of street lighting, presence of commercial developments, presence of facilities that are used by vulnerable road users, intersection skew, and proximity to horizontal and vertical curves.

This information can be gathered from a variety of data sources, such as those listed below.

- Project survey data
- Roadway as-built plans
- Recent aerial and street-level photography
- Previous traffic studies or planning documentation
- ***Roadway Characteristic Inventory (RCI)***
- Field observations and measurements

The data sources should be documented; for many data elements, field verification is recommended. In addition to documenting the existing conditions, the project safety analyst should document if there are any recent changes in the project area, such as newly completed roadway projects or major developments. If there were any major changes during the five-year crash period, those changes should be accounted for and documented in the analysis as they may necessitate use of fewer years of crash data than typical.

Proposed roadway geometry, access and intersection control data should be obtained as they are required to support predictive safety models.

3.3 Traffic Volumes

Annual Average Daily Traffic (AADT) or Average Daily Traffic (ADT) (if AADT is not available) volumes are used in existing and predictive crash analysis. Traffic volume measures the amount of driving exposure to crashes and is a major factor for existing and predictive crash analysis. Volume is used to calculate crash rates, examine crash trends and patterns relative to volume trends, and perform predictive crash analyses.

The traffic volumes used for safety analysis should be the same as those developed for the traffic operations analysis.

Traffic data includes bicycles, pedestrians and freight volumes in the project area. Pedestrians and bicyclist counts are essential to support and integrate safety analysis of vulnerable road users. ***FDOT Multimodal Data System Program*** should be consulted for more information about multimodal data collection efforts.

The predictive method uses total entering volume to predict crashes at intersections and two-way segment volume to predict crashes on roadway segments.

3.4 Traffic Operational Characteristics

Traffic operations features that can be collected include posted speed limit, queue lengths, bottleneck location and formation, signal timing and signal coordination, frequency of blocking intersection, railroad crossing, non-conforming signing and pavement marking, accommodation of pedestrians at the intersections and midblock crossings, line of sight issues with signals and other traffic control devices.

3.5 Field Observations

Field observations are necessary to confirm the existing roadway and traffic operating conditions, as well as capture users' behavioral factors such as lane utilization, speed variability, non-motorized movements, and potential conflict issues which affect the safety of operations. Driver and pedestrian behaviors and interactions observed in the field are essential to identifying the likelihood of crashes under different conditions. Field observations can provide additional insights regarding local conditions and indications of risk factors that might otherwise be overlooked. For example, field observations may reveal swerving, emergency stopping, pedestrian/bicycle conflicts, failures to yield, or truck turning radii issues.

Reviews of recent street-level photography and aerial photos should not replace field observations.

Field observations should be conducted during time periods when project-area issues are most apparent. For example, in congested corridors it may be useful to observe the peak period. For other projects, off-peak period or night-time observations may be warranted. Field observations methods may be conducted as informal RSAs of existing conditions. The ***FHWA RSA website*** contains information and resources about RSAs and access to prompt lists in support of field reviews.

3.6 Data Quality

A successful use of safety data to the project development process is contingent on the data quality. Timeliness, accuracy, completeness, and consistency/uniformity are the four important attributes for evaluating the quality of safety data and application of such data in the analysis. As such, project safety analysts should be familiar with data quality attributes and how they affect data collection, data analysis, and project decisions.

Understanding the timeframe for all data collected helps to make data comparison and integration meaningful when evaluating safety problems on the project. Outdated data or mismatched data may lead to less accurate analysis and unreliable results. Additionally, understanding where data is incomplete or has inconsistencies or incorrect information is critical to safety analysis. Therefore, project safety analysis should document all data issues and how the issues were reconciled in the analysis. For instance, if there was a major change in traffic volume or patterns during the crash analysis period, project safety analysts should document and use appropriate traffic volumes reflecting the change in the analysis period.

4 Existing Safety Performance

Existing safety analysis is used to support the Purpose and Need for the project by identifying whether a safety problem exists. Typically, crash data is compared to the statewide average rates for similar facilities and cluster analysis is performed to identify and present areas where a safety problem exists. When evaluating and incorporating safety problems in the Purpose and Need for a project, all affected road users, including drivers, rail, transit, and particularly those more vulnerable such as the elderly, children, disabled, pedestrians, and bicyclists, should be considered.

4.1 Crash Data Analysis

Existing safety analysis includes evaluation of observed crash data to determine crash frequency, severity for historical crashes, crash patterns over historical time periods, and crash contributing factors. The outcome of existing safety analysis can be used to identify applicable countermeasures for future safety mitigation during alternatives development and evaluation.

The depth of safety analysis in a PD&E study depends on the type and context of the project, and the importance of safety to the project. Crash data analysis involves compiling and examining data, analyzing crash trends and characteristics, determining contributing factors and calculating crash rates.

4.1.1 Compile and Examine Data

Compile crash, roadway characteristics, traffic volume, and traffic operations data for the analysis area. While compiling crash data it is important to determine if the crash is roadway segment-related or intersection-related. Additionally, it is important to request and review long-forms for all fatal crashes to determine their contributing factors. See Chapter 3 for guidance on data collection.

Additionally, examine attributes in the crashes and relate them to human factor attributes to determine how road users and vehicles interact with the roadway environment.

The project safety analyst should exercise caution when reviewing crash locations as there may be discrepancies in geo-coding of the crashes. For instance, some of the crashes occurring at the parking lot near the roadway may show on the roadway.

4.1.2 Analyze Crash Trends and Characteristics

Crash trends in the project area can be discerned by evaluating observed crashes by location, type, time of day, year, severity, presence of overhead lighting, weather, distraction, contributing factors, etc., to determine the presence of any patterns and identify appropriate countermeasures. There are various tools that can be used to analyze crashes to indicate the presence of a crash pattern. These tools may produce crash summary tables, figures, charts or maps by type, severity, and crash event. The tools can help the project safety analyst to investigate locations with high crash frequency, unexpected crash clusters or any observed anomalies to determine crash contributing factors. Trend analysis includes analyzing the reason for the increase (or decrease) of crashes which is an important consideration in determination of crash countermeasures.

There is no preference of format for visual presentation of crash data analysis. **Figure 4-1** shows examples of visual presentation that may be prepared to illustrate crash pattern in the project area.

Figure 4-1: Crash Pattern Examples

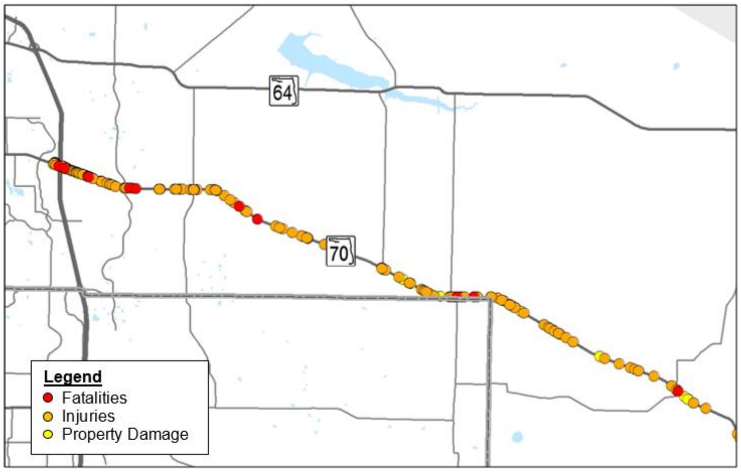
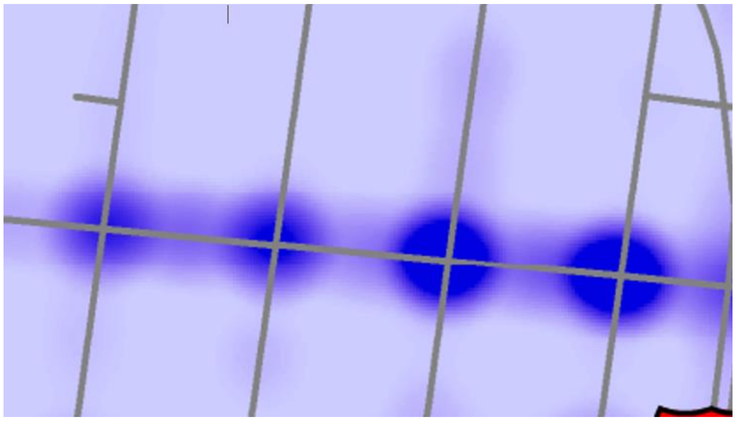
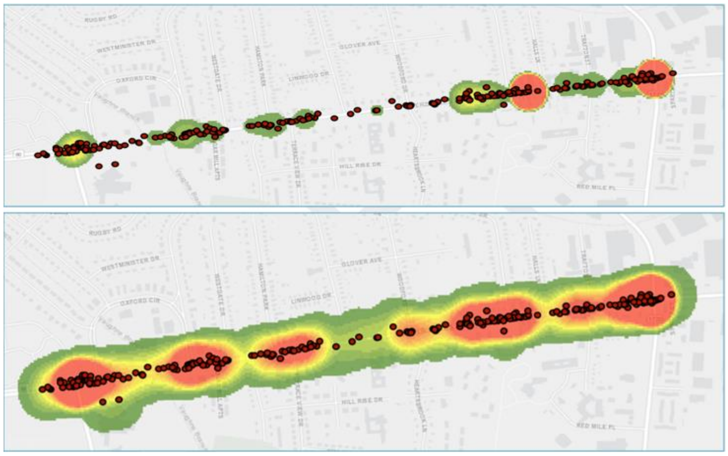
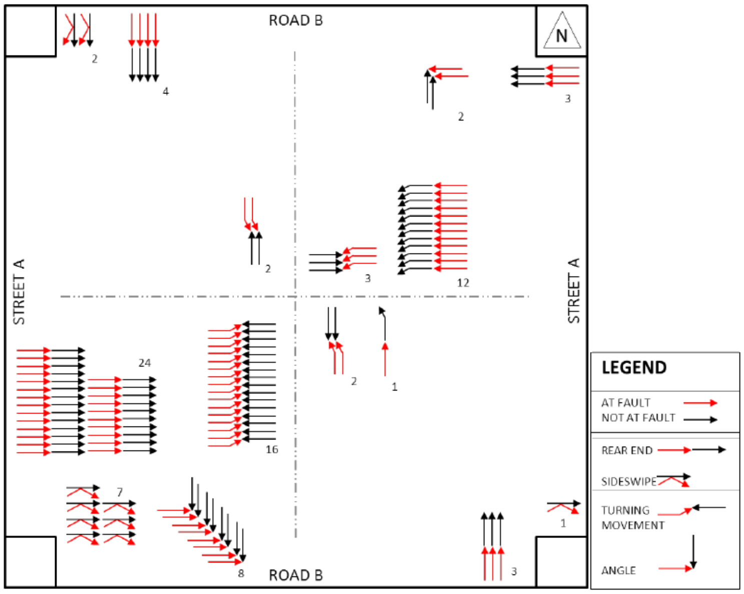
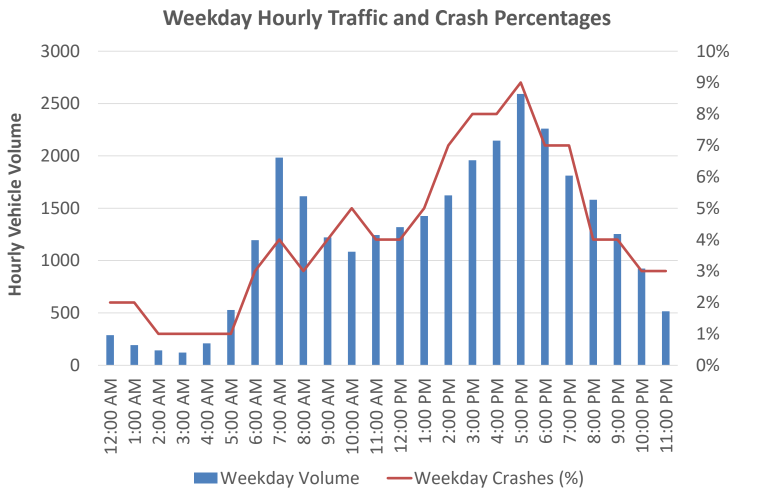
<table>
<tr><td>
</td><td>A crash map showing crash locations by severity level</td></tr>
<tr><td></td><td>A crash density map highlighting hot spots areas</td></tr>
<tr><td></td><td>Crash frequency and heat map</td></tr>
</table>

Figure 4-1: Crash Pattern Examples



Adapted from FHWA Signalized Intersections: Informational Guide

Collision diagram



Graphs

4.1.3 Calculate Crash Rates

The crash rate performance measure normalizes the number of crashes relative to traffic exposure variables which are explained by vehicles miles of travel or total intersection volume. Crash rate evaluates the relative safety of a segment or intersection of a project with respect to statewide averages for comparable facilities. A location with significantly higher crash rates than the statewide average typically requires further analysis. Crash rates are calculated for total crashes and fatal and injury crashes. Roadway segment crash rates are typically calculated per Million Vehicle Miles Travel (MVMT). Intersection crash rates are calculated per Million Entering Vehicles (MEV). MVMT and MEV are traffic exposure variables.

The equation for a roadway segment crash rate is:

$$Crash\ Rate = \frac{Total\ number\ of\ Crashes\ x\ 1{,}000{,}000}{Segment\ Length\ x\ AADTx\ (number\ of\ years\ x\ 365)}$$

Where:

Total Number of Crashes = Total number of crashes in the study period (e.g., five years)

Segment Length = Length of the roadway segment measured in miles

AADT = Annual Average Daily Traffic Volume, or Average Daily Traffic volume if AADT is not available

The equation for an intersection crash rate is:

$$Crash\ Rate = \frac{Total\ number\ of\ Crashes\ x\ 1{,}000{,}000}{Total\ Intersection\ Entering\ Volume\ Per\ Day\ x(number\ of\ years\ x\ 365)}$$

Where:

Total Number of Crashes = Total number of crashes in the study period (e.g., five years)

Total Intersection Entering Volume = Sum of daily traffic volume (AADT or ADT) entering an intersection from each approach

Example: Calculating Crash Rates for a Segment

A PD&E Study is being conducted for widening a 2.5 mile four-lane divided corridor in a suburban area. Review of historic crash records showed that 120 crashes have been reported in this segment from 2011 to year 2015. AADT from the segment is 35,000 vehicles per day. The statewide average crash rate for comparable facilities is 0.8 crashes per MVMT. A crash rate analysis was performed to substantiate the existing safety problem on this corridor.

$$Crash\ Rate = \frac{Total\ number\ of\ Crashes\ x\ 1{,}000{,}000}{Segment\ Length\ x\ AADTx(number\ of\ years\ x\ 365)}$$

$$Crash\ Rate = \frac{120\ x\ 1{,}000{,}000}{2.5\ x\ 35{,}000x(5\ x\ 365)} = 0.75$$

The 0.75 crashes per MVMT is less than the statewide average rate 0.8. Since the crash rate is close to the statewide average, the segment should be evaluated further to identify crash patterns, contributing factors and countermeasures that would be incorporated in the alternatives development and evaluation.

Since traffic volume is a key input in crash rate calculations, the project analyst should carefully review the variation of volumes. An increase in traffic volume may reduce the crash rate which may mislead the performance measure. Additionally, crash rate calculations can be misleading when the crash sample size is small. The problem is prevalent for fatal and injury rates because the number of data points is often small. For these reasons, predicting crash frequency is preferred to crash-rate-based methods for assessing both project needs and proposed project changes.

4.2 Potential for Safety Improvement Analysis

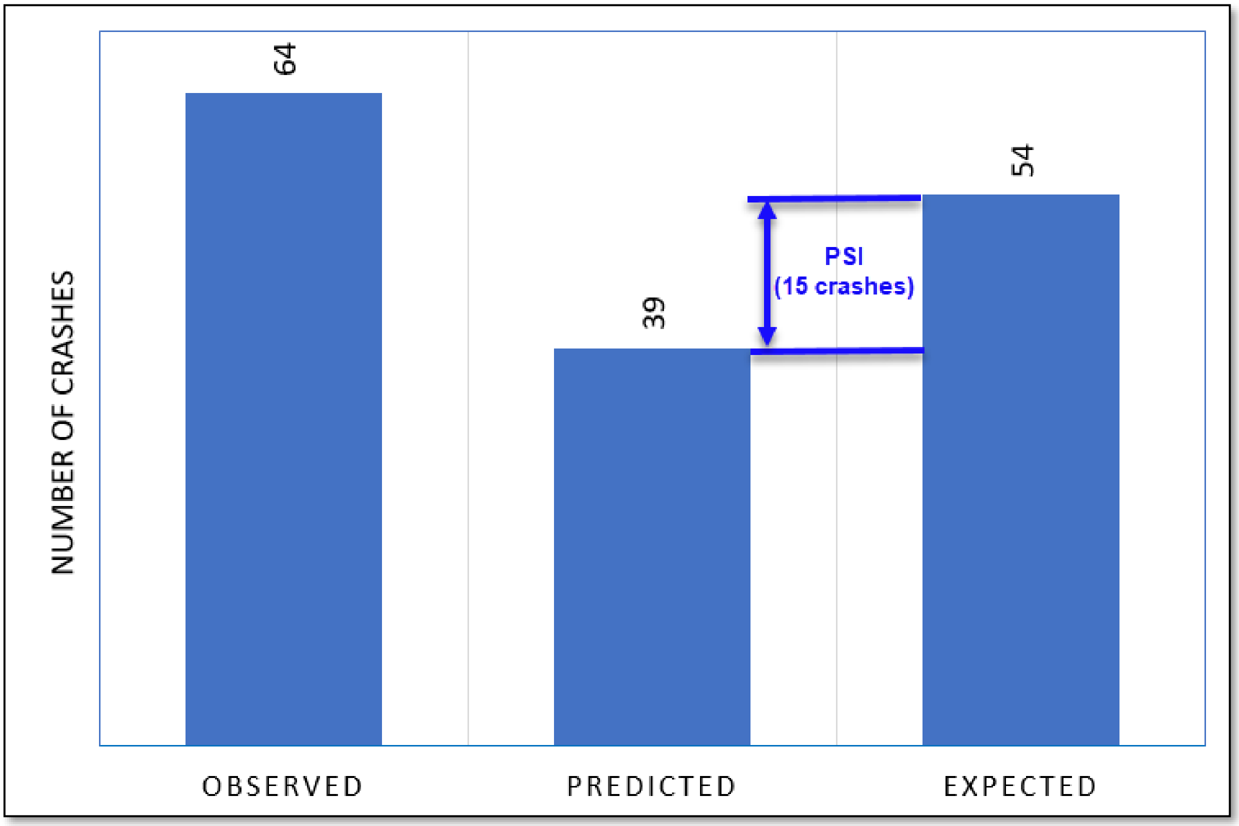
The Potential for Safety Improvement (PSI) analysis uses the HSM predictive method to compare the expected average crash frequency (using EB method) to the predicted average crash frequency to determine how much the long-term crash frequency could be reduced in the analysis area. The HSM also refers to the PSI as the expected excess crash method. This method, yields a statistically valid quantitative assessment of the safety of the highway. This method is used to evaluate existing conditions.

Figure 4-2: Calculating Potential for Safety Improvement for an Urban Arterial

320 crashes were observed in a four-lane urban undivided arterial over the past 5 years. The highway is one-mile long and has three major intersections, including one at either end of the corridor. The project team completed a PSI analysis (Figure 4-3) to determine the potential for long-term crash reduction.

- Using HSM predictive method, the total predicted number of crashes for the five years was 193 (39/year).
- The observed crashes were used to apply the EB method at the segment and intersection level, resulting in an expected value of 270 crashes over 5 years (54/year).
- The PSI for this one-mile segment of road was 15 crashes per year (54-39=15), which is a reduction of 28% compared to the expected crash frequency. This means that the long-term average crash frequency at this roadway is greater than for comparable roadways.
- Since expected crashes are greater than predicted crashes, there is a potential for safety improvement and the problem could be investigated further for potential crash countermeasures. Therefore, safety could be added in the purpose and need for the project.
- If PSI is a negative value (expected crashes are less than predicted crashes), the site experiences fewer crashes than expected.

Figure 4-3: Potential for Safety Improvement Example



4.3 Documentation of Existing Safety Analysis

Documentation of existing safety analysis should summarize crash frequency per year by severity and by crash type, identify and discuss crash trends and patterns and highlight potential safety areas and possible crash countermeasures. The report should also discuss crash rates and their comparisons to statewide averages, and discuss high crash locations. The following is a typical outline.

- Field Observation Narrative, including locations which have common crash contributing factors based on crash history, roadway geometry and operating characteristics.
- Data Collection, including description of data needs and assumptions used
- Study Area
- Traffic Conditions and Traffic Volumes
- Crash Data, including description of fatal, severe injury, pedestrian, and bicycle crashes
- Crash Analysis Results
- Appendix, including data used to produce the analysis

5 Future Conditions Safety Analysis

There are various methods for evaluating safety impacts in development and analysis of alternatives.

5.1 Crash Modification Factors Analysis

A Crash Modification Factor (CMF) is a measure of the safety effectiveness of a safety treatment (countermeasure) or design alternative on a project. It is a value which quantifies the change in average crash frequency as the result of implementing a specific countermeasure on a project. Therefore, CMFs are applied to the estimated or observed crashes without treatment to compute the estimated crashes with treatment.

For example, a CMF of a certain treatment is 0.90 and the average number of crashes without treatment is 14 crashes per year upon application of the treatment, the estimated average crashes will be 0.9 multiplied by 14 or 12.6 crashes per year. The estimated change in average crash frequency is 14 minus 12.6 or a reduction of 1.4 crashes per year.

A CMF is only an estimated value of the crash reduction potential of a treatment or alternative. The confidence level of a potential crash reduction from proposed conditions can be estimated from the standard error for the CMF. Standard errors are available for some CMFs in the HSM and the CMF Clearinghouse.

The value of the CMF indicates the safety effectiveness of the treatment as presented in **Table 5-1**.

Table 5-1: CMF Value Description

CMF Value	Effectiveness of Treatment
< 1.0	The treatment has a potential to reduce crash frequency, severity or type.
1.0	The treatment has no effect on the crash frequency, severity, or type.
> 1.0	The treatment has a potential to increase crash frequency, severity or type.

Estimated crashes without a treatment can be obtained from:

- Expected number of crashes using a calibrated SPF and EB
- Predicted number of crashes calculated using a calibrated SPF
- Historic crash data

Figure 5-1: Estimating Crashes Using CMF

Crash Type	Year					Average
	2014	2015	2016	2017	2018	
Total Crashes	42	55	37	39	60	46.6

CMF = 0.96

Observed crashes without treatment = 46.6 crashes/year

Estimated crashes with treatment = CMF x Observed crashes without treatment

= 0.96 x 46.6 = 44.7 crashes/year (or 1.9 crashes/year reduction)

5.2 Selecting an Appropriate CMF

There are two types of CMFs—HSM Part C CMFs and countermeasure CMFs:

- HSM Part C CMFs are used in the predictive models as adjustment factors to the base condition SPF to site specific geometric design and traffic control features. For example, in the HSM, 12-foot lane is the base condition for the SPF for a rural, two-lane roadway; if the proposed typical section is 11-foot lanes, a Part C CMF of 1.05 should be used to adjust the base predicted crashes. **Part C CMFs will be called SPF adjustment factors in the Second Edition of the HSM**. Part C CMFs should only be used on Part C HSM predictive method as they were developed to support the HSM predictive method.

- Countermeasure CMFs are used to estimate how a countermeasure will change crashes at a specific location. Countermeasure CMFs are developed using multiple sites and statistical methods located in the HSM Part D and FHWA ***CMF Clearinghouse***. The FHWA CMF Clearinghouse has extensive information from research projects from around the world which should be reviewed before applying a CMF on the project. It is important that the specifics of the countermeasure (such as standard error, site context, star quality rating, study information, and crash type) in the CMF Clearinghouse be examined carefully before they are used.
- CMF from published research. New research is constantly being completed that improves on the available CMF information. Use of CMFs from research (that are not included in the CMF Clearinghouse) should be examined and approved by FDOT before they are used.

CMFs have been developed for many different roadway and intersection conditions. When selecting an appropriate CMF, it is necessary to identify a CMF that best matches the project conditions by considering factors such as the applicability of available CMFs and the quality of applicable CMFs. CMFs should not be chosen solely based on potential crash reduction without reviewing their applicability and quality.

- Applicability of a CMF requires an analyst to determine if the project context (e.g., roadway characteristics, surrounding environment, traffic control, traffic volume, and state from which the CMF was developed) matches an identified treatment in the Clearinghouse. Same treatments in a different project context may have different CMF values. Therefore, to increase the reliability of safety performance estimates, it is very important to apply CMFs to conditions that closely match those from which the CMF was developed.

- Applicability of a CMF also depends on the specific scenario that the CMF was created, for instance area type, crash severity, crash type, total crashes, etc.
- Both HSM Part D and CMF Clearinghouse provide the standard error for (many but not all) CMFs which can be used to differentiate the results where a small error is desired. Additionally, the CMFs in the CMF Clearinghouse include quality ratings. A five-star rating indicates a greater level of confidence on estimating safety performance. CMFs with a star rating of three or higher should be used.
- Crash type or severity - Each CMF is associated with certain crash types or severities. The CMF should be applied to a subset of crashes at a site that are applicable to the CMF. For example, the rural multilane highway lane-width CMF in the HSM applies only to single-vehicle run-off road and multiple-vehicle head-on, opposite direction sideswipe, and same direction sideswipe crashes. In such cases, the effect of the CMF must be adjusted to apply only to the affected crash types.

To avoid misusing CMFs, it is important to review the details of the CMF prior to selecting. For example, a CMF for changes to signals and signage developed using data from Europe may not have direct relevance to U.S. roadways. It is essential that the CMF description, crash type or severity characteristic, and the research supporting the CMF be reviewed to verify that it applies to the project.

5.3 Effects from Multiple CMFs

CMFs are typically developed independently of any other roadway treatments, and therefore multiple CMFs from multiple treatments may be applied to observed crashes provided the treatments are independent. Thus, engineering judgment should be used and documented when verifying the assumption of independence among multiple CMFs. If the target crash type overlaps for a given treatment, then there is no independence. For example, it may be reasonable to apply a CMF for shoulder widening and another for left-turn lanes at major intersections in the same corridor (there is independence); however, it is not reasonable to apply three separate CMFs for shoulder widening, rumble strips, and improvements to the clear zone, as they are all likely to impact the same run-off road crashes (there is no independence). CMFs for similar treatments should not be combined to estimate cumulative effects. Some CMFs apply to specific crash types or crash severities. Verify that the CMF is being applied to the correct crash type/severity before including in the effectiveness calculations.

The current HSM practice is to assume that CMFs are multiplicative, if they are assumed to be independent. HSM Method for combining multiple CMFs is as follows:

$$N = N_b (CMF_1 \times CMF_2 \times CMF_3)$$

Where:

N is the estimated crash frequency after treatment is applied,

N_b is crash frequency under base conditions (no treatment applied), and

CMF_i is the crash modification factor associated with treatment.

Because of the limitation and uncertainty in combining CMFs discussed in this section, no more than three CMFs should be used.

5.4 Relative Comparison of CMFs

This method compares the relative potential safety impacts in estimated percent change in crashes (same crash type or severities) using only CMFs for proposed treatments or alternatives. The estimated percent change in crashes is equal to 100*(1-CMF); e.g., if a design element has a CMF of 0.96, then it is expected that there is a four percent (4%) reduction in crashes.

This method is used when crash data is not available. Although this method is simple to apply, it may lead to unreliable results as it does not provide an estimate of change in the number of crashes. This method is suitable for screening of viable alternatives from a large list of potential safety treatments; however, this would not be suitable as the only safety analysis performed.

Relative comparison of CMFs should not be used when there are substantial differences among the alternatives in terms of factors such as number of lanes, land use context, or traffic volume.

Figure 5-2: Relative Comparison of Alternatives using CMFs

Two intersection concepts—a traffic signal and a roundabout— are being considered in a PD&E study that evaluates safety and operations issues of a 10-mile segment of a rural two-lane two-way highway. As part of the safety analysis for this project, relative comparison of CMFs was used to evaluate and compare the potential safety impacts of the two build alternatives so that they can be considered with other evaluation factors related to operations, cost, and environmental impacts. The following table presents the details of the alternatives considered

Intersection Concept	Number of Approaches	AADT	Traffic Control
No-Build	4	18,000	Two-way stop control
Alternative 1	4	18,000	Traffic signal
Alternative 2	4	18,000	Single lane roundabout

The following table presents the CMFs for each build alternative along with the baseline condition and applicability. Note that all CMFs apply to total crashes at rural, four-legged intersections.

Build Alternative	CMF		Crash Severity
	Value (SE)	Applicability (star rating)	
Alternative 1: Convert two-way stop-control to traffic signal	0.66 (0.105)	Rural 4-leg intersection (4)	All
Alternative 2: Convert two-way stop-control to single-lane roundabout	0.29 (0.5)	Rural 4-leg intersection (5)	All

Alternative 1 includes changes to only one feature—i.e., changing stop controlled intersection to a traffic signalized intersection. As such, it is not necessary to combine CMFs. Based on the CMF for installing a traffic signal, Alternative 1 is expected to reduce total crashes by 34 percent (100(1-0.66)) compared to the existing conditions.*

Alternative 2 also includes changes to only one feature—i.e., changing stop controlled intersection to a roundabout intersection. As such, it is not necessary to combine CMFs. Based on the CMF for installing a single-lane roundabout, Alternative 2 is expected to reduce total crashes by 71 percent (100(1-0.29)) compared to the existing conditions. Based on the relative comparison of CMFs, either alternative would enhance safety compared to the no-build conditions, but Alternative 2 (single-lane roundabout) is anticipated to have larger safety benefits than Alternative 1 (traffic signal). The potential safety impacts can now be considered in conjunction with other factors such as cost, operational and potential environmental impacts.*

Adapted and Modified from FHWA's Crash Modification Factors in Practice

5.5 Observed Crashes with CMF Adjustment

This method adjusts the observed number of crashes in the study area based on a CMF of proposed changes to roadway characteristics. The potential change in crash frequency is estimated by multiplying a CMF by the observed average crashes (five-year average) yielding estimated or potential change in crash frequency as the result of proposed improvements. Unlike the relative comparison of CMFs, this method estimates the change in crash frequency as the result of proposed treatment in an alternative. Additionally, this method can estimate the relative cost of the alternatives evaluated by multiplying the average cash cost with the estimated change in crash frequency.

Figure 5-3: Estimating Crash Frequency using CMF and Observed Crash Data

The 5-year historic crash data on a roadway segment is shown below. The average number of crashes on this segment is 46.6. Estimate the net change of the average number of crashes if a treatment with a CMF of 0.96 is proposed in this segment.

Crash Type	Year					Average
	2014	2015	2016	2017	2018	
Total Crashes	42	55	37	39	60	46.6

CMF = 0.96

Observed average number of crashes without treatment = 46.6 crashes/year

Estimated average number of crashes with treatment = CMF x Observed crashes without treatment

= 0.96 x 46.6 = 44.7 crashes/year

Net change in the average number of crashes is 46.6 – 44.7 or 1.9 crashes/year (reduction)

5.6 Documenting Results of CMF Analysis

The results of the CMF analysis should be explained in the PD&E safety analysis documentation. This should include the CMF value, base condition, source, standard error/star rating, and CMF ID if taken from the CMF Clearinghouse. The analysis results should be clearly shown in a table of outcomes with an interpretation. The documentation should indicate whether the CMF increases (CMF > 1.0) or decreases (CMF < 1.0) the crashes. The change in the number of crashes should be compared between alternatives, including the No-Build condition. If the volume on the roadway is anticipated to change between alternatives, the analyst should take exposure into consideration and normalize the results.

6 HSM Predictive Method

The HSM predictive method estimates average crash frequency and severity by facility type as a function of the roadway characteristics and traffic volume which can be used to evaluate current and future safety performance of roadway projects.

The HSM method has five key components:

1. SPFs which are regression equations developed from national crash data. SPFs are developed for specific facilities (e.g., two-lane rural highways, urban four-leg signalized intersections, urban multi-lane highways, and freeways). For roadway segments, the basic inputs to most SPFs are AADT and length while the basic input for intersections is the total entering traffic volume.

2. HSM Part C CMFs or Adjustment Factors (in the Second Edition HSM) are factors that modify the predicted baseline crashes to reflect the specific characteristics of the roadway segment or intersection. The adjustment factors address items such as lane width, median width, curvature, signal phasing, number of driveways, and many other topics depending on the facility type. Adjustment factors are specific to a SPF and should be used with that SPF.

   Part C provides the predictive methods for segments and intersections for the following facility types:
   - Chapter 10 – Rural Two-Lane, Two-Way Roads
   - Chapter 11 – Rural Multilane Highways
   - Chapter 12 – Urban and Suburban Arterials
   - Freeway procedures are contained in the ***ISATe Users Manual*** and will be added in the second edition of the HSM

3. Calibration Factors are factors that adjust the predicted crashes to account for the difference between state/local crash frequency and reporting, and the data that was used to develop the SPFs. The SPFs were developed using data from five states (not including Florida). It is important to adjust these equations to match Florida conditions. The FDOT calibration factors are available online at the ***FDOT State Safety Office – Highway Safety Manual website***.

4. Empirical Bayes (EB) Method (SPF weighted with observed crash data) – The EB method uses historical crash data to adjust the SPF predicted crash data to an expected number of crashes. The method uses historical crash data; therefore, to use this method for a proposed condition there cannot be substantial changes to the roadway geometry or land use context. EB has limited applicability for most alternatives evaluation in the PD&E process. However, EB can be used to support the purpose and need by identifying highways that have more crashes than as estimated using the PSI method.

6.1 Approach to Applying the Predictive Method

Applying the HSM predictive method requires careful application of the procedures outlined in the HSM as well as the selection of appropriate tools for implementing those procedures. Methods and assumptions that are set during project scoping may be refined during the project execution when the data and improvement alternatives are fully understood. The HSM predictive method consists of 18 steps which are shown in **Table 6-1**.

Table 6-1: Overview of HSM Predictive Method Analysis

HSM Step	Description of the Step	Comments
Step 1	Define roadway limits and facility type	These steps should be completed when preparing methodology for safety analysis
Step 2	Define the period of study	
Step 3	Determine AADT and availability of crash data for every year in the period of interest	Collect and compile data, and study area segmentation
Step 4	Determine geometric conditions	
Step 5	Divide roadway into individual roadway segments and intersection	
Step 6	Assign observed crashes to individual sites (if applicable)	This step is only applicable when using site specific EB method
Step 7	Select a roadway segment or intersection. If there are no more sites to analyze, go to Step 15.	Repeat Steps 7, 8, 9, 10, 11, 12, 13 and 14 until all sites are analyzed
Step 8	Select first or next year of the evaluation period. If there are no more years to be evaluated for that site, proceed to Step 15.	
Step 9	Select and apply SPF	Apply the appropriate SPFs for the site's facility type and traffic control features to predict baseline average crash frequency
Step 10	Apply CMF	Adjust the results of Step 9 to predict average crash frequency to specific geometry and traffic control features
Step 11	Apply calibration factor	Adjust the results of Step 10 to Florida roadway conditions
Step 12	Repeat Step 8 if there is another year for analysis, otherwise proceed to Step 13	
Step 13	Apply site specific EB method (if applicable)	Optional step used if site by site observed crash data are available and geometric features for no-build and build conditions are the same.
Step 14	Repeat Step 7 if there is another site to analyze, otherwise proceed to Step 15	
Step 15	Apply project-level EB method (if applicable)	Optional step used if observed crash data are available but can only be allocated to the project area as a whole and geometric features for no-build and build conditions are the same.
Step 16	Sum all sites and years	This will estimate the average crashes for the alternative
Step 17	Go to Step 3 if there is another alternative or forecast AADT to be evaluated	If there are more than one alternative or AADT to evaluate
Step 18	Compare and evaluate results	

The first 11 steps of the 18 steps can be grouped into 5 basic steps as follows:

1. Determine data needs
2. Divide locations into homogeneous segments or intersections
3. Identify and apply the appropriate SPF
4. Apply CMFs to calculated SPF values
5. Apply local calibration factor

Using these steps, predicted crash frequency, ($N_{predicted}$) can be calculated using the following equation:

$$N_{predicted} = SPF \times (CMF_1 \times CMF_2 \times \ldots.) \times C$$

Where:

SPF is the safety performance function,

CMF_i is crash modification factor for treatment i, and

C is local calibration factor.

Steps that involve application of EB methods are supplemental steps and are not applicable to all project conditions.

6.2 Segmentation of the Study Area

Proper segmentation of the study area highways is essential to achieve accurate analysis results. Once the study facilities have been segmented, SPFs can be selected and the data required to implement each SPF can be compiled. Segmentation can be one of the most time consuming but also informative steps in the HSM process. HSM recommends limiting the minimum segment length to 0.1 miles to minimize calculation efforts and not affect results. Segmentation is one of the more critical steps in the prediction process. Careful planning, documentation, and quality review is critical to the overall outcome of the analysis. Experience, engineering judgment, and sensitivity testing ultimately inform the segmentation process. IHSDM will segment facilities within the software; however detailed input checking is recommended.

The study area highways should be segmented into homogenous sections which have the following similar attributes:

- Traffic volume,
- Typical section elements (number of through lanes, shoulder, median, etc.),
- Land use type, and
- Speed limit.

New segments begin at the center of an intersection or where any key attributes change enough to change the substantive safety performance (as defined in the HSM for each SPF). It is important to note that, each HSM predictive model has different segmenting requirements, therefore the project safety analyst should refer to the appropriate HSM chapter for segmentation details. Additionally, segmentation requirements for freeways and interchanges are discussed in Chapter 2 of the ISATe User Manual.

Figure 6-2 shows an example of segmentation of a two-lane roadway. In this example, segments 1 and 2 are in a suburban area and segments 3 through 8 are in a rural area. Engineering judgment should be employed to identify proper analysis segments that will result in reasonable crash predictions. Assumptions should always be thoroughly documented.

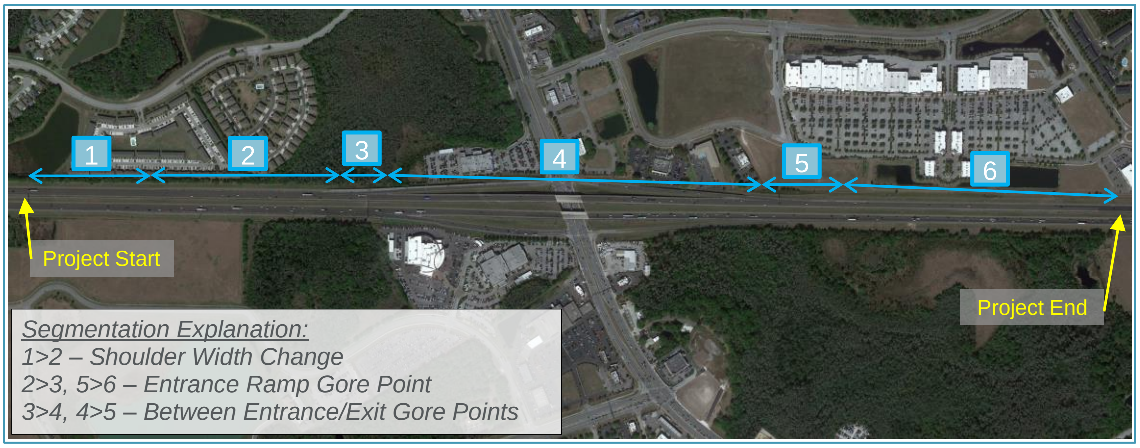
Figure 6-1: Segmentation Example for a Two-Lane Roadway

Intersections should be considered separately as they are treated as points and do not affect segment. If the EB method is used, then the Step 6 of the HSM predictive method should be used to assign appropriate crashes onto the segments and intersections. In general, this process assigns crashes inside the intersection to the intersection and crashes within 250 feet of the intersection are assigned based on the crash characteristics. It is critical that crashes not be double-counted during this process.

Figure 6-2 shows an example of segmentation of freeways. The HSM specifies that creating very short segments (<0.04 miles) is unlikely to improve model accuracy. For example, when freeways are segmented for ISATe, if the gore points on both sides of the freeway are within 100 feet of each other they are often assumed to both be located at the midpoint of a common segment to keep the analysis manageable.

Ramp terminal intersections should be considered separately in the analysis. The surface street intersection predictive method should not be used for ramp terminals, and vice versa. This is an important consideration when an interchange and an intersection are being compared to each other.

Figure 6-2: Segmentation Example (Freeway)



6.3 Calibration Factors

Calibration factors adjusts HSM SPF crash estimates to reflect local conditions such as climate, driver population characteristics, crash reporting, and other factors excluded from the SPF that affect crash risk. FDOT calibration factors for use in predictive safety analysis for a variety of roadway and intersection types can be found at the FDOT HSM website. There are no FDOT calibration factors for interstate analysis at this time.

HSM Calibration Factors Website

www.fdot.gov/safety/11a-safetyengineering/TransSafEng/HighwaySafetyManual.shtm

6.4 Multiple Years Analysis

Depending on the situation, method, and tool being used, it may be necessary to estimate the average number of crashes for other analysis years. Typically, this would only require changing the volume inputs and any volume-dependent CMFs as the geometric characteristics would not change. One benefit of ISATe and IHSDM is that these tools will interpolate the inputs to provide outputs for multiple years. When the HSM spreadsheets are used, inputs must be prepared for all years for which results are required.

6.5 Applying Empirical Bayes

Applying the EB method increases the reliability of the predicted crashes by combining the estimates of Part C predictive model and observed crash frequencies. The EB method adjusts a predicted crash frequency to an expected crash frequency for past and future conditions and using either site-specific level or project-specific level crash data (where observed data may be known for a facility and not at the specific-site level). Use of EB method requires:

- Applicable SPF that is calibrated to Florida conditions and
- Observed crashes appropriately assigned to individual sites (segments or intersection) or for the corridor as a whole.

The EB method should be applied for the analysis involving:

- Sites at which roadway geometrics and traffic control are not being changed (no-build alternative);
- Projects in which the roadway cross section is modified but the basic number of through lanes remains the same;
- Projects in which minor changes in alignment are made; and
- Projects in which passing lane or a short four-lane section is added to a rural two-lane roadway to increase passing opportunities.

Most of the projects described above are minor in scope and would not require a PD&E study.

The EB method is not applicable to the following project types:

- Projects in which a new alignment is developed for a substantial portion of the project length,
- Widening project that changes the typical section of the roadway (e.g. adding new lanes, median), and
- Intersection at which the basic number of intersection legs or types of control is changed as part of a project.

Alternatives analyses for these projects would not apply the EB method. Therefore, most of the alternatives analysis for PD&E studies would not require application of EB method as these projects involves changing geometric of the existing conditions. However, EB method could be used to evaluate no-build conditions when assessing or establishing the purpose and need for a PD&E study where a PSI could be estimated.

6.6 Document Results

Document the results of HSM predictive analysis in the Project Traffic Analysis Report. Include discussion of the study area, study period, scope (including alternatives evaluated in detail), methodology, tools and data. Summarize the safety analysis, explain how the project safety goals were addressed in each alternative and quantitatively contrast and compare all viable alternatives.

6.7 Tools for Applying the Predictive Method and Case

This section presents the three major tools for implementing the HSM predictive method.

Highway Safety Manual (HSM) Spreadsheets

The HSM spreadsheets were developed in conjunction with NCHRP 17-38: Highway Safety Manual Implementation and Training Materials. The spreadsheets implement the HSM predictive method for:

- Rural Two-Lane Roads (segments and intersections)
- Rural Multilane Highways (segments and intersections)
- Urban-Suburban Multilane Arterials (segments and intersections)

The analysis conducted within these spreadsheets follows the HSM Part C methodology for predicting crashes for each of these facility types. For each spreadsheet analysis, the user must divide the roadway into homogeneous segments and follow the instructions to input the applicable data for each segment and intersection. The spreadsheets come with two segments and two intersections by default, but this tool allows the user to copy the analysis tabs for additional segments or intersections as needed.

The spreadsheets also apply the EB method to calculate expected crashes. To do so, existing crash data is input on the site total and project total tab(s) of the spreadsheet tool.

FDOT HSM Spreadsheets Link
https://www.fdot.gov/traffic/trafficservices/studies/muts/muts.shtm

Enhanced Interchange Safety Analysis Tool (ISATe)

The ISATe tool is a safety analysis spreadsheet tool designed to perform predictive safety analysis along freeway, ramp, ramp terminal, or collector-distributor segments. The spreadsheet provides embedded instruction and troubleshooting for the input and analysis process and adapts the data requirements for each roadway segment. The user must divide the study network into homogenous segments for evaluation, enter required geometric and traffic data, and verify that the records are complete and correct.

ISATe Spreadsheets Link
http://www.highwaysafetymanual.org/documents/NCHRP-1738_XLS.zip

Once the data for all of the segments is input into the spreadsheet appropriately, the tool will estimate the predicted number of crashes on the facility consistent with the HSM freeway chapters.

Safety Performance for Intersection Control Evaluation (SPICE)

FDOT's SPICE spreadsheet analysis tool was developed to provide an easy-to-use tool that automates the predictive HSM safety analysis for intersections and provides results consistent with the HSM Spreadsheets and IHSDM. This tool should accompany the Intersection Control Evaluation (ICE) process in order to provide safety information for decision-making related to intersection alternatives. This tool provides a comparative (relative difference) analysis between various intersection alternatives.

The SPICE tool requires the same user input data as the HSM for the intersection approach geometry and AADT (opening and design year) for each of the possible intersection configurations and control types, and then provides predictive crash summaries for each alternative, allowing for comparisons. Additionally, historical crash data can be entered to calculate the EB expected crash adjustment; however, this capability is limited to signalized and two-way stop control intersection evaluations (four-way stop control, roundabouts, etc. are not supported). FDOT HSM calibration factors can also be included in the SPICE analysis.

FDOT SPICE Link
http://www.fdot.gov/traffic/trafficservices/Intersection_Operations.shtm

Interactive Highway Safety Design Model (IHSDM)

IHSDM is a free FHWA software analysis tool that applies the HSM predictive method. The standalone software package has multiple modules which allow for different variants (station or site-based analyses) for the evaluation of rural highways (two-lane and multilane); arterials (urban and suburban); freeways (segments, ramps, and interchanges); and intersections.

- The station-based analysis approach allows the user to either (a) import roadway geometry features directly from a design alignment file or (b) manually input stationing and features. Station-based analysis allows for the automation of segmentation, and improves analysis accuracy because alignments are directly imported without translation.
- The site-based analysis approach is more simplified. The user must manually input roadway data, and must manually segment the study network.

Either analysis approach can be used, as long as the facility type is covered within IHSDM. The output results are the same for either approach.

IHSDM analysis can be adjusted to provide more accurate and locally reflective results, via either modification of default parameters or importing specific parameters in a similarly formatted spreadsheet. Once the values are entered and saved (using the IHSDM admin configuration tool), they will be selectable and should be selected prior to evaluation.

It is important to remember that the IHSDM software implements the same calculations that are in the HSM 1st Edition, the HSM Spreadsheets, and ISATe. Analysts should not treat IHSDM as a "black box", but should carefully check the inputs as well as the intermediate and final outputs. For example, it is possible to confirm that adjustment factors are being calculated properly, and to output these factors (and results) into a spreadsheet for review.

The IHSDM tool is the only method currently available for implementing the new six-lane arterial and one-way street SPFs, unless the analyst develops a custom spreadsheet.

FHWA IHSDM Software Link
http://www.fhwa.dot.gov/research/tfhrc/projects/safety/comprehensive/ihsdm/

FDOT Systems Implementation Office

The FDOT Systems Implementation Office periodically provides training programs for DOT and other agency staff and consultants. Training related safety analysis as part of Interchange Access Requests is available on this site. This information could be useful as additional guidance for safety analysis at interchanges.

FHWA System Implementation Office
https://www.fdot.gov/planning/systems/training.shtm

6.8 Limitation of HSM Predictive Method

The predictive models used in the HSM predictive methods were prepared using geometric and traffic characteristics data from data from five states in the United States (Florida was not included). Additionally, development of the HSM predictive models did include the effects of various physical characteristics of the roadway environment and non-geometric factors on crash occurrences. Some of the limitations of this method as stated in the HSM include:

- Does not account for variability of driver population from one region to another.
- Does not include the effect of weather.
- Does not account for traffic variability as HSM uses AADT volumes.
- Ignores correlation between individual geometric features and traffic control features. HSM assumes independence of these factors on crash occurrences.
- Does not account for the influence[3] of freeways with 11 or more through lanes in urban areas, influence of freeways with 9 or more through lanes in rural areas, toll plazas, reversible lanes, use of shoulder as through lanes, ramp metering, managed lanes.
- Does account for ramp or Collector-Distributor roads with two or more lanes in rural areas, or three or more lanes in urban areas.
- Does not account for the influence of unique or innovative intersection or roadway designs

HSM Part C predictive methods report pedestrians and bicycle crashes, however their predictive models are less developed than automobile predictive models. Additionally, ISATe does not predict pedestrian or bicycle crashes that may be using ramp terminals.

[3] Review Safety Prediction Methodology and Analysis Tool for Freeways and Interchanges. NCHRP Project No. 17-5 Final Report for more limitation

7 Safety Analysis Documentation

Documentation for safety analysis should include the following:

- Executive Summary – Summary of report and findings. Required if a standalone Safety Analysis Report is prepared.
- Project Introduction – Location, project description, purpose and need. Required if a standalone Safety Analysis Report is prepared.
- Study Area
- Analysis Years
- Analysis Methods – Analysis assumptions, discussion of methods and tools and limitations.
- Existing Safety Conditions – Evaluation of existing crash data highlighting key findings.
- Alternatives Evaluation – Evaluation of the safety performance for No-Build and Build alternatives.
- Summary Results – Summary of safety findings.
- Appendix - Raw data, detailed calculation sheets, and oversize figures.

Documentation for safety analysis should address the items in sufficient detail to show the data, analysis methods, and results in a manner that could be understood by readers. Documentation should also include figures, tables, and maps to better illustrate the analysis and conclusions.

7.1 Study Area

The study area should be presented in a manner that clearly identifies roadways and intersections included in the analysis. This can be presented in a table, text or a study area map. If certain areas are limited to qualitative analysis, this should be specified too. If any facilities were excluded for a specific reason, this should also be documented.

7.2 Analysis Years

The specific study years (e.g., existing, opening and design year) should be specified.

7.3 Analysis Method

The methods for analyzing each alternative should be explained, including why each method was selected and any variation of the methods that may have been used. The documentation should be sufficient for a reviewer to understand the approach to each analysis; detailed considerations and caveats should be presented with the analysis summary.

Critical information to document associated with each method is summarized in **Table 7-1.**

Table 7-1: Analysis Methods Information for Documentation

Method	Example Information to Document
Existing Conditions Analysis	• Provide examples of the types of analyses applied. • Agency specific ranking/identification criteria applied, if any. • State/ regional averages used for comparison, if any.
Crash Modification Factors	• Why the CMF method was selected. • Sources reviewed to identify potential CMFs.
Predictive Method	• Predictive or Empirical Bayes and why? • High level discussion of consistency of facility and traffic volumes with selected SPFs (e.g., are traffic volumes within the limits of the model); and assumptions in using the method. • Software and tool (e.g., ISATe, IHSDM, HSM Spreadsheets).

If the project evaluation methods are largely consistent with the HSM predictive method, or if CMFs were readily available and relatively easy to select, the methods documentation section can be relatively straightforward and brief. However, if the project safety analyses included a blending of methods, extensive assumptions, or engineering judgment, the safety analysis methods should explain the techniques used and the justification.

7.4 Data Collection

7.4.1 Crash Data

The documentation should be specific about the crash data source and the years of crash data included in the analysis. If when compiling the data, it became necessary to manipulate the data in any substantive way, this should be documented in the report as well. The crash data should be saved in the project files, but does not need to be included in the submitted project documentation.

7.4.2 Roadway Data

The predictive methods, as well as some CMFs, require detailed roadway characteristics information such as lane width, shoulder width, horizontal curve radius, presence and location of guard rail, or intersection control. Often, this information can be obtained from field investigations, online aerial photography, project as-builts, or preliminary designs of project alternatives. The project documentation should specify the sources and any caveats associated with this data.

7.4.3 Volume Data

The source and years of the traffic volume data – existing and future - should be reported. In addition, any data manipulations should be documented (e.g., converting peak-hour volumes to AADT or ADT volumes or interpolating AADT volumes to fill in a gap year needed for the study).

7.5 Existing Safety Conditions

The existing crash analysis should comprehensively consider and evaluate crashes by type, severity, contributing factor, mode, behavior, etc. However, not every component of the analysis will be included in the project documentation. The project documentation should itemize the analyses conducted, and provide a summary of the most relevant findings of the analysis. At a minimum, this will include:

- The total number of crashes;
- Crash severity information tabulated by the number of crash events and the number of participants;
- A mix of maps, tables or other graphics summarizing crashes (including location, severity and type);
- A comparison of crash frequency, severity or rate to FDOT averages;
- A discussion of crash locations that would benefit from safety improvements, if any, and why;
- A discussion of over-represented crash types, if any; and
- A discussion of the type of contributing factors in the study area and if/how these might be addressed through the proposed project.

The objective of the existing conditions analysis is to identify and document existing crash conditions and characteristics, identify locations or characteristics that show potential for safety improvement, and lay the foundation for identifying treatments to include in the alternatives development.

7.6 Alternatives Evaluation

The documentation for the Future Build and No-Build safety conditions should show how the specified methods were applied, present the results of the evaluation, and describe how the results influence the proposed project alternative(s).

7.6.1 Crash Modification Factors

If CMFs were applied, the documentation will itemize the CMFs associated with each safety treatment on the project. The documentation for the selected CMFs should include:

- CMFs considered and selected for each treatment;
- CMF Characteristics including: base condition, confidence interval (if available), and quality rating;
- Values of selected CMFs;
- Justification for selected CMFs; and
- Source of the CMFs considered and selected including FHWA CMF Clearinghouse CMF identification number.

The documentation should summarize, most likely in a table, the selected CMF and the results of applying the CMF to the proposed alternative(s). Text should describe the interpretation of results, any caveats, and recommendations based on the analysis.

7.6.2 Predictive Method

If the predictive method is applied to the Build or No-Build condition, the evaluation section should summarize the analysis, the results, and the interpretation and conclusions based on the analysis.

For each alternative evaluated (i.e., Build and No-Build alternative(s)), this section should:

- Document the predictive method applied and tools used to complete the analysis including SPFs used in the analysis (and their sources); source(s) of calibration factors and the year calibration was conducted; and software used in the analysis (e.g. ISATe, IHSDM, HSM Spreadsheets, etc.).
- Explain detailed assumptions needed to apply the analysis, rationale for the assumptions, and the potential implications to the results.
- Explain the segmentation process and/or study intersections sufficiently for a reviewer to verify the approach and understanding of segmentation.
- Present and explain the results of the analysis for all alternatives. The results of the analysis will likely be presented as a mix of tables, text and maps showing predicted/expected crashes. The results should be presented in summary; for larger projects, this section should also show how individual components (e.g., ramp terminal intersections, a critical intersection, a freeway weave section) will perform from a crash frequency or severity perspective. The documentation should compare the results of the analysis for each alternative and present the safety outcomes associated with the estimated future crash conditions.

7.6.3 Summary of Findings

The findings from existing conditions and each of the Build and No-Build scenarios should be summarized.

8 Examples

This section provides four examples to use as guides in conducting safety analysis:

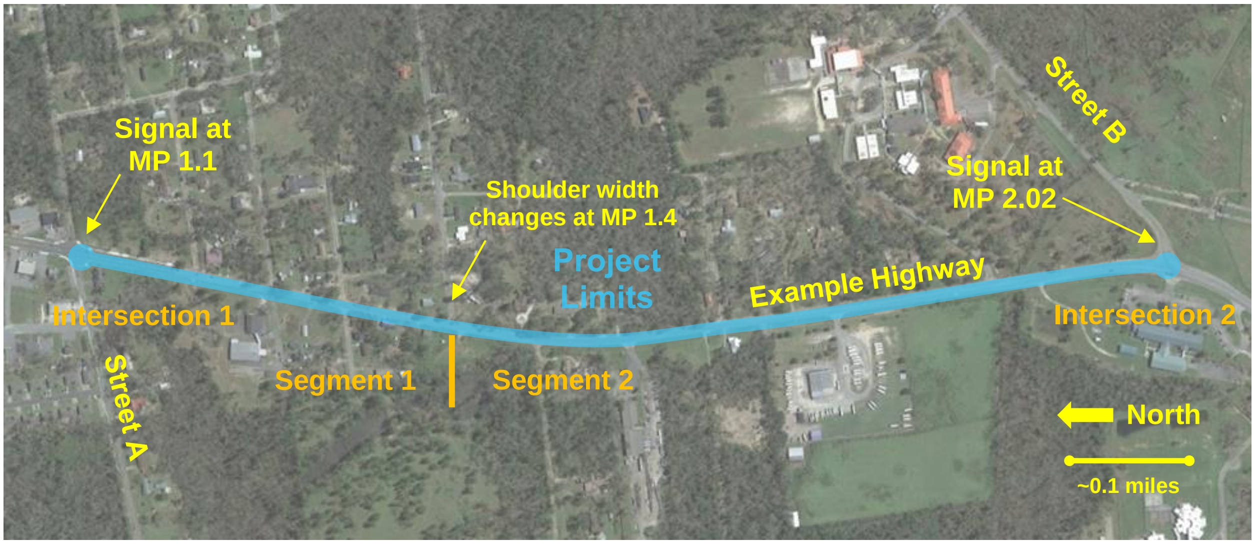
- Example 1: Widening a Two-Lane Rural Highway to Four Lanes – Build and No-Build Crashes
- Example 2: Adding a Median to an Urban Five-Lane Arterial with Two-Way Left Turn Lanes – Build and No-Build Crashes
- Example 3: Eliminating a Freeway Weaving Segment with a Collector-Distributor System – Build and No-Build Crashes
- Example 4: Adding a Median to an Urban Five-Lane Arterial with Two-Way Left Turn Lanes – Build Crashes and Crash Severity per Year with the Project

8.1 Example 1: Comparing the Safety Performance of No-Build and Build Alternatives for a Rural Two-Lane Widening Project

8.1.1 Background and Problem Statement

A PD&E Study is being conducted to evaluate widening a two-lane rural state highway to a four-lane divided highway with a 16-foot wide median and six-foot shoulders. The design speed is 35 miles per hour. The project limits are shown in **Figure 8-1** and extend from MP 1.1 to MP 2.02 on the Example Highway. The project has been proposed because the existing highway is often congested and the forecasted traffic demand exceeds the current capacity. There have also been several severe crashes in the corridor. In addition, the historical crash data evaluation showed that the existing crash rate is three times higher than the statewide average for comparable highways. Given this information, safety was included in the purpose and need for the project. As a result, it was necessary to quantitatively compare the predicted safety performance of the No-Build and Build alternatives.

Figure 8-1: Project Limits



8.1.2 Procedures and Calculations

Step 1: Determine Data Needs (HSM Steps 1 and 2)

During methodology development it was agreed that the future safety performance for the No-Build and Build alternatives would be compared using the 2022 (opening year) and 2042 (design year) predicted crash frequencies. The predictions would be developed using the Safety Performance Functions (SPFs) for rural two-lane and multilane highways from the Highway Safety Manual (HSM). The HSM Crash Modification Factors (which will be referred to as adjustment factors in future editions) would be used along with the relevant FDOT calibration factors. The Empirical Bayes (EB) method was not applicable for this evaluation, because the proposed project would change the typical section by adding new through lanes. The HSM Spreadsheets would be used to conduct the analysis. **Table 8-1** summarizes the proposed scope and methodology.

Table 8-1: Summary Scope and Methods

Feature	No-Build Condition	Build Condition
Study Area	Example Highway (MP 1.1 to MP 2.02)	Example Highway (MP 1.1 to MP 2.02)
Analysis Years	2022 and 2042	2022 and 2042
Roadway Type	Rural 2-lane (R2U)	Rural 4-Lane Divided (R4D)
SPFs	HSM Chapter 10 (R2U)	HSM Chapter 11 (R4D)
Software / Tools	FDOT MUTS Form 750-020-21A	FDOT MUTS Form 750-020-21B
Segment Length, L (miles)	0.92	0.92
Forecasted Segment AADT (Year)	12,000 (2022); 17,800 (2042) *	12,000 (2022); 20,000 (2042) *
Calibration Factors	1.00†	0.68†

**It is assumed that the No-Build AADT will be slightly lower than Build conditions.*

† ***FDOT Highway Safety Manual Website*** *(The most recent FDOT HSM calibration factors are posted on this website.)*

Step 2: Divide Locations into Homogeneous Segments or Intersections (HSM Steps 3, 4, 5, and 6)

The input data required for the No-Build analysis is presented in **Table 8-2**. The No-Build alternative has been segmented into two homogeneous segments due to the change in shoulder width at MP 1.4.

Table 8-2: No-Build Scenario Highway Input Data (Two Lane Rural Highway SPF)

Input Data Category	SPF Base Condition	Segment 1	Segment 2
Length (miles)	-	0.3	0.62
Lane Width (feet)	12	12	12
Shoulder Width (left/right in feet)	6/6	4/4	8/8
Shoulder Type (left/right in feet)	Paved/Paved	Paved/Paved	Paved/Paved
Length of Horizontal Curvature (mi)	None	None	0.15
Radius of Curvature (feet)	NA	NA	2,400
Spiral Transition Curve	NA	NA	NA
Superelevation Variance	NA	NA	NA
Grade (%)	0	0	0
Driveway Density (driveways/mile)	4	20	8
Centerline Rumble Strips	None	None	None
Passing Lanes	None	None	None
Two-way Left Turn Lane	None	None	None
Roadside Hazard Rating	3	3	3
Lighting	None	None	None
Automated Speed Enforcement	None	None	None

Table 8-3 presents the Build alternative input data. The SPF for rural multilane highways requires different inputs from the rural two-lane SPF. Since the typical section for the proposed new road is homogeneous throughout the limits of analysis, only one analysis segment is used.

Table 8-3: Build Scenario Highway Input Data (Rural Multilane Highway SPF)

Input Data Category	SPF Base Condition	Segment 1
Roadway Type (undivided/divided)	Undivided	Divided
Length (miles)	-	0.92
Lane Width (feet)	12	12
Shoulder Width† (feet)	8	6
Shoulder Type†	Paved	Paved
Median Width for Divided (feet)	30	16
Side Slope for Undivided	1:7 or flatter	Not Applicable‡
Lighting	None	Not Present
Automated Speed Enforcement	None	Not Present

† Right Shoulder Width for Divided *‡ This factor is not applicable to the divided highway SPF.*

Step 3 Identify and Apply the Appropriate SPF (HSM Steps 7, 8, 9, 10, 14, and 17)

Input data for each alternative is entered into the appropriate HSM spreadsheet which automatically calculates the SPFs and the CMFs where they differ from the baseline condition. For the No-Build condition the opening year data inputs are shown in **Table 8-4** and **Table 8-5** and for the Build condition the opening year data inputs are shown in **Table 8-6**. Detailed HSM input tables for both the opening and design year are included in **Table 8-14** through **Table 8-25**.

Table 8-4: Rural Two-Lane SPF Data Inputs – No-Build Segment 1

Worksheet 1A -- General Information and Input Data for Rural Two-Lane Two-Way Roadway Segments						
General Information		**Location Information**				
Analyst Agency or Company Date Performed	FDOT	Roadway Roadway Section Jurisdiction Analysis Year	Example Highway MP 1.10 to MP 1.40 Rural, FL 2022			
Input Data		**Base Conditions**	**Site Conditions**			
Length of segment, L (mi)		--	0.3			
AADT (veh/day)	$AADT_{MAX}$ = 17,800 (veh/day)	--	12,000			
Lane width (ft.)		12	12			
Shoulder width (ft.)		6	Right Shld:	4	Left Shld:	4
Shoulder type		Paved	Right Shld:	Paved	Left Shld:	Paved
Length of horizontal curve (mi)		0	0.0			
Radius of curvature (ft.)		0	0			
Spiral transition curve (present/not present)		Not Present	Not Present			
Superelevation variance (ft./ft.)		< 0.01	0			
Grade (%)		0	0			
Driveway density (driveways/mile)		5	20			
Centerline rumble strips (present/not present)		Not Present	Not Present			
Passing lanes [present (1 lane) /present (2 lane) / not present)]		Not Present	Not Present			
Two-way left-turn lane (present/not present)		Not Present	Not Present			
Roadside hazard rating (1-7 scale)		3	3			
Segment lighting (present/not present)		Not Present	Not Present			
Auto speed enforcement (present/not present)		Not Present	Not Present			
Calibration Factor, Cr		1	1.00			

Table 8-5: Rural Two-Lane SPF Data Inputs – No-Build Segment 2

Worksheet 1A -- General Information and Input Data for Rural Two-Lane Two-Way Roadway Segments						
General Information		**Location Information**				
Analyst		Roadway	Example Highway			
Agency or Company	FDOT	Roadway Section	MP 1.40 to MP 2.02			
Date Performed		Jurisdiction	Rural, FL			
		Analysis Year	2022			
Input Data		**Base Conditions**	**Site Conditions**			
Length of segment, L (mi)		--	0.62			
AADT (veh/day)	AADT$_{MAX}$ = 17,800 (veh/day)	--	12,000			
Lane width (ft.)		12	12			
Shoulder width (ft.)		6	Right Shld:	8	Left Shld:	8
Shoulder type		Paved	Right Shld:	Paved	Left Shld:	Paved
Length of horizontal curve (mi)		0	0.15			
Radius of curvature (ft.)		0	2400			
Spiral transition curve (present/not present)		Not Present	Not Present			
Superelevation variance (ft./ft.)		< 0.01	0			
Grade (%)		0	0			
Driveway density (driveways/mile)		5	8			
Centerline rumble strips (present/not present)		Not Present	Not Present			
Passing lanes [present (1 lane) /present (2 lane) / not present)]		Not Present	Not Present			
Two-way left-turn lane (present/not present)		Not Present	Not Present			
Roadside hazard rating (1-7 scale)		3	3			
Segment lighting (present/not present)		Not Present	Not Present			
Auto speed enforcement (present/not present)		Not Present	Not Present			
Calibration Factor, Cr		1	1.00			

Table 8-6: Rural Multilane SPF Data Inputs – Build Segment

Worksheet 1A -- General Information and Input Data for Rural Multilane Roadway Segments			
General Information		**Location Information**	
Analyst		Roadway	Example Highway
Agency or Company	FDOT	Roadway Section	MP 1.10 to MP 2.02
Date Performed		Jurisdiction	Rural, FL
		Analysis Year	2022
Input Data		**Base Conditions**	**Site Conditions**
Roadway type (divided / undivided)		Undivided	Divided
Length of segment, L (mi)		--	0.92
AADT (veh/day)	AADT$_{MAX}$ = 89,300 (veh/day)	--	12,000
Lane width (ft.)		12	12
Shoulder width (ft.) - right shoulder width for divided [if differ for directions of travel, use average width]		8	6
Shoulder type - right shoulder type for divided		Paved	Paved
Median width (ft.) - for divided only		30	20
Side Slopes - for undivided only		1:7 or flatter	
Lighting (present/not present)		Not Present	Not Present
Auto speed enforcement (present/not present)		Not Present	Not Present
Calibration Factor, Cr		1.00	0.68

Step 4 Apply CMFs to Calculated SPF Values (HSM Steps 10)

The HSM spreadsheets use the input data to calculate the necessary CMFs for each SPF. For the No-Build conditions, the CMFs are presented in **Table 8-7** and **Table 8-8**. For Segment 1 the shoulder width and driveway density increase the predicted crashes by a combined 23.3% (column 13). For Segment 2 the shoulder width reduces the predicted crashes compared to the baseline, while the horizontal curve and driveway density increase the predicted crashes, for a combined increase of 8.7% (column 13).

Table 8-7: Rural Two-Lane Adjustment Factors – No-Build Segment 1

Worksheet 1B -- Crash Modification Factors for Rural Two-Lane Two-Way Roadway Segments												
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
CMF for Lane Width	CMF for Shoulder Width and Type	CMF for Horizontal Curves	CMF for Super-elevation	CMF for Grades	CMF for Driveway Density	CMF for Centerline Rumble Strips	CMF for Passing Lanes	CMF for Two-Way Left-Turn Lane	CMF for Roadside Design	CMF for Lighting	CMF for Automated Speed Enforcement	Combined CMF
CMF 1r	*CMF 2r*	*CMF 3r*	*CMF 4r*	*CMR 5r*	*CMF 6r*	*CMF 7r*	*CMF 8r*	*CMF 9r*	*CMF 10r*	*CMF 11r*	*CMF 12r*	*CMF*
from Equation 10-11	from Equation 10-12	from Equation 10-13	from Equations 10-14, 10-15, or 10-16	from Table 10-11	from Equation 10-17	from Section 10.7.1	from Section 10.7.1	from Equation 10-18 & 10-19	from Equation 10-20	from Equation 10-21	from Section 10.7.1	(1)x(2)x … x(11)x(12)
1.00	1.09	1.00	1.00	1.00	1.14	1.00	1.00	1.00	1.00	1.00	1.00	1.233

Table 8-8: Rural Two-Lane Adjustment Factors – No-Build Segment 2

Worksheet 1B -- Crash Modification Factors for Rural Two-Lane Two-Way Roadway Segments												
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
CMF for Lane Width	CMF for Shoulder Width and Type	CMF for Horizontal Curves	CMF for Super-elevation	CMF for Grades	CMF for Driveway Density	CMF for Centerline Rumble Strips	CMF for Passing Lanes	CMF for Two-Way Left-Turn Lane	CMF for Roadside Design	CMF for Lighting	CMF for Automated Speed Enforcement	Combined CMF
CMF 1r	*CMF 2r*	*CMF 3r*	*CMF 4r*	*CMR 5r*	*CMF 6r*	*CMF 7r*	*CMF 8r*	*CMF 9r*	*CMF 10r*	*CMF 11r*	*CMF 12r*	*CMF*
from Equation 10-11	from Equation 10-12	from Equation 10-13	from Equations 10-14, 10-15, or 10-16	from Table 10-11	from Equation 10-17	from Section 10.7.1	from Section 10.7.1	from Equation 10-18 & 10-19	from Equation 10-20	from Equation 10-21	from Section 10.7.1	(1)x(2)x … x(11)x(12)
1.00	0.93	1.14	1.00	1.00	1.03	1.00	1.00	1.00	1.00	1.00	1.00	1.087

The CMFs for the Build conditions **(Table 8-9)** show the shoulder width and median width increase the predicted crashes by a combined increase of 6% (column 6).

Table 8-9: Rural Multilane Adjustment Factors – Build Segment

Worksheet 1B (a) -- Crash Modification Factors for Rural Multilane Divided Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
CMF for Lane Width	CMF for Right Shoulder Width	CMF for Median Width	CMF for Lighting	CMF for Automated Speed Enforcement	Combined CMF
CMF 1rd	CMF 2rd	CMF 3rd	CMF 4rd	CMF 5rd	CMF comb
from Equation 11-16	from Table 11-17	from Table 11-18	from Equation 11-17	from Section 11.7.2	(1)*(2)*(3)*(4)*(5)
1.00	1.04	1.02	1.00	1.00	1.06

Step 5 Apply Local Calibration Factors (HSM Step 11)

The FDOT calibration factors are 1.0 for the rural two-lane SPF and 0.68 for the rural multilane SPF. The updated FDOT calibration factors are maintained on the FDOT website, and should always be consulted for use in safety analysis.

Step 6 - Repeat Process for Other Years (HSM Step 12)

The predictive analysis is repeated for the No-Build and Build scenarios for 2042. The only factor that changes for the 2042 analysis is the volume. The results of the 2042 analysis are presented in Step 8. Detailed analysis tables for both opening and design year conditions are included in **Appendix A**.

Step 7 - Apply Empirical Bayes When Applicable (HSM Steps 13, 15)

This step is not applicable because of the major proposed change to the typical section.

Step 8 - Evaluate Results (HSM Step 16 and 18)

The results of the No-Build and Build alternatives analyses are examined and compared. Because a calibration factor was applied, the comparison can be presented as a change in crash frequency and a percentage change in crashes.

The 2022 and 2042 predicted crashes are summarized in **Table 8-10**. For reference, the HSM spreadsheets showing the 2022 predicted No-Build and Build crashes are presented in **Table 8-11**, **Table 8-12**, and **Table 8-13**. Detailed HSM output tables for opening and design year are included in **Table 8-14** through **Table 8-25**.

Table 8-10: Predicted Average Crash Frequency

Analysis Year	Crash Severity Level	No- Build Alternative			Build Alternative	Crash Reduction	Percent Change
		Segment 1	Segment 2	Segment 1 and 2			
2022	Total	1.186	2.161	3.347	1.519	1.828	-55%
	Fatal and Injury (FI)	0.381	0.694	1.075	0.780	0.295	-27%
	Property Damage Only (PDO)	0.805	1.467	2.272	0.739	1.533	-67%
2042*	Total	1.625	3.151	4.776	2.595	2.181	-46%
	Fatal and Injury (FI)	0.522	1.012	1.534	1.272	0.262	-17%
	Property Damage Only (PDO)	1.104	2.140	3.244	0.772	2.472	-76%

**AADT for Design Year (2042) No-Build and Build conditions is assumed to differ due to roadway capacity and speeds.*

Table 8-11: Rural Two-Lane Predicted Crash Frequency – No-Build Segment 1

Worksheet 1C -- Roadway Segment Crashes for Rural Two-Lane Two-Way Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**N spf rs**	**Overdispersion Parameter, k**	**Crash Severity Distribution**	**N spf rs by Severity Distribution**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted average crash frequency, N predicted rs (crashes/year)**
	from Equation 10-6	from Equation 10-7	from Table 10-3 (proportion)	(2)TOTAL x (4)	(13) from Worksheet 1B		(5)x(6)x(7)
Total	0.962	0.79	1.000	0.962	1.23	1.00	1.186
Fatal and Injury (FI)	--	--	0.321	0.309	1.23	1.00	0.381
Property Damage Only (PDO)	--	--	0.679	0.653	1.23	1.00	0.805

Table 8-12: Rural Two-Lane Predicted Crash Frequency – No-Build Segment 2

Worksheet 1C -- Roadway Segment Crashes for Rural Two-Lane Two-Way Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**N spf rs**	**Overdispersion Parameter, k**	**Crash Severity Distribution**	**N spf rs by Severity Distribution**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted average crash frequency, N predicted rs (crashes/year)**
	from Equation 10-6	from Equation 10-7	from Table 10-3 (proportion)	(2)TOTAL x (4)	(13) from Worksheet 1B		(5)x(6)x(7)
Total	1.988	0.38	1.000	1.988	1.09	1.00	2.161
Fatal and Injury (FI)	--	--	0.321	0.638	1.09	1.00	0.694
Property Damage Only (PDO)	--	--	0.679	1.350	1.09	1.00	1.467

Table 8-13: Rural Multilane 2022 Predicted Crash Frequency – Build Segment

Worksheet 1C (a) -- Roadway Segment Crashes for Rural Multilane Divided Roadway Segments								
(1)	(2)			(3)	(4)	(5)	(6)	(7)
Crash Severity Level	**SPF Coefficients**			**N spf rd**	**Overdispersion Parameter, k**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted average crash frequency, N predicted rs(d)**
	from Table 11-5					(6) from Worksheet 1B (a)		
	a	b	c	from Equation 11-9	from Equation 11-10			(3)*(5)*(6)
Total	-9.025	1.049	1.549	2.105	0.231	1.06	0.68	1.519
Fatal and Injury (FI)	-8.837	0.958	1.687	1.081	0.201	1.06	0.68	0.780
Fatal and Injury[a] (FI[a])	-8.505	0.874	1.740	0.684	0.191	1.06	0.68	0.494
Property Damage Only (PDO)	--	--	--	--	--	--	--	$(7)_{TOTAL} - (7)_{FI}$ 0.739

NOTE: [a] Using the KABCO scale, these include only KAB crashes. Crashes with severity level C (possible injury) are not included.

The summary for both alternatives and analysis years are presented in **Table 8-10**. As shown, the proposed Build project is predicted to decrease the predicted total crashes by 55% in the opening year and 46% in the design year with an annual decrease of 1.8 crashes in the first year and 2.2 crashes in the design year. The reduction in fatal and injury crashes (opening year: 27%, design year: 17%) is lower than the reduction in property damage crashes (opening year: 67%, design year: 76%). It is important to consider the forecasted difference in exposure in the design year conditions (No-Build AADT = 17,800, Build AADT = 20,000), this would result in the No-Build crashes potentially being under represented as the 2,200 daily vehicles would be elsewhere on the highway network. Therefore, the crash reduction benefit of the Build condition may be greater than shown. A comparison of the design year crash rates also demonstrates the benefit of the project as the No-Build condition would have a crash rate of 79.9 crashes per 100 million vehicle miles, while the Build condition would have a crash rate of 38.6 crashes per 100 million vehicle miles, a reduction of 52%. This analysis would support that the proposed design addresses the purpose and need of the project with respect to safety performance of the facility.

SUPPLEMENTARY HSM SPREADSHEET INPUT/OUTPUT TABLES

Opening Year (2022) Inputs

Table 8-14: Rural Two-Lane SPF Data Inputs – No-Build Segment 1

Worksheet 1A -- General Information and Input Data for Rural Two-Lane Two-Way Roadway Segments						
General Information		**Location Information**				
Analyst		Roadway		Example Highway		
Agency or Company	FDOT	Roadway Section		MP 1.10 to MP 1.40		
Date Performed		Jurisdiction		Rural, FL		
		Analysis Year		2022		
Input Data		**Base Conditions**	**Site Conditions**			
Length of segment, L (mi)		--	0.3			
AADT (veh/day)	$AADT_{MAX}$ = 17,800 (veh/day)	--	12,000			
Lane width (ft.)		12	12			
Shoulder width (ft.)		6	Right Shld:	4	Left Shld:	4
Shoulder type		Paved	Right Shld:	Paved	Left Shld:	Paved
Length of horizontal curve (mi)		0	0.0			
Radius of curvature (ft.)		0	0			
Spiral transition curve (present/not present)		Not Present	Not Present			
Superelevation variance (ft./ft.)		< 0.01	0			
Grade (%)		0	0			
Driveway density (driveways/mile)		5	20			
Centerline rumble strips (present/not present)		Not Present	Not Present			
Passing lanes [present (1 lane) /present (2 lane) / not present)]		Not Present	Not Present			
Two-way left-turn lane (present/not present)		Not Present	Not Present			
Roadside hazard rating (1-7 scale)		3	3			
Segment lighting (present/not present)		Not Present	Not Present			
Auto speed enforcement (present/not present)		Not Present	Not Present			
Calibration Factor, Cr		1	1.00			

Table 8-15: Rural Two-Lane SPF Data Inputs – No-Build Segment 2

Worksheet 1A -- General Information and Input Data for Rural Two-Lane Two-Way Roadway Segments						
General Information		**Location Information**				
Analyst Agency or Company Date Performed	FDOT	Roadway Roadway Section Jurisdiction Analysis Year	Example Highway MP 1.40 to MP 2.02 Rural, FL 2022			
Input Data		**Base Conditions**	**Site Conditions**			
Length of segment, L (mi)		--	0.62			
AADT (veh/day)	AADT$_{MAX}$ = 17,800 (veh/day)	--	12,000			
Lane width (ft.)		12	12			
Shoulder width (ft.)		6	Right Shld:	8	Left Shld:	8
Shoulder type		Paved	Right Shld:	Pave d	Left Shld:	Pave d
Length of horizontal curve (mi)		0	0.2			
Radius of curvature (ft.)		0	2400			
Spiral transition curve (present/not present)		Not Present	Not Present			
Superelevation variance (ft./ft.)		< 0.01	0			
Grade (%)		0	0			
Driveway density (driveways/mile)		5	8			
Centerline rumble strips (present/not present)		Not Present	Not Present			
Passing lanes [present (1 lane) /present (2 lane) / not present)]		Not Present	Not Present			
Two-way left-turn lane (present/not present)		Not Present	Not Present			
Roadside hazard rating (1-7 scale)		3	3			
Segment lighting (present/not present)		Not Present	Not Present			
Auto speed enforcement (present/not present)		Not Present	Not Present			
Calibration Factor, Cr		1	1.00			

Table 8-16: Rural Multilane SPF Data Inputs – Build Segment

Worksheet 1A -- General Information and Input Data for Rural Multilane Roadway Segments			
General Information		**Location Information**	
Analyst Agency or Company Date Performed	FDOT	Roadway Roadway Section Jurisdiction Analysis Year	Example Highway MP 1.10 to MP 2.02 Rural, FL 2022
Input Data		**Base Conditions**	**Site Conditions**
Roadway type (divided / undivided)		Undivided	Divided
Length of segment, L (mi)		--	0.92
AADT (veh/day)	AADT$_{MAX}$ = 89,300 (veh/day)	--	12,000
Lane width (ft.)		12	12
Shoulder width (ft.) - right shoulder width for divided [if differ for directions of travel, use average width]		8	6
Shoulder type - right shoulder type for divided		Paved	Paved
Median width (ft.) - for divided only		30	20
Side Slopes - for undivided only		1:7 or flatter	
Lighting (present/not present)		Not Present	Not Present
Auto speed enforcement (present/not present)		Not Present	Not Present
Calibration Factor, Cr		1.00	0.68

Design Year (2042) Inputs

Table 8-17: Rural Two-Lane SPF Data Inputs – No-Build Segment 1

Worksheet 1A -- General Information and Input Data for Rural Two-Lane Two-Way Roadway Segments							
General Information		**Location Information**					
Analyst Agency or Company Date Performed	FDOT	Roadway Roadway Section Jurisdiction Analysis Year		Example Highway MP 1.10 to MP 1.40 Rural, FL 2042			
Input Data		**Base Conditions**	**Site Conditions**				
Length of segment, L (mi)		--	0.3				
AADT (veh/day)	$AADT_{MAX}$ = 17,800 (veh/day)	--	17,800				
Lane width (ft.)		12	12				
Shoulder width (ft.)		6	Right Shld:	4	Left Shld:	4	
Shoulder type		Paved	Right Shld:	Pave d	Left Shld:	Pave d	
Length of horizontal curve (mi)		0	0.0				
Radius of curvature (ft.)		0	0				
Spiral transition curve (present/not present)		Not Present	Not Present				
Superelevation variance (ft./ft.)		< 0.01	0				
Grade (%)		0	0				
Driveway density (driveways/mile)		5	20				
Centerline rumble strips (present/not present)		Not Present	Not Present				
Passing lanes [present (1 lane) /present (2 lane) / not present)]		Not Present	Not Present				
Two-way left-turn lane (present/not present)		Not Present	Not Present				
Roadside hazard rating (1-7 scale)		3	3				
Segment lighting (present/not present)		Not Present	Not Present				
Auto speed enforcement (present/not present)		Not Present	Not Present				
Calibration Factor, Cr		1	1.00				

Table 8-18: Rural Two-Lane SPF Data Inputs – No-Build Segment 2

Worksheet 1A -- General Information and Input Data for Rural Two-Lane Two-Way Roadway Segments						
General Information		**Location Information**				
Analyst Agency or Company Date Performed	FDOT	Roadway Roadway Section Jurisdiction Analysis Year		Example Highway MP 1.40 to MP 2.02 Rural, FL 2042		
Input Data		**Base Conditions**	**Site Conditions**			
Length of segment, L (mi)		--	0.62			
AADT (veh/day)	AADT$_{MAX}$ = 17,800 (veh/day)	--	17,800			
Lane width (ft.)		12	12			
Shoulder width (ft.)		6	Right Shld:	8	Left Shld:	8
Shoulder type		Paved	Right Shld:	Paved	Left Shld:	Paved
Length of horizontal curve (mi)		0	0.2			
Radius of curvature (ft.)		0	2400			
Spiral transition curve (present/not present)		Not Present	Not Present			
Superelevation variance (ft./ft.)		< 0.01	0			
Grade (%)		0	0			
Driveway density (driveways/mile)		5	8			
Centerline rumble strips (present/not present)		Not Present	Not Present			
Passing lanes [present (1 lane) /present (2 lane) / not present)]		Not Present	Not Present			
Two-way left-turn lane (present/not present)		Not Present	Not Present			
Roadside hazard rating (1-7 scale)		3	3			
Segment lighting (present/not present)		Not Present	Not Present			
Auto speed enforcement (present/not present)		Not Present	Not Present			
Calibration Factor, Cr		1	1.00			

Table 8-19: Rural Multilane SPF Data Inputs – Build Segment

Worksheet 1A -- General Information and Input Data for Rural Multilane Roadway Segments			
General Information		**Location Information**	
Analyst Agency or Company Date Performed	FDOT	Roadway Roadway Section Jurisdiction Analysis Year	Example Highway MP 1.10 to MP 2.02 Rural, FL 2042
Input Data		**Base Conditions**	**Site Conditions**
Roadway type (divided / undivided)		Undivided	Divided
Length of segment, L (mi)		--	0.92
AADT (veh/day)	AADT$_{MAX}$ = 89,300 (veh/day)	--	20,000
Lane width (ft.)		12	12
Shoulder width (ft.) - right shoulder width for divided [if differ for directions of travel, use average width]		8	6
Shoulder type - right shoulder type for divided		Paved	Paved
Median width (ft.) - for divided only		30	20
Side Slopes - for undivided only		1:7 or flatter	
Lighting (present/not present)		Not Present	Not Present
Auto speed enforcement (present/not present)		Not Present	Not Present
Calibration Factor, Cr		1.00	0.68

Opening Year (2022) Outputs

Table 8-20: Rural Two-Lane Predicted Crash Frequency – No-Build Segment 1

Worksheet 1C -- Roadway Segment Crashes for Rural Two-Lane Two-Way Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**Nspfrs**	**Overdispersion Parameter, k**	**Crash Severity Distribution**	**N spf rs by Severity Distribution**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted average crash frequency, N predicted rs (crashes/year)**
	from Equation 10-6	from Equation 10-7	from Table 10-3 (proportion)	(2)TOTAL x (4)	(13) from Worksheet 1B		(5)x(6)x(7)
Total	0.962	0.79	1.000	0.962	1.23	1.00	1.186
Fatal and Injury (FI)	--	--	0.321	0.309	1.23	1.00	0.381
Property Damage Only (PDO)	--	--	0.679	0.653	1.23	1.00	0.805

Table 8-21: Rural Two-Lane Predicted Crash Frequency – No-Build Segment 2

Worksheet 1C -- Roadway Segment Crashes for Rural Two-Lane Two-Way Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**Nspfrs**	**Overdispersion Parameter, k**	**Crash Severity Distribution**	**N spf rs by Severity Distribution**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted average crash frequency, N predicted rs (crashes/year)**
	from Equation 10-6	from Equation 10-7	from Table 10-3 (proportion)	(2)TOTAL x (4)	(13) from Worksheet 1B		(5)x(6)x(7)
Total	1.988	0.38	1.000	1.988	1.09	1.00	2.161
Fatal and Injury (FI)	--	--	0.321	0.638	1.09	1.00	0.694
Property Damage Only (PDO)	--	--	0.679	1.350	1.09	1.00	1.467

Table 8-22: Rural Multilane 2022 Predicted Crash Frequency – Build Segment

Worksheet 1C (a) -- Roadway Segment Crashes for Rural Multilane Divided Roadway Segments								
(1)	(2)			(3)	(4)	(5)	(6)	(7)
Crash Severity Level	**SPF Coefficients** from Table 11-5			**Nspf rd**	**Overdispersion Parameter, k**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted average crash frequency, N predicted rs(d)**
	a	b	c	from Equation 11-9	from Equation 11-10	(6) from Worksheet 1B (a)		(3)*(5)*(6)
Total	-9.025	1.049	1.549	2.105	0.231	1.06	0.68	1.519
Fatal and Injury (FI)	-8.837	0.958	1.687	1.081	0.201	1.06	0.68	0.780
Fatal and Injury[a] (FI[a])	-8.505	0.874	1.740	0.684	0.191	1.06	0.68	0.494
Property Damage Only (PDO)	--	--	--	--	--	--	--	(7)TOTAL - (7)FI 0.739

NOTE: [a] Using the KABCO scale, these include only KAB crashes. Crashes with severity level C (possible injury) are not included.

Design Year (2042) Outputs

Table 8-23: Rural Two-Lane Predicted Crash Frequency – No-Build Segment 1

Worksheet 1C -- Roadway Segment Crashes for Rural Two-Lane Two-Way Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**N spf rs**	**Overdispersion Parameter, k**	**Crash Severity Distribution**	**N spf rs by Severity Distribution**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted average crash frequency, N predicted rs (crashes/year)**
	from Equation 10-6	from Equation 10-7	from Table 10-3 (proportion)	(2)TOTAL x (4)	(13) from Worksheet 1B		(5)x(6)x(7)
Total	1.427	0.79	1.000	1.427	1.14	1.00	1.625
Fatal and Injury (FI)	--	--	0.321	0.458	1.14	1.00	0.522
Property Damage Only (PDO)	--	--	0.679	0.969	1.14	1.00	1.104

Table 8-24: Rural Two-Lane Predicted Crash Frequency – No-Build Segment 2

Worksheet 1C -- Roadway Segment Crashes for Rural Two-Lane Two-Way Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**N spf rs**	**Overdispersion Parameter, k**	**Crash Severity Distribution**	**N spf rs by Severity Distribution**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted average crash frequency, N predicted rs (crashes/year)**
	from Equation 10-6	from Equation 10-7	from Table 10-3 (proportion)	(2)TOTAL x (4)	(13) from Worksheet 1B		(5)x(6)x(7)
Total	2.949	0.38	1.000	2.949	1.07	1.00	3.151
Fatal and Injury (FI)	--	--	0.321	0.946	1.07	1.00	1.012
Property Damage Only (PDO)	--	--	0.679	2.002	1.07	1.00	2.140

Table 8-25: Rural Multilane 2042 Predicted Crash Frequency – Build Segment

Worksheet 1C (a) -- Roadway Segment Crashes for Rural Multilane Divided Roadway Segments								
(1)	(2)			(3)	(4)	(5)	(6)	(7)
Crash Severity Level	**SPF Coefficients**			**N spf rd**	**Overdispersion Parameter, k**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted average crash frequency, N predicted rs(d)**
	from Table 11-5							
	a	b	c	from Equation 11-9	from Equation 11-10	(6) from Worksheet 1B (a)		(3)*(5)*(6)
Total	-9.025	1.049	1.549	3.598	0.231	1.06	0.68	2.595
Fatal and Injury (FI)	-8.837	0.958	1.687	1.763	0.201	1.06	0.68	1.272
Fatal and Injury[a] (FI[a])	-8.505	0.874	1.740	1.070	0.191	1.06	0.68	0.772
Property Damage Only (PDO)	--	--	--	--	--	--	--	$(7)_{TOTAL} - (7)_{FI}$ 1.323

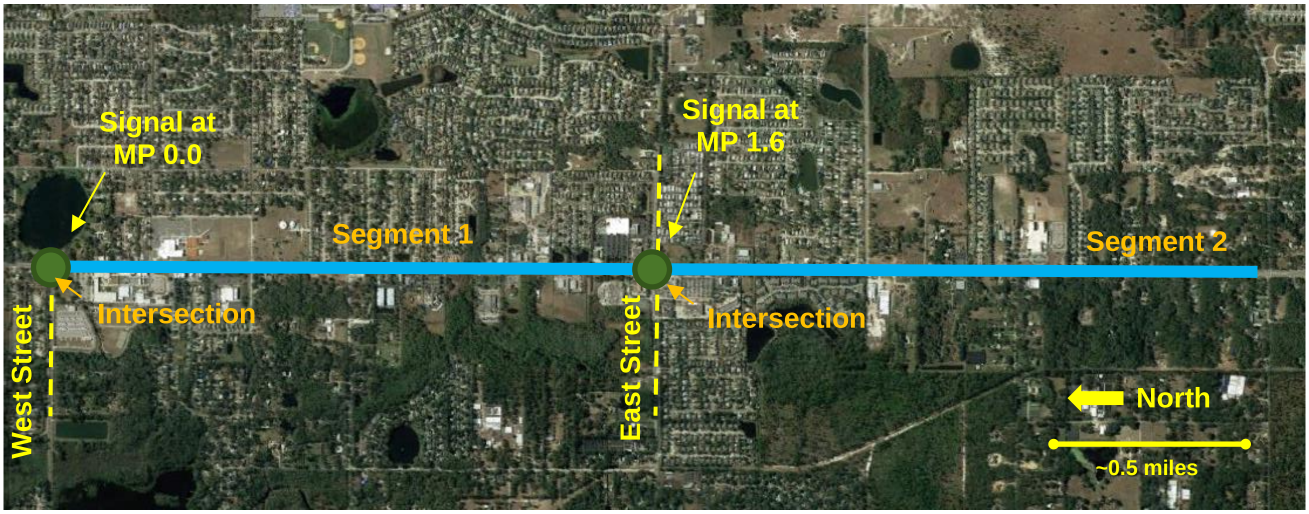
NOTE: [a] Using the KABCO scale, these include only KAB crashes. Crashes with severity level C (possible injury) are not included.

8.2 Example 2: Comparing the Safety Performance of No-Build and Build Alternatives for an Urban Arterial Project

8.2.1 Background and Problem Statement

A PD&E Study is being conducted to evaluate the impacts of installing a raised median along a five-lane urban arterial that currently has a two-way left-turn lane (TWLTL). The project covers 3.2-miles on an arterial in a typical suburban town of Central Florida. The project limits are shown in **Figure 8-2**. Under No-Build conditions, the road has four-lanes with a TWLTL, a 3-leg signalized intersection on the western project limit, and a 4-leg signalized intersection directly in the middle of the project. The current posted speed is 40 mph on Segment 1 and 45 mph on Segment 2. The proposed Build alternative would install a raised median the full length of the corridor. The intersections would not be modified. The project is being proposed because the corridor experiences many left turn crashes at driveways as well as median cross-over crashes. Safety has been included in the purpose and need statement for the project. Safety performance of the project will be estimated using the HSM predictive method for urban and suburban arterials.

Figure 8-2: Project Limits



8.2.2 Procedures and Calculations

Step 1 - Determine Data Needs (HSM Steps 1 and 2)

During methodology development it was agreed that the HSM predictive method for urban and suburban arterials would be used to estimate safety performance for the No-Build and Build alternatives in the 2020 (opening year) and 2040 (design year). For this example, the No-Build condition is a five-lane arterial including a center TWLTL; a 5T facility as defined in the HSM. The Build condition would convert the facility to a four-lane divided highway; a 4D facility as defined in the HSM.

The HSM method will be implemented using the FDOT Manual of Uniform Traffic Studies Form Number 750-020-21C.[4] The Safety Performance Function (SPF) for Urban and Suburban Roadway

[4] Link to FDOT HSM spreadsheets: https://www.fdot.gov/traffic/trafficservices/studies/muts/muts.shtm

Segments and Intersections applies four SPF's based on the location and type of crash. The HSM Crash Modification Factors (CMFs) will be used along with the relevant FDOT calibration factors to complete the predictive methodology. The Empirical Bayes (EB) method was not used for this evaluation, because the proposed project would change the typical section, leading to the use of different SPFs for the two alternatives. **Table 8-26** summarizes the proposed scope and methodology details.

Table 8-26: Summary Scope and Methods

Feature	No-Build Condition	Build Condition
Study Area	Example Arterial (MP 0.0 to MP 3.2)	Example Arterial (MP 0.0 to MP 3.2)
Analysis Years	2020 and 2040	2020 and 2040
Roadway Type	Urban 5-Lane with TWLTL (5T)	Urban 4-Lane (4D)
Intersections	Int1: Signalized 3Leg (3SG) Int2: Signalized 4our-leg (4SG)	Int1: Signalized 3Leg (3SG) Int2: Signalized 4our-leg (4SG)
SPFs	HSM Chapter 12 (5T)	HSM Chapter 12 (4D)
Software / Tools	FDOT MUTS Form 750-020-21C	FDOT MUTS Form 750-020-21C
Segment Length, L (miles)	3.2	3.2
Forecasted Segment AADT (Year)	24,000 (2020) 33,600 (2040)	24,000 (2020) 33,600 (2040)

Step 2 - Divide Locations into Homogeneous Segments or Intersections (HSM Steps 3, 4, 5, and 6)

The input data required for the No-Build and Build segment analyses is presented in **Table 8-27**. Intersection 2 divides the corridor into two homogenous segments. Input data for the intersections is provided in **Table 8-28**.

Table 8-27: No-Build and Build Alternatives – 2020 and 2040 Segment Input Data

Input Data Category	SPF Base Condition	Segment 1		Segment 2	
		No-Build	Build	No-Build	Build
Roadway Type	--	5-Lane Urban (5T)	4-Lane Divided (4D)	5-Lane Urban (5T)	4-Lane Divided (4D)
Length (mile)	--	1.6	1.6	1.6	1.6
AADT (veh/day)	--	2020 = 24,000 2040 = 33,600		2020 = 24,000 2040 = 33,600	
On-Street Parking (Type/ %)	None/ 0%	None/ 0%		None/ 0%	
Median Width (ft) – divided only	15	Not Present	15	Not Present	15
Lighting (present/not present)	Not Present	Present	Present	Present	Present
Auto Speed Enforcement	Not Present	Not Present	Not Present	Not Present	Not Present
Major Commercial Driveways (number)	--	5	5	3	3
Minor Commercial Driveways (number)	--	25	25	18	18
Major Industrial/Institutional Driveways (number)	--	0	0	1	1
Minor Industrial/Institutional Driveways (number)	--	15	15	6	6
Major Residential Driveways (number)	--	5	5	4	4
Minor Residential Driveways (number)	--	10	10	3	3
Other Driveways (number)	--	0	0	0	0
Posted Speed (mph)	--	40	40	45	45
Roadside Fixed Objects per Mile (number)	0	20	20	12	12
Offset to Roadside Fixed Objects (ft)		10	10	10	10
Calibration Factor		0.7†	1.63†	0.7†	1.63†

† *FDOT Highway Safety Manual Website (The most recent FDOT HSM calibration factors are posted on this website.)*

Table 8-28: No-Build and Build Alternatives – 2020 and 2040 Signalized Intersection Input Data (Urban Arterial SPF)

Input Data Category	SPF Base Condition	Intersection 1	Intersection 2
Intersection Type	--	3-Leg Signalized (3SG)	4-Leg Signalized (4SG)
AADT Major (veh/day)	--	2020 = 24,000 2040 = 33,600	2020 = 24,000 2040 = 33,600
AADT Minor (veh/day)	--	2020 = 7,900 2040 = 11,100	2020 = 9,000 2040 = 12,600
Intersection Lighting	Not Present	Not Present	Not Present
Calibration Factor	1.00	1.56†	1.00†
Number of Approaches with Left-turn lanes	0	2	4
Number of Approaches with Right -turn Lanes	0	2	4
Number of Approaches with Left-turn Phasing	--	2	4
Type of Left-turn Phasing for Leg #1	Permissive	Protected / Permissive	Protected / Permissive
Type of Left-turn Phasing for Leg #2	--	Permissive	Protected / Permissive
Type of Left-turn Phasing for Leg #3	--	n/a	Permissive
Type of Left-turn Phasing for Leg #4	--	n/a	Permissive
Sum of All Pedestrian Crossing Volumes	--	10	10
Maximum Number of Lanes Crossed by Pedestrian	0	5	5

† *FDOT Highway Safety Manual Website (The most recent FDOT HSM calibration factors are posted on this website.)*

Step 3 - Identify and Apply the Appropriate SPF (HSM Steps 7, 8 9, 10, 14, and 17)

On arterial segments, crashes are predicted as a function of three separate components: roadway segment crashes, vehicle-pedestrian crashes, and vehicle-bike crashes. Two separate SPFs are used to predict crashes on a roadway segment: one for single vehicle crashes and one for multiple vehicle crashes. Subsequently, all five individual components are summed together to predict the total crash frequency for a roadway segment.

The SPFs are applied by entering the data for each scenario into the FDOT HSM forms, using the segment and intersection sheets. The form automatically calculates the SPFs and sums the predicted crashes. **Table 8-29** and **Table 8-30** show the 2020 No-Build Alternative segment inputs and **Table 8-31** and **Table 8-32** show the 2020 Build Alternative segment inputs. The 2020 intersection data inputs are shown in **Table 8-33** and **Table 8-34**. *As the intersection data is unchanged between the No-Build and Build Alternatives only the No-Build intersection input tables is presented. The 2040 input sheets are identical to the 2020 input sheets with the exception of the traffic volume data; therefore, they are not presented.*

Table 8-29: Urban Multi-lane SPF Data Inputs – No-Build Segment 1

Worksheet 1A -- General Information and Input Data for Urban and Suburban Roadway Segments			
General Information		**Location Information**	
Analyst		Roadway	Example Arterial
Agency or Company	FDOT	Roadway Section	MP 0.0 to MP 1.6
Date Performed	05/09/19	Jurisdiction	Suburban, FL
		Analysis Year	2020
Input Data		**Base Conditions**	**Site Conditions**
Roadway type (2U, 3T, 4U, 4D, 5T)		--	5T
Length of segment, L (mi)		--	1.6
AADT (veh/day)	$AADT_{MAX}$ = 53,800 (veh/day)	--	24,000
Type of on-street parking (none/parallel/angle)		None	None
Proportion of curb length with on-street parking		--	0
Median width (ft.) - for divided only		15	Not Present
Lighting (present / not present)		Not Present	Present
Auto speed enforcement (present / not present)		Not Present	Not Present
Major commercial driveways (number)		--	5
Minor commercial driveways (number)		--	25
Major industrial / institutional driveways (number)		--	0
Minor industrial / institutional driveways (number)		--	15
Major residential driveways (number)		--	5
Minor residential driveways (number)		--	10
Other driveways (number)		--	0
Speed Category		--	Posted Speed Greater than 30 mph
Roadside fixed object density (fixed objects / mi)		0	20
Offset to roadside fixed objects (ft.) [If greater than 30 or Not Present, input 30]		30	10
Calibration Factor, Cr		1.00	0.70

Table 8-30: Urban Multi-lane SPF Data Inputs – No-Build Segment 2

Worksheet 1A -- General Information and Input Data for Urban and Suburban Roadway Segments			
General Information		**Location Information**	
Analyst		Roadway	Example Arterial
Agency or Company	FDOT	Roadway Section	MP 1.6 to MP 3.2
Date Performed	05/09/19	Jurisdiction	Suburban, FL
		Analysis Year	2020
Input Data		**Base Conditions**	**Site Conditions**
Roadway type (2U, 3T, 4U, 4D, 5T)		--	5T
Length of segment, L (mi)		--	1.6
AADT (veh/day)	$AADT_{MAX}$ = 53,800 (veh/day)	--	24,000
Type of on-street parking (none/parallel/angle)		None	None
Proportion of curb length with on-street parking		--	0
Median width (ft.) - for divided only		15	Not Present
Lighting (present / not present)		Not Present	Present
Auto speed enforcement (present / not present)		Not Present	Not Present
Major commercial driveways (number)		--	3
Minor commercial driveways (number)		--	18
Major industrial / institutional driveways (number)		--	1
Minor industrial / institutional driveways (number)		--	6
Major residential driveways (number)		--	4
Minor residential driveways (number)		--	3
Other driveways (number)		--	0
Speed Category		--	Posted Speed Greater than 30 mph
Roadside fixed object density (fixed objects / mi)		0	20
Offset to roadside fixed objects (ft.) [If greater than 30 or Not Present, input 30]		30	10
Calibration Factor, Cr		1.00	0.70

Table 8-31: Urban Multi-lane SPF Data Inputs – Build Segment 1

Worksheet 1A -- General Information and Input Data for Urban and Suburban Roadway Segments			
General Information		**Location Information**	
Analyst		Roadway	Example Arterial
Agency or Company	FDOT	Roadway Section	MP 0.0 to MP 1.6
Date Performed	05/09/19	Jurisdiction	Suburban, FL
		Analysis Year	2020
Input Data		**Base Conditions**	**Site Conditions**
Roadway type (2U, 3T, 4U, 4D, 5T)		--	4D
Length of segment, L (mi)		--	1.6
AADT (veh/day)	$AADT_{MAX}$ = 53,800 (veh/day)	--	24,000
Type of on-street parking (none/parallel/angle)		None	None
Proportion of curb length with on-street parking		--	0
Median width (ft.) - for divided only		15	15
Lighting (present / not present)		Not Present	Present
Auto speed enforcement (present / not present)		Not Present	Not Present
Major commercial driveways (number)		--	5
Minor commercial driveways (number)		--	25
Major industrial / institutional driveways (number)		--	0
Minor industrial / institutional driveways (number)		--	15
Major residential driveways (number)		--	5
Minor residential driveways (number)		--	10
Other driveways (number)		--	0
Speed Category		--	Posted Speed Greater than 30 mph
Roadside fixed object density (fixed objects / mi)		0	20
Offset to roadside fixed objects (ft.) [If greater than 30 or Not Present, input 30]		30	10
Calibration Factor, Cr		1.00	1.63

Table 8-32: Urban Multi-lane SPF Data Inputs – Build Segment 2

Worksheet 1A -- General Information and Input Data for Urban and Suburban Roadway Segments			
General Information		**Location Information**	
Analyst		Roadway	Example Arterial
Agency or Company	FDOT	Roadway Section	MP 1.6 to MP 3.2
Date Performed	05/09/19	Jurisdiction	Suburban, FL
		Analysis Year	2020
Input Data		**Base Conditions**	**Site Conditions**
Roadway type (2U, 3T, 4U, 4D, 5T)		--	4D
Length of segment, L (mi)		--	1.6
AADT (veh/day)	$AADT_{MAX}$ = 53,800 (veh/day)	--	24,000
Type of on-street parking (none/parallel/angle)		None	None
Proportion of curb length with on-street parking		--	0
Median width (ft.) - for divided only		15	Not Present
Lighting (present / not present)		Not Present	Present
Auto speed enforcement (present / not present)		Not Present	Not Present
Major commercial driveways (number)		--	3
Minor commercial driveways (number)		--	18
Major industrial / institutional driveways (number)		--	1
Minor industrial / institutional driveways (number)		--	6
Major residential driveways (number)		--	4
Minor residential driveways (number)		--	3
Other driveways (number)		--	0
Speed Category		--	Posted Speed Greater than 30 mph
Roadside fixed object density (fixed objects / mi)		0	20
Offset to roadside fixed objects (ft.) [If greater than 30 or Not Present, input 30]		30	10
Calibration Factor, Cr		1.00	1.63

Table 8-33: Urban Intersection SPF Data Inputs – Intersection 1

Worksheet 2A -- General Information and Input Data for Urban and Suburban Arterial Intersections			
General Information		**Location Information**	
Analyst		Roadway	Example Arterial
Agency or Company	FDOT	Intersection	Intersection 1 - West
Date Performed	05/09/19	Jurisdiction	Suburban, FL
		Analysis Year	2020
Input Data		**Base Conditions**	**Site Conditions**
Intersection type (3ST, 3SG, 4ST, 4SG)		--	3SG
AADT $_{major}$ (veh/day)	$AADT_{MAX}$ = 58,100 (veh/day)	--	24,000
AADT $_{minor}$ (veh/day)	$AADT_{MAX}$ = 16,400 (veh/day)	--	7,900
Intersection lighting (present/not present)		Not Present	Not Present
Calibration factor, C_i		1.00	1.56
Data for unsignalized intersections only:		--	
Number of major-road approaches with left-turn lanes (0,1,2)		0	0
Number of major-road approaches with right-turn lanes (0,1,2)		0	0
Data for signalized intersections only:		--	
Number of approaches with left-turn lanes (0,1,2,3,4) [for 3SG, use maximum value of 3]		0	2
Number of approaches with right-turn lanes (0,1,2,3,4) [for 3SG, use maximum value of 3]		0	2
Number of approaches with left-turn signal phasing [for 3SG, use maximum value of 3]		--	2
Type of left-turn signal phasing for Leg #1		Permissive	Protected / Permissive
Type of left-turn signal phasing for Leg #2		--	Permissive
Type of left-turn signal phasing for Leg #3		--	Not Applicable
Type of left-turn signal phasing for Leg #4 (if applicable)		--	Not Applicable
Number of approaches with right-turn-on-red prohibited [for 3SG, use maximum value of 3]		0	0
Intersection red light cameras (present/not present)		Not Present	Not Present
Sum of all pedestrian crossing volumes (PedVol) -- Signalized intersections only			10
Maximum number of lanes crossed by a pedestrian (n_{lanesx})		--	5
Number of bus stops within 300 m (1,000 ft.) of the intersection		0	0
Schools within 300 m (1,000 ft.) of the intersection (present/not present)		Not Present	Not Present
Number of alcohol sales establishments within 300 m (1,000 ft.) of the intersection		0	0

Table 8-34: Urban Intersection SPF Data Inputs – Intersection 2

Worksheet 2A -- General Information and Input Data for Urban and Suburban Arterial Intersections			
General Information		**Location Information**	
Analyst		Roadway	Example Arterial
Agency or Company	FDOT	Intersection	Intersection 1 - West
Date Performed	05/09/19	Jurisdiction	Suburban, FL
		Analysis Year	2020
Input Data		**Base Conditions**	**Site Conditions**
Intersection type (3ST, 3SG, 4ST, 4SG)		--	4SG
AADT $_{major}$ (veh/day)	$AADT_{MAX}$ = 58,100 (veh/day)	--	24,000
AADT $_{minor}$ (veh/day)	$AADT_{MAX}$ = 16,400 (veh/day)	--	9,000
Intersection lighting (present/not present)		Not Present	Not Present
Calibration factor, C_i		1.00	1.00
Data for unsignalized intersections only:		--	
Number of major-road approaches with left-turn lanes (0,1,2)		0	0
Number of major-road approaches with right-turn lanes (0,1,2)		0	0
Data for signalized intersections only:		--	
Number of approaches with left-turn lanes (0,1,2,3,4) [for 3SG, use maximum value of 3]		0	4
Number of approaches with right-turn lanes (0,1,2,3,4) [for 3SG, use maximum value of 3]		0	4
Number of approaches with left-turn signal phasing [for 3SG, use maximum value of 3]		--	4
Type of left-turn signal phasing for Leg #1		Permissive	Protected / Permissive
Type of left-turn signal phasing for Leg #2		--	Protected / Permissive
Type of left-turn signal phasing for Leg #3		--	Permissive
Type of left-turn signal phasing for Leg #4 (if applicable)		--	Permissive
Number of approaches with right-turn-on-red prohibited [for 3SG, use maximum value of 3]		0	0
Intersection red light cameras (present/not present)		Not Present	Not Present
Sum of all pedestrian crossing volumes (PedVol) -- Signalized intersections only			10
Maximum number of lanes crossed by a pedestrian (n_{lanesx})		--	5
Number of bus stops within 300 m (1,000 ft.) of the intersection		0	0
Schools within 300 m (1,000 ft.) of the intersection (present/not present)		Not Present	Not Present
Number of alcohol sales establishments within 300 m (1,000 ft.) of the intersection		0	0

Step 4 - Apply CMFs to Calculated SPF Values (HSM Step 10)

The HSM forms automatically calculate the necessary CMFs using the input data. **Table 8-35** through **Table 8-38** present the crash modification factors for the 2020 No-Build segments and intersections, respectively. **Table 8-39** through **Table 8-42** present the crash modification factors for the 2020 Build segments. The Build intersection CMFs are the same as the No-Build CMFs.

For the segments, the combined No-Build CMFs are 0.95 and 0.94 for Segments 1 and 2, respectively. For the Build Alternative, they are slightly lower at 0.94 and 0.92, respectively. The intersection CMFs are 0.78 and 0.55 for Intersection 1 and 2, respectively. These low numbers are due in large part to the presence of left and right turn lanes.

Table 8-35: Urban Multi-Lane Adjustment Factors – No-Build Segment 1

Worksheet 1B -- Crash Modification Factors for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
CMF for On-Street Parking	CMF for Roadside Fixed Objects	CMF for Median Width	CMF for Lighting	CMF for Automated Speed Enforcement	Combined CMF
CMF 1r	*CMF 2r*	*CMF 3r*	*CMF 4r*	*CMF 5r*	*CMF comb*
from Equation 12-32	from Equation 12-33	from Table 12-22	from Equation 12-34	from Section 12.7.1	(1)*(2)*(3)*(4)*(5)
1.00	1.01	1.00	0.94	1.00	0.95

Table 8-36: Urban Multi-Lane Adjustment Factors – No-Build Segment 2

Worksheet 1B -- Crash Modification Factors for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
CMF for On-Street Parking	CMF for Roadside Fixed Objects	CMF for Median Width	CMF for Lighting	CMF for Automated Speed Enforcement	Combined CMF
CMF 1r	*CMF 2r*	*CMF 3r*	*CMF 4r*	*CMF 5r*	*CMF comb*
from Equation 12-32	from Equation 12-33	from Table 12-22	from Equation 12-34	from Section 12.7.1	(1)*(2)*(3)*(4)*(5)
1.00	1.00	1.00	0.94	1.00	0.94

Table 8-37: Urban Arterial Intersection Adjustment Factors – No-Build Intersection 1

Worksheet 2B -- Crash Modification Factors for Urban and Suburban Arterial Intersections						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
CMF for Left-Turn Lanes	CMF for Left-Turn Signal Phasing	CMF for Right-Turn Lanes	CMF for Right Turn on Red	CMF for Lighting	CMF for Red Light Cameras	Combined CMF
CMF 1i	CMF 2i	CMF 3i	CMF 4i	CMF 5i	CMF 6i	CMF COMB
from Table 12-24	from Table 12-25	from Table 12-26	from Equation 12-35	from Equation 12-36	from Equation 12-37	(1)*(2)*(3)*(4)*(5)*(6)
0.86	0.99	0.92	1.00	1.00	1.00	0.78

Table 8-38: Urban Arterial Intersection Adjustment Factors – No-Build Intersection 2

Worksheet 2B -- Crash Modification Factors for Urban and Suburban Arterial Intersections						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
CMF for Left-Turn Lanes	CMF for Left-Turn Signal Phasing	CMF for Right-Turn Lanes	CMF for Right Turn on Red	CMF for Lighting	CMF for Red Light Cameras	Combined CMF
CMF 1i	CMF 2i	CMF 3i	CMF 4i	CMF 5i	CMF 6i	CMF COMB
from Table 12-24	from Table 12-25	from Table 12-26	from Equation 12-35	from Equation 12-36	from Equation 12-37	(1)*(2)*(3)*(4)*(5)*(6)
0.66	0.98	0.85	1.00	1.00	1.00	0.55

Table 8-39: Urban Multi-Lane Adjustment Factors – Build Segment 1

Worksheet 1B -- Crash Modification Factors for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
CMF for On-Street Parking	CMF for Roadside Fixed Objects	CMF for Median Width	CMF for Lighting	CMF for Automated Speed Enforcement	Combined CMF
CMF 1r	*CMF 2r*	*CMF 3r*	*CMF 4r*	*CMF 5r*	*CMF comb*
from Equation 12-32	from Equation 12-33	from Table 12-22	from Equation 12-34	from Section 12.7.1	(1)*(2)*(3)*(4)*(5)
1.00	1.03	1.00	0.91	1.00	0.94

Table 8-40: Urban Multi-Lane Adjustment Factors – Build Segment 2

Worksheet 1B -- Crash Modification Factors for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
CMF for On-Street Parking	CMF for Roadside Fixed Objects	CMF for Median Width	CMF for Lighting	CMF for Automated Speed Enforcement	Combined CMF
CMF 1r	*CMF 2r*	*CMF 3r*	*CMF 4r*	*CMF 5r*	*CMF comb*
from Equation 12-32	from Equation 12-33	from Table 12-22	from Equation 12-34	from Section 12.7.1	(1)*(2)*(3)*(4)*(5)
1.00	1.00	1.00	0.91	1.00	0.92

Step 5 - Apply Local Calibration Factors (HSM Step 11)

The FDOT calibration factors are 0.70 for an urban 5-lane roadway with a center TWLTL, 1.63 for an urban 4-Lane divided roadway, 1.56 for an urban 3-leg signalized intersection, and 1.00 for an urban 4-leg signalized intersection. The calibration factors are entered into the data input spreadsheets and are used to develop the final crash prediction estimates. The FDOT calibration factors are available on the FDOT HSM website.

Step 6 - Repeat Process for Other Years (HSM Step 12)

Design year (2040) results are calculated by repeating the process with updated traffic volume and roadway inputs. In this example, the only change for the design year is a growth in traffic volume as shown in **Table 8-26** through **Table 8-28**. The summary analysis results for both years are presented in Step 8.

Step 7 - Apply Empirical Bayes When Applicable (HSM Steps 13, 15)

This step is not applicable for this example because the proposed alternative substantively changes the cross-section of the roadway and is best represented by a different SPF. This means that the results from this analysis are predicted crashes, not expected crashes, as defined by the HSM.

Step 8 - Evaluate Results (HSM Steps 16 and 18)

The results of the No-Build and Build alternatives analyses are examined and compared. Because a calibration factor was applied, the comparison can be presented as a change in crash frequency and a percentage change in crashes.

The 2020 and 2040 predicted crashes are summarized in **Table 8-41**. For reference, the HSM spreadsheets showing the 2020 and 2040 predicted No-Build and Build crashes are presented in **Table 42** through **Table 45**.

Table 8-41: Predicted Average Crash Frequency

Analysis Year	Crash Severity Level	No- Build Alternative			Build Alternative			Crash Reduction	Percent Change
		Segment Crashes	Intersection Crashes	Total	Segment Crashes	Intersection Crashes	Total		
2020	**Total**	28.3	9.3	37.7	26.1	9.3	35.4	2.3	6.0%
	Fatal and Injury (FI)	8.1	3.2	11.3	7.3	3.2	10.5	0.8	7%
	Property Damage Only (PDO)	20.2	6.2	26.4	18.7	6.2	24.9	1.4	5%
2040	**Total**	40.8	14.5	55.3	39.3	14.5	53.9	1.5	3%
	Fatal and Injury (FI)	11.6	4.8	16.4	11.0	4.8	15.8	0.6	4%
	Property Damage Only (PDO)	29.2	9.7	38.9	28.3	9.7	38.0	0.9	2%

As shown in **Table 7-41**, the proposed Build project is predicted to decrease the predicted total crashes by 2.3 (6%) in 2020 and 1.5 (3%) in 2040. The percentage reduction in fatal and injury crashes is slightly larger with a decrease of 7% in 2020 and 4% in 2040.

Given that the intersection crash prediction results are the same for both alternatives, the difference is entirely due to the change in the segment crash predictions. The segment crash predictions are influenced by three main elements, the SPF results, the CMFs, and the calibration factors. The unadjusted No-Build SPF calculations resulted in approximately 44 total segment crashes, compared to the unadjusted Build segment results of approximately 18 total crashes. Since the CMFs for both the No-Build and Build Alternatives are similar, it is the calibration factors (0.70 and 1.63 for the No-Build and Build respectively) that result in final predictions that are similar in magnitude.

Table 8-42: Predicted Crash Frequency – 2020 No-Build

Worksheet 4A -- Predicted Crashes by Collision and Site Type and Observed Crashes Using the Project-Level EB Method for Urban and Suburban Arterials

(1)	(2)	(3)	(4)
Collision type / Site type	**Predicted crashes**		
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)
ROADWAY SEGMENTS			
Multiple-vehicle nondriveway			
Segment 1	8.706	2.334	6.372
Segment 2	8.610	2.308	6.302
Single-vehicle			
Segment 1	1.994	0.454	1.540
Segment 2	1.972	0.449	1.523
Multiple-vehicle driveway-related			
Segment 1	3.587	0.965	2.622
Segment 2	2.480	0.667	1.813
INTERSECTIONS			
Multiple-vehicle			
Intersection 1	4.957	1.626	3.331
Intersection 2	3.659	1.223	2.435
Single-vehicle			
Intersection 1	0.371	0.109	0.261
Intersection 2	0.225	0.057	0.168
COMBINED (sum of column)	36.559	10.193	26.366

Worksheet 4B -- Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials

(1)	(2)	(3)
Site Type	N_{ped}	N_{bike}
ROADWAY SEGMENTS		
Segment 1	0.329	0.171
Segment 2	0.300	0.157
Segment 3		
Segment 4		
INTERSECTIONS		
Intersection 1	0.007	0.059
Intersection 2	0.012	0.058
Intersection 3		
Intersection 4		
COMBINED (sum of column)	0.648	0.445

Table 8-43: Predicted Crash Frequency – 2040 No-Build

Worksheet 4A -- Predicted Crashes by Collision and Site Type and Observed Crashes Using the Project-Level EB Method for Urban and Suburban Arterials

(1)	(2)	(3)	(4)
Collision type / Site type	**Predicted crashes**		
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)
ROADWAY SEGMENTS			
Multiple-vehicle nondriveway			
Segment 1	12.905	3.417	9.488
Segment 2	12.764	3.380	9.384
Single-vehicle			
Segment 1	2.391	0.508	1.883
Segment 2	2.364	0.503	1.862
Multiple-vehicle driveway-related			
Segment 1	5.322	1.431	3.890
Segment 2	3.678	0.989	2.689
INTERSECTIONS			
Multiple-vehicle			
Intersection 1	7.867	2.436	5.431
Intersection 2	5.666	1.955	3.711
Single-vehicle			
Intersection 1	0.489	0.145	0.345
Intersection 2	0.310	0.073	0.237
COMBINED (sum of column)	53.756	14.837	38.919

Worksheet 4B -- Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials

(1)	(2)	(3)
Site Type	N_{ped}	N_{bike}
ROADWAY SEGMENTS		
Segment 1	0.474	0.247
Segment 2	0.433	0.226
Segment 3		
Segment 4		
INTERSECTIONS		
Intersection 1	0.007	0.092
Intersection 2	0.014	0.090
Intersection 3		
Intersection 4		
COMBINED (sum of column)	0.928	0.655

Table 8-44: Predicted Crash Frequency – 2020 Build

Worksheet 4A -- Predicted Crashes by Collision and Site Type and Observed Crashes Using the Project-Level EB Method for Urban and Suburban Arterials

(1)	(2)	(3)	(4)
Collision type / Site type	**Predicted crashes**		
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)
ROADWAY SEGMENTS			
Multiple-vehicle nondriveway			
Segment 1	9.692	2.686	7.006
Segment 2	9.456	2.621	6.835
Single-vehicle			
Segment 1	1.795	0.314	1.481
Segment 2	1.751	0.306	1.445
Multiple-vehicle driveway-related			
Segment 1	1.633	0.464	1.169
Segment 2	1.114	0.316	0.798
INTERSECTIONS			
Multiple-vehicle			
Intersection 1	4.957	1.626	3.331
Intersection 2	3.659	1.223	2.435
Single-vehicle			
Intersection 1	0.371	0.109	0.261
Intersection 2	0.225	0.057	0.168
COMBINED (sum of column)	34.653	9.724	24.930

Worksheet 4B -- Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials

(1)	(2)	(3)
Site Type	N_{ped}	N_{bike}
ROADWAY SEGMENTS		
Segment 1	0.249	0.066
Segment 2	0.234	0.062
Segment 3		
Segment 4		
INTERSECTIONS		
Intersection 1	0.007	0.059
Intersection 2	0.012	0.058
Intersection 3		
Intersection 4		
COMBINED (sum of column)	0.503	0.244

Table 8-45: Predicted Crash Frequency – 2040 Build

Worksheet 4A -- Predicted Crashes by Collision and Site Type and Observed Crashes Using the Project-Level EB Method for Urban and Suburban Arterials

(1)	(2)	(3)	(4)
Collision type / Site type	**Predicted crashes**		
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)
ROADWAY SEGMENTS			
Multiple-vehicle nondriveway			
Segment 1	15.317	4.143	11.174
Segment 2	14.944	4.042	10.902
Single-vehicle			
Segment 1	2.102	0.389	1.713
Segment 2	2.051	0.380	1.671
Multiple-vehicle driveway-related			
Segment 1	2.369	0.673	1.696
Segment 2	1.616	0.459	1.157
INTERSECTIONS			
Multiple-vehicle			
Intersection 1	7.867	2.436	5.431
Intersection 2	5.666	1.955	3.711
Single-vehicle			
Intersection 1	0.489	0.145	0.345
Intersection 2	0.310	0.073	0.237
COMBINED (sum of column)	52.732	14.694	38.038

Worksheet 4B -- Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials

(1)	(2)	(3)
Site Type	N_{ped}	N_{bike}
ROADWAY SEGMENTS		
Segment 1	0.376	0.099
Segment 2	0.354	0.093
Segment 3		
Segment 4		
INTERSECTIONS		
Intersection 1	0.007	0.092
Intersection 2	0.014	0.090
Intersection 3		
Intersection 4		
COMBINED (sum of column)	0.751	0.374

8.3 Example 3: Comparing the No-Build and Build Predictive Safety Analyses to Address a Freeway Weaving Segment

8.3.1 Background and Problem Statement

An interstate PD&E Study is being conducted to address traffic congestion and crashes between two urban diamond interchanges, separated by a short distance. **Figure 8-3** shows the project limits and segmentation for mainline segments, speed change lane segments, and ramp segments. Congestion and high rates of sideswipe crashes between these two interchanges appear to be caused by the weaving of on-ramp traffic interacting with downstream off-ramp traffic. One of the alternatives being analyzed is building a collector-distributor roadway in both directions between the two interchanges to eliminate the weaving (which is currently a Type B weave movement). **Figure 8-4** shows that the study limits will remain the same but with revised segmentation due to the collector-distributor roadways.

The HSM predictive method will be used to quantitatively compare the predicted safety performance of the future No-Build and Build alternatives.

Figure 8-3: Project Study Limits

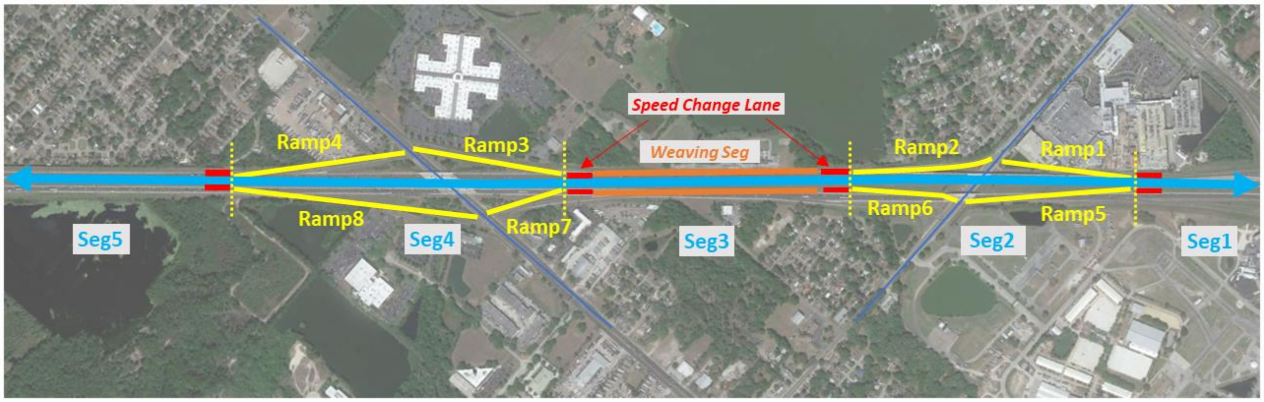
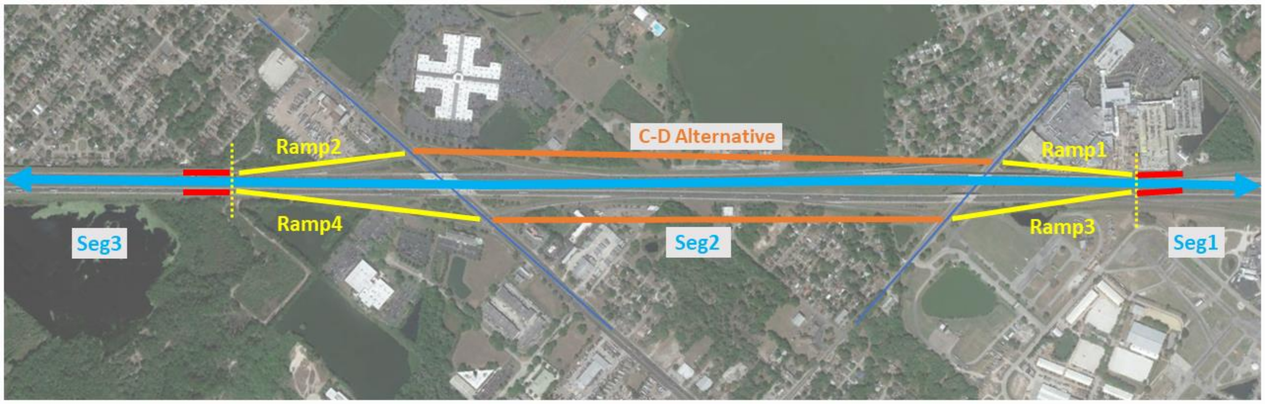


Figure 8-4: Build Alternative Study Limits



8.3.2 Procedures and Calculations

Step 1 - Determine Data Needs (HSM Steps 1 and 2)

During methodology development it was agreed that the future safety performance for the No-Build and Build alternatives would be compared using the 2020 (opening year) and 2040 (design year) predicted crash frequencies using the Safety Performance Functions (SPFs) for Freeway Sections and Ramps/Collector-Distributor roads from the Highway Safety Manual (HSM).

The Empirical Bayes (EB) method of adjusting the predictive method results based on observed crashes is not applicable for this evaluation since the proposed project includes significant changes in geometry including construction of the C-D road system.

The Enhanced Interchange Safety Analysis Tool (ISATe) applies the HSM Predictive Method for freeway design alternatives. **Table 8-46** summarizes the proposed scope and methodology for the No-Build and Build conditions.

The Build Alternative would replace both weave sections with 2-lane C-D road segments between the two interchanges. It would also include the construction of 2-lane exit and entrance ramps, with longer speed change lanes, to accommodate the higher ramp volumes.

Table 8-46: Summary Scope and Methods

Feature	No-Build Condition	Build Condition
Study Area	Interstate 100 (MP 0 to MP 2.1)	Interstate 100 (MP 0 to MP 2.1)
Study Years	2020 and 2040	2020 and 2040
Roadway Type	Freeway with two Diamond Interchanges	Freeway with 2 lane C-D
Number of Lanes	Freeway = 6, Ramps = 1	Freeway = 6, C-D = 2, Ramps = 2
SPFs	HSM Chapter 18	HSM Chapter 18
Software / Tools	ISATe	ISATe
Segment Length, L (miles)	2.1	2.1
Annual Growth Rate	2%	2%
Calibration Factors	None	None
Empirical Bayes and Special Methods	Not Applicable for this Evaluation	Not Applicable for this Evaluation

Step 2 - Divide Locations into Homogenous Segments (HSM Steps 3, 4, 5, and 6)

The input data needed for the No-Build predictive models are presented in **Table 8-47**. The project area is divided into homogeneous segments based on where there are changes from the documented SPF base condition. The identified segments have the same basic cross section for the entire length (same number of lanes, lane widths, shoulder widths, and clear zone width).

The No-Build Alternative has been segmented into five parts based on the locations of the freeway gore points. The No-Build ramp segment details are shown in **Table 8-48**.

A summary of the Build Alternative freeway inputs is shown in **Table 8-49** and the Build ramp segment and C-D road details are shown in **Table 8-50.**

Note that Mainline Segment 3, which has the weaving section, is 0.35 miles long. This is shorter than the 0.85-mile threshold required by ISATe methodology. If the length exceeds 0.85 miles, then the auxiliary lane is counted as a through lane that starts as a lane-add ramp entrance and ends as a lane-drop ramp exit.

Table 8-47: No-Build Alternative ISATe Input Data (Six Lane Urban Freeway)

Input Data Category	Seg 1	Seg 2	Seg 3	Seg 4	Seg 5
Roadway Type	Freeway	Freeway	Freeway	Freeway	Freeway
Number of Through Lanes	6	6	6	6	6
Length (miles)	0.3	0.54	0.35	0.61	0.3
Lane Width (feet)	12	12	12	12	12
Shoulder Width (outside/inside in feet)	10/8	10/8	10/8	10/8	10/8
Median Width (feet)	50	50	50	50	50
Horizontal Curve in Segment	None	None	None	None	None
Barrier in Median (yes/no)	No	No	No	No	No
Clear Zone Width (feet)	30	30	30	30	30
Ramp in Segment (ent/exit, increasing MP)	Exit	No	Ent/Exit	No	Ent
Length of Ramp Entrance or Exit (miles)	0.04		0.14/ 0.04		0.14
Ramp AADT	8,000		10,000/ 5,000		6,000
Ramp in Segment (ent/exit, decreasing MP)	Ent		Ent/ Exit		Exit
Length of Ramp Entrance or Exit (miles)	0.14		0.14/ 0.04		0.04
Ramp AADT	7,000		6,000/ 9,000		5,000
Type B Weave (Increasing MP/ Decreasing MP)	No/ No	No/ No	Yes/ Yes	No/ No	No/ No
Proportion of AADT in Peak Hour	0.3	0.3	0.3	0.3	0.3
Freeway AADT (2020)	100,000	85,000	104,000	93,000	104,000
Annual Growth Rate	2%	2%	2%	2%	2%

Table 8-48: No-Build Alternative ISATe Input Data (Ramp Segments)

Input Data Category	Seg 1	Seg 2	Seg 3	Seg 4	Seg 5	Seg 6	Seg 7	Seg 8
Roadway Type	Ramp 1	Ramp 2	Ramp 3	Ramp 4	Ramp 5	Ramp 6	Ramp 7	Ramp 8
Direction (Increasing MP/ Decreasing MP)	Inc MP	Inc MP	Inc MP	Inc MP	Dec MP	Dec MP	Dec MP	Dec MP
Number of Through Lanes	1	2	1	1	1	1	2	1
Length (miles)	0.22	0.28	0.35	0.25	0.32	0.20	0.22	0.39
Average Traffic Speed on Freeway	75	75	75	75	75	75	75	75
Segment Type	Exit	Ent	Exit	Ent	Ent	Exit	Ent	Exit
Type of Terminal Control	Signal	None	Signal	None	None	Signal	None	Signal
Horizontal Curve in Segment	None	None	None	None	None	None	None	None
Lane Width (feet)	14	14	14	14	14	14	14	14
Shoulder Width (outside/inside in feet)	8/4	8/4	8/4	8/4	8/4	8/4	8/4	8/4
Presence of Lane Add/Drop by Taper	No	No	No	No	No	No	No	No
Presence of Barrier	No	No	No	No	No	No	No	No
Ramp Access - Entrance	No	No	No	No	No	No	No	No
Ramp AADT (2020)	8,000	10,000	5,000	6,000	7,000	9,000	6,000	5,000
Annual Growth Rate	2%	2%	2%	2%	2%	2%	2%	2%

Table 8-49: Build Alternative ISATe Input Data (Six Lane Urban Freeway)

Input Data Category	Seg 1	Seg 2	Seg 3
Roadway Type	Freeway	Freeway	Freeway
Number of Through Lanes	6	6	6
Length (miles)	0.3	1.5	0.3
Lane Width (feet)	12	12	12
Shoulder Width (outside/inside in feet)	10/8	10/8	10/8
Median Width (feet)	50	50	50
Horizontal Curve in Segment	None	None	None
Barrier in Median (yes/no)	No	No	No
Clear Zone Width (feet)	30	30	30
Ramp in Segment (ent/exit, increasing MP)	Exit	No	Ent
Length of Ramp Entrance or Exit (miles)	0.04		0.3
Ramp AADT	13,000		16,000
Ramp in Segment (ent/exit, decreasing MP)	Ent	No	Exit
Length of Ramp Entrance or Exit (miles)	0.3		0.04
Ramp AADT	13,000		14,000
Proportion of AADT in Peak Hour	0.3	0.3	0.3
Freeway AADT (2020)	100,000	74,000	104,000
Annual Growth Rate	2%	2%	2%

Table 8-50: Build Alternative ISATe Input Data (Ramp Segments)

Input Data Category	Seg 1	Seg 2	Seg 3	Seg 4	Seg 5	Seg 6
Roadway Type	Ramp 1	C-D Road 1	Ramp 2	Ramp 3	C-D Road 2	Ramp 4
Length (miles)	0.22	0.98	0.25	0.32	0.76	0.39
Average Traffic Speed on Freeway	75	75	75	75	75	75
Segment Type	Exit	C-D	Ent	Ent	C-D	Exit
Type of Terminal Control	Signal	-	None	None	-	Signal
Horizontal Curve in Segment	None	None	None	None	None	None
Lane Width (feet)	14	12	14	14	12	14
Shoulder Width (outside/inside in feet)	8/4	8/4	8/4	8/4	8/4	8/4
Presence of Lane Add/Drop by Taper	No	No	No	No	No	No
Presence of Barrier	No	No	No	No	No	No
Ramp Access - Entrance	No	No	No	No	No	No
Ramp AADT (2020)	13,000	15,000	16,000	13,000	15,000	14,000
Annual Growth Rate	2%	2%	2%	2%	2%	2%

To further support the need for the project, historical crash data was examined and is shown in **Table 8-51**. The data shows that a disproportionate number of rear-end and sideswipe crashes in the corridor occur in the 0.35-mile-long freeway segment between the two interchanges (represented by Segment 3). Although the historical crash data supports the need for the project, it was not used in the predictive crash analysis because the Empirical Bays method was not applicable given the significant changes to the freeway geometry.

Table 8-51: Historical Crash Data (2013-2017)

	Seg 1	Seg 2	Seg 3	Seg 4	Seg 5	Total
Rear End	7	8	17	9	18	59
Sideswipe	15	4	40	22	14	95
Run off Road	10	3	10	0	0	23

Step 3 - Identify and Apply the Appropriate SPFs (HSM Steps 7, 8, 9, 14, and 17)

The SPFs are applied by entering the data for each alternative as presented in **Table 46** through **Table 48** into the appropriate ISATe workbook tabs for Segments, Ramps, and Terminals. The ISATe workbook calculates the SPFs and the CMFs where they differ from the baseline condition. ISATe data inputs for the No-Build Alternative and Build Alternative are shown in **Table 8-52** and **Table 8-53**, respectively.

The inputs shown in **Table 8-52** through **Table 8-55** are for the opening year 2020 scenario.

The following tables are screenshots from the ISATe workbook to illustrate the inputs and outputs used in this example. *These tables do not contain all data fields in the ISATe workbooks, but contain the applicable fields for this analysis.*

Table 8-52: Freeway SPF Data Inputs – No-Build 2020 Analysis

Input Worksheet for Freeway Segments		Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
Clear	Echo Input Values (View results in Column AV) / Check Input Values (View results in Advisory Messages)	**Study Period**	**Study Period**	**Study Period**	**Study Period**	**Study Period**
Basic Roadway Data						
Number of through lanes (n):		6	6	6	6	6
Freeway segment description:		FR1	FR2	FR3	FR4	FR5
Segment length (L), mi:		0.3	0.54	0.35	0.61	0.3
Alignment Data						
Horizontal Curve Data	See note					
1	Horizontal curve in segment?:	No	No	No	No	No
	Curve radius (R_1), ft:					
	Length of curve (L_{c1}), mi:					
	Length of curve in segment ($L_{c1,seg}$), mi:					
2	Horizontal curve in segment?:					
	Curve radius (R_2), ft:					
	Length of curve (L_{c2}), mi:					
	Length of curve in segment ($L_{c2,seg}$), mi:					
3	Horizontal curve in segment?:					
	Curve radius (R_3), ft:					
	Length of curve (L_{c3}), mi:					
	Length of curve in segment ($L_{c3,seg}$), mi:					
Cross Section Data						
Lane width (W_l), ft:		12	12	12	12	12
Outside shoulder width (W_s), ft:		10	10	10	10	10
Inside shoulder width (W_{is}), ft:		8	8	8	8	8
Median width (W_m), ft:		50	50	50	50	50
Rumble strips on outside shoulders?:		No	No	No	No	No
	Length of rumble strips for travel in increasing milepost direction, mi:					
	Length of rumble strips for travel in decreasing milepost direction, mi:					
Rumble strips on inside shoulders?:		No	No	No	No	No
	Length of rumble strips for travel in increasing milepost direction, mi:					
	Length of rumble strips for travel in decreasing milepost direction, mi:					
Presence of barrier in median:		None	None	None	None	None
Ramp Access Data						
Travel in Increasing Milepost Direction						
Entrance Ramp	Ramp entrance in segment? (If yes, indicate type.):	No	No	Lane Add	No	S-C Lane
	Distance from begin milepost to upstream entrance ramp gore ($X_{b,ent}$), mi:	999	999		0.35	
	Length of ramp entrance ($L_{en,inc}$), mi:					0.14
	Length of ramp entrance in segment ($L_{en,seg,inc}$), mi:					0.14
	Entrance side?:					Right
Exit Ramp	Ramp exit in segment? (If yes, indicate type.):	S-C Lane	No	Lane Drop	No	No
	Distance from end milepost to downstream exit ramp gore ($X_{e,ext}$), mi:		0.35		999	999
	Length of ramp exit ($L_{ex,inc}$), mi:	0.04				
	Length of ramp exit in segment ($L_{ex,seg,inc}$), mi:	0.04				
	Exit side?:	Right				
Weave	Type B weave in segment?:	No	No	Yes	No	No
	Length of weaving section ($L_{wev,inc}$), mi:			0.35		
	Length of weaving section in segment ($L_{wev,seg,inc}$), mi:			0.35		
Travel in Decreasing Milepost Direction						
Entrance Ramp	Ramp entrance in segment? (If yes, indicate type.):	S-C Lane	No	Lane Add	No	No
	Distance from end milepost to upstream entrance ramp gore ($X_{e,ent}$), mi:		0.35		999	999
	Length of ramp entrance ($L_{en,dec}$), mi:	0.14				
	Length of ramp entrance in segment ($L_{en,seg,dec}$), mi:	0.14				
	Entrance side?:	Right				
Exit Ramp	Ramp exit in segment? (If yes, indicate type.):	No	No	Lane Drop	No	S-C Lane
	Distance from begin milepost to downstream exit ramp gore ($X_{b,ext}$), mi:	999	999		0.35	
	Length of ramp exit ($L_{ex,dec}$), mi:					0.04
	Length of ramp exit in segment ($L_{ex,seg,dec}$), mi:					0.04
	Exit side?:					Right
Weave	Type B weave in segment?:	No	No	Yes	No	No
	Length of weaving section ($L_{wev,dec}$), mi:			0.35		
	Length of weaving section in segment ($L_{wev,seg,dec}$), mi:			0.35		
Traffic Data	**Year**					
Proportion of AADT during high-volume hours (P_{hv}):		0.3	0.3	0.3	0.3	0.3
Freeway Segment Data	2020	100000	85000	104000	93000	104000

Table 8-53: Ramp SPF Data Inputs – No-Build 2020 Analysis

Input Worksheet for Ramp Segments

Clear / Echo Input Values (View results in Column CJ) / Check Input Values (View results in Advisory Messages)	Year	Segment 1 Study Period	Segment 2 Study Period	Segment 3 Study Period	Segment 4 Study Period	Segment 5 Study Period	Segment 6 Study Period	Segment 7 Study Period	Segment 8 Study Period
Basic Roadway Data									
Number of through lanes (n):		1	2	1	1	1	1	2	1
Ramp segment description:		R1	R2	R3	R4	R5	R6	R7	R8
Segment length (L), mi:		0.22	0.28	0.35	0.25	0.32	0.2	0.22	0.39
Average traffic speed on the freeway (V_{frwy}), mi/h:		75	75	75	75	75	75	75	75
Segment type (ramp or collector-distributor road):		Exit	Entrance	Exit	Entrance	Entrance	Exit	Entrance	Exit
Type of control at crossroad ramp terminal:		Signal	None	Signal	None	None	Signal	None	Signal
Alignment Data									
Horizontal Curve Data See notes									
1 Horizontal curve?:		No	No	No	No	No	No	No	No
Curve radius (R_1), ft:									
Length of curve (L_{c1}), mi:									
Length of curve in segment ($L_{c1,seg}$), mi:									
Cross Section Data									
Lane width (W_l), ft:		14	14	14	14	14	14	14	14
Right shoulder width (W_{rs}), ft:		8	8	8	8	8	8	8	8
Left shoulder width (W_{ls}), ft:		4	4	4	4	4	4	4	4
Presence of lane add or lane drop by taper:		No	No	No	No	No	No	No	No
Length of taper in segment ($L_{add,seg}$ or $L_{drop,seg}$), mi:									
Roadside Data									
Presence of barrier on right side of roadway:		No	No	No	No	No	No	No	No
1 Length of barrier ($L_{rb,1}$), mi:									
Distance from edge of traveled way to barrier face ($W_{off,r,1}$), ft:									
2 Length of barrier ($L_{rb,2}$), mi:									
Distance from edge of traveled way to barrier face ($W_{off,r,2}$), ft:									
3 Length of barrier ($L_{rb,3}$), mi:									
Distance from edge of traveled way to barrier face ($W_{off,r,3}$), ft:									
4 Length of barrier ($L_{rb,4}$), mi:									
Distance from edge of traveled way to barrier face ($W_{off,r,4}$), ft:									
5 Length of barrier ($L_{rb,5}$), mi:									
Distance from edge of traveled way to barrier face ($W_{off,r,5}$), ft:									
Presence of barrier on left side of roadway:		No	No	No	No	No	No	No	No
Ramp Access Data See note									
Ramp Entrance – Ramp entrance in segment? (If yes, indicate type.):		No	No	No	No	No	No	No	No
Ramp Entrance – Length of entrance s-c lane in segment ($L_{en,seg}$), mi:									
Ramp Exit – Ramp exit in segment? (If yes, indicate type.):		No	No	No	No	No	No	No	No
Ramp Exit – Length of exit s-c lane in segment ($L_{ex,seg}$), mi:									
Weaving Section – Weave section in collector-distributor road segment?:									
Weaving Section – Length of weaving section (L_{wev}), mi:									
Weaving Section – Length of weaving section in segment ($L_{wev,seg}$), mi:									
Traffic Data	Year								
Average daily traffic ($AADT_r$ or $AADT_c$) by year, veh/d:	2020	8000	10000	5000	6000	7000	9000	6000	5000

Table 8-54: Freeway SPF Data Inputs – Build 2020 Analysis

Input Worksheet for Freeway Segments		Segment 1 Study Period	Segment 2 Study Period	Segment 3 Study Period
Clear / Echo Input Values (View results in Column AV) / Check Input Values (View results in Advisory Messages)				
Basic Roadway Data				
Number of through lanes (n):		6	6	6
Freeway segment description:		FR1	FR2	FR3
Segment length (L), mi:		0.3	1.50	0.3
Alignment Data				
Horizontal Curve Data	See note			
1	Horizontal curve in segment?:	No	No	No
	Curve radius (R_1), ft:			
	Length of curve (L_{c1}), mi:			
	Length of curve in segment ($L_{c1,seg}$), mi:			
2	Horizontal curve in segment?:			
	Curve radius (R_2), ft:			
	Length of curve (L_{c2}), mi:			
	Length of curve in segment ($L_{c2,seg}$), mi:			
3	Horizontal curve in segment?:			
	Curve radius (R_3), ft:			
	Length of curve (L_{c3}), mi:			
	Length of curve in segment ($L_{c3,seg}$), mi:			
Cross Section Data				
Lane width (W_l), ft:		12	12	12
Outside shoulder width (W_s), ft:		10	10	10
Inside shoulder width (W_{is}), ft:		8	8	8
Median width (W_m), ft:		50	50	50
Rumble strips on outside shoulders?:		No	No	No
	Length of rumble strips for travel in increasing milepost direction, mi:			
	Length of rumble strips for travel in decreasing milepost direction, mi:			
Rumble strips on inside shoulders?:		No	No	No
	Length of rumble strips for travel in increasing milepost direction, mi:			
	Length of rumble strips for travel in decreasing milepost direction, mi:			
Presence of barrier in median:		None	None	None
Ramp Access Data				
Travel in Increasing Milepost Direction				
Entrance Ramp	Ramp entrance in segment? (If yes, indicate type.):	No	No	S-C Lane
	Distance from begin milepost to upstream entrance ramp gore ($X_{b,ent}$), mi:	999	999	
	Length of ramp entrance ($L_{en,inc}$), mi:			0.3
	Length of ramp entrance in segment ($L_{en,seg,inc}$), mi:			0.3
	Entrance side?:			Right
Exit Ramp	Ramp exit in segment? (If yes, indicate type.):	S-C Lane	No	No
	Distance from end milepost to downstream exit ramp gore ($X_{e,ext}$), mi:		999	999
	Length of ramp exit ($L_{ex,inc}$), mi:	0.04		
	Length of ramp exit in segment ($L_{ex,seg,inc}$), mi:	0.04		
	Exit side?:	Right		
Weave	Type B weave in segment?:	No	No	No
	Length of weaving section ($L_{wev,inc}$), mi:			
	Length of weaving section in segment ($L_{wev,seg,inc}$), mi:			
Travel in Decreasing Milepost Direction				
Entrance Ramp	Ramp entrance in segment? (If yes, indicate type.):	S-C Lane	No	No
	Distance from end milepost to upstream entrance ramp gore ($X_{e,ent}$), mi:		999	999
	Length of ramp entrance ($L_{en,dec}$), mi:	0.3		
	Length of ramp entrance in segment ($L_{en,seg,dec}$), mi:	0.3		
	Entrance side?:	Right		
Exit Ramp	Ramp exit in segment? (If yes, indicate type.):	No	No	S-C Lane
	Distance from begin milepost to downstream exit ramp gore ($X_{b,ext}$), mi:	999	999	
	Length of ramp exit ($L_{ex,dec}$), mi:			0.04
	Length of ramp exit in segment ($L_{ex,seg,dec}$), mi:			0.04
	Exit side?:			Right
Weave	Type B weave in segment?:	No	No	No
	Length of weaving section ($L_{wev,dec}$), mi:			
	Length of weaving section in segment ($L_{wev,seg,dec}$), mi:			
Traffic Data	Year			
Proportion of AADT during high-volume hours (P_{hv}):		0.3	0.3	0.3
Freeway Segment Data	2020	100000	74000	104000

Table 8-55: Ramps and C-D SPF Data Inputs – Build 2020 Analysis

Input Worksheet for Ramp Segments	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Segment 6
Clear / Echo Input Values (View results in Column CJ) / Check Input Values (View results in Advisory Messages)	Study Period	Study Period	Study Period	Study Period	Study Period	Study Period
Basic Roadway Data						
Number of through lanes (n):	2	2	2	2	2	2
Ramp segment description:	R1	C-D Road 1	R2	R3	C-D Road 2	R4
Segment length (L), mi:	0.22	0.98	0.25	0.32	0.76	0.39
Average traffic speed on the freeway (V_{frwy}), mi/h:	75	75	75	75	75	75
Segment type (ramp or collector-distributor road):	Exit	C-D Road	Entrance	Entrance	C-D Road	Exit
Type of control at crossroad ramp terminal:	Signal		None	None		Signal
Alignment Data						
Horizontal Curve Data See notes						
1 Horizontal curve?:	No	No	No	No	No	No
Curve radius (R_1), ft:						
Length of curve (L_{c1}), mi:						
Length of curve in segment ($L_{c1,seg}$), mi:						
Cross Section Data						
Lane width (W_l), ft:	14	12	14	14	12	14
Right shoulder width (W_{rs}), ft:	8	8	8	8	8	8
Left shoulder width (W_{ls}), ft:	4	4	4	4	4	4
Presence of lane add or lane drop by taper:	No	No	No	No	No	No
Length of taper in segment ($L_{add,seg}$ or $L_{drop,seg}$), mi:						
Roadside Data						
Presence of barrier on right side of roadway:	No	No	No	No	No	No
1 Length of barrier ($L_{rb,1}$), mi:						
Distance from edge of traveled way to barrier face ($W_{off,r,1}$), ft:						
2 Length of barrier ($L_{rb,2}$), mi:						
Distance from edge of traveled way to barrier face ($W_{off,r,2}$), ft:						
3 Length of barrier ($L_{rb,3}$), mi:						
Distance from edge of traveled way to barrier face ($W_{off,r,3}$), ft:						
4 Length of barrier ($L_{rb,4}$), mi:						
Distance from edge of traveled way to barrier face ($W_{off,r,4}$), ft:						
5 Length of barrier ($L_{rb,5}$), mi:						
Distance from edge of traveled way to barrier face ($W_{off,r,5}$), ft:						
Presence of barrier on left side of roadway:	No	No	No	No	No	No
Ramp Access Data See note						
Ramp Entrance – Ramp entrance in segment? (If yes, indicate type.):	No	No	No	No	No	No
Ramp Entrance – Length of entrance s-c lane in segment ($L_{en,seg}$), mi:						
Ramp Exit – Ramp exit in segment? (If yes, indicate type.):	No	No	No	No	No	No
Ramp Exit – Length of exit s-c lane in segment ($L_{ex,seg}$), mi:						
Weaving Section – Weave section in collector-distributor road segment?:		No			No	
Weaving Section – Length of weaving section (L_{wev}), mi:						
Weaving Section – Length of weaving section in segment ($L_{wev,seg}$), mi:						
Traffic Data Year						
Average daily traffic ($AADT_r$ or $AADT_c$) by year, veh/d: 2020	13000	15000	16000	13000	15000	14000

Step 4 - Apply Crash Modification Factors (CMFs) to Calculated SPF values (HSM Step 10)

The ISATe workbook uses the input data to calculate the appropriate CMFs. **Table 8-56** and **Table 8-57** show the CMFs in this example that differ from base conditions. For example, for fatal and injury crashes, the inside shoulder width of 8 feet reduces the predicted crash frequency by a factor of 0.966, while the median width increases the predicted crash frequency of multiple vehicle crashes by a 1.043 factor and reduces single vehicle crashes by a 0.986 factor.

Table 8-56: Freeway and Ramp Crash Modification Factors – No-Build 2020 Analysis

Output Worksheet for Freeway Segments					Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
MV = multiple-vehicle model SV = single-vehicle model	ENR = ramp entrance model EXR = ramp exit model				**Study Period**	**Study Period**	**Study Period**	**Study Period**	**Study Period**
	Applicable Models (*y*)								
Crash Modification Factors									
Fatal-and-Injury Crash CMFs									
Horizontal curve ($CMF_{1,w,ac,y,fi}$):	MV		ENR	EXR	1.000	1.000	1.000	1.000	1.000
		SV			1.000	1.000	1.000	1.000	1.000
Lane width ($CMF_{2,w,ac,y,fi}$):	MV	SV	ENR	EXR	1.000	1.000	1.000	1.000	1.000
Outside shoulder width ($CMF_{8,fs,ac,sv,fi}$):		SV			1.000	1.000	1.000	1.000	1.000
Inside shoulder width ($CMF_{3,w,ac,y,fi}$):	MV	SV	ENR	EXR	0.966	0.966	0.966	0.966	0.966
Median width ($CMF_{4,w,ac,y,fi}$):	MV		ENR	EXR	1.043	1.043	1.043	1.043	1.043
		SV			0.986	0.986	0.986	0.986	0.986
Median barrier ($CMF_{5,w,ac,y,fi}$):	MV	SV	ENR	EXR	1.000	1.000	1.000	1.000	1.000
Shoulder rumble strip ($CMF_{9,fs,ac,sv,fi}$):		SV			1.000	1.000	1.000	1.000	1.000
Outside clearance ($CMF_{10,fs,ac,sv,fi}$):		SV			1.000	1.000	1.000	1.000	1.000
Outside barrier ($CMF_{11,fs,ac,sv,fi}$):		SV			1.000	1.000	1.000	1.000	1.000
Lane change ($CMF_{7,fs,ac,mv,fi}$):	MV								
			Year:	2020	1.150	1.001	2.111	1.001	1.163
Property-Damage-Only Crash CMFs									
Horizontal curve ($CMF_{1,w,ac,y,pdo}$):	MV		ENR	EXR	1.000	1.000	1.000	1.000	1.000
		SV			1.000	1.000	1.000	1.000	1.000
Lane width ($CMF_{2,w,ac,y,pdo}$):	MV	SV	ENR	EXR	1.000	1.000	1.000	1.000	1.000
Outside shoulder width ($CMF_{8,fs,ac,sv,pdo}$):		SV			1.000	1.000	1.000	1.000	1.000
Inside shoulder width ($CMF_{3,w,ac,y,pdo}$	MV	SV	ENR	EXR	0.970	0.970	0.970	0.970	0.970
Median width ($CMF_{4,w,ac,y,pdo}$):	MV		ENR	EXR	1.042	1.042	1.042	1.042	1.042
		SV			1.041	1.041	1.041	1.041	1.041
Median barrier ($CMF_{5,w,ac,y,pdo}$):	MV	SV	ENR	EXR	1.000	1.000	1.000	1.000	1.000
Shoulder rumble strip ($CMF_{9,fs,ac,sv,pdo}$):		SV			1.000	1.000	1.000	1.000	1.000
Outside clearance ($CMF_{10,fs,ac,sv,pdo}$):		SV			1.000	1.000	1.000	1.000	1.000
Outside barrier ($CMF_{11,fs,ac,sv,pdo}$):		SV			1.000	1.000	1.000	1.000	1.000
Lane change ($CMF_{7,fs,ac,mv,pdo}$):	MV								
			Year:	2020	1.138	1.001	1.785	1.001	1.150

Table 8-57: Freeway and C-D Crash Modification Factors – Build 2020 Analysis

Output Worksheet for Freeway Segments					Segment 1	Segment 2	Segment 3
MV = multiple-vehicle model SV = single-vehicle model	ENR = ramp entrance model EXR = ramp exit model Applicable Models (*y*)				Study Period	Study Period	Study Period
Crash Modification Factors							
Fatal-and-Injury Crash CMFs							
Horizontal curve ($CMF_{1,w,ac,y,fi}$):	MV		ENR	EXR	1.000	1.000	1.000
		SV			1.000	1.000	1.000
Lane width ($CMF_{2,w,ac,y,fi}$):	MV	SV	ENR	EXR	1.000	1.000	1.000
Outside shoulder width ($CMF_{8,fs,ac,sv,fi}$):		SV			1.000	1.000	1.000
Inside shoulder width ($CMF_{3,w,ac,y,fi}$):	MV	SV	ENR	EXR	0.966	0.966	0.966
Median width ($CMF_{4,w,ac,y,fi}$):	MV		ENR	EXR	1.043	1.043	1.043
		SV			0.986	0.986	0.986
Median barrier ($CMF_{5,w,ac,y,fi}$):	MV	SV	ENR	EXR	1.000	1.000	1.000
Shoulder rumble strip ($CMF_{9,fs,ac,sv,fi}$):		SV			1.000	1.000	1.000
Outside clearance ($CMF_{10,fs,ac,sv,fi}$):		SV			1.000	1.000	1.000
Outside barrier ($CMF_{11,fs,ac,sv,fi}$):		SV			1.000	1.000	1.000
Lane change ($CMF_{7,fs,ac,mv,fi}$):	MV						
			Year:	2020	1.129	1.000	1.124
Property-Damage-Only Crash CMFs							
Horizontal curve ($CMF_{1,w,ac,y,pdo}$):	MV		ENR	EXR	1.000	1.000	1.000
		SV			1.000	1.000	1.000
Lane width ($CMF_{2,w,ac,y,pdo}$):	MV	SV	ENR	EXR	1.000	1.000	1.000
Outside shoulder width ($CMF_{8,fs,ac,sv,pdo}$):		SV			1.000	1.000	1.000
Inside shoulder width ($CMF_{3,w,ac,y,pdo}$	MV	SV	ENR	EXR	0.970	0.970	0.970
Median width ($CMF_{4,w,ac,y,pdo}$):	MV		ENR	EXR	1.042	1.042	1.042
		SV			1.041	1.041	1.041
Median barrier ($CMF_{5,w,ac,y,pdo}$):	MV	SV	ENR	EXR	1.000	1.000	1.000
Shoulder rumble strip ($CMF_{9,fs,ac,sv,pdo}$):		SV			1.000	1.000	1.000
Outside clearance ($CMF_{10,fs,ac,sv,pdo}$):		SV			1.000	1.000	1.000
Outside barrier ($CMF_{11,fs,ac,sv,pdo}$):		SV			1.000	1.000	1.000
Lane change ($CMF_{7,fs,ac,mv,pdo}$):	MV						
			Year:	2020	1.118	1.000	1.113

Step 5 - Apply Local Calibration Factors (HSM Step 11)

There are no FDOT calibration factors for interstate analysis at this time. *FDOT may develop calibration factors in the future for ISATe analysis and the FDOT website should be consulted for the latest safety calibration factors.*

Step 6 - Repeat Process for Other Years (HSM Step 12)

The predictive analysis is repeated for the No-Build and Build Alternatives for 2040. The only traffic input factor that changes from the 2020 analysis to the 2040 analysis is the increase in volume. The ISATe workbook linearly interpolates volumes to calculate crash frequency information for the years between the opening and design year. The summary results of the 2020 and 2040 analyses are presented in Step 8.

Step 7 - Apply Empirical Bayes When Applicable (HSM Steps 13 and 15)

This Empirical Bayes method is not applicable because the proposed project will substantially change the freeway geometry by adding a C-D road system.

Step 8 - Evaluate Results (HSM Steps 16 and 18)

Because a local calibration factor was not applied, the comparison of results is presented as a percentage change in crashes and not a change in crash frequency between the No-Build and Build Alternatives.

The summary of the alternatives analysis is presented in **Table 8-58**. The Build Alternative is expected to decrease the predicted total crashes by 7.1% in the opening year and 10% in the design year. The percent decrease is smaller for fatal and injury crashes than for property damage only crashes.

Table 8-58: No-Build and Build Crash Average Frequency Predictions for 2020 and 2040.

Analysis Year	Alternative	FI Crashes	PDO Crashes	Total Crashes
2020	No-Build	16.5	33.1	49.6
	Build	15.5	30.6	46.1
	Change	- 1	- 2.5	- 3.5
	Percent Change	-6.1%	-7.6%	-7.1%
2040	No-Build	24.7	55.3	80.0
	Build	23.5	48.5	72.0
	Change	-1.2	-6.8	- 8.0
	Percent Change	-4.9%	-12.3%	-10.0%

The predicted crashes by year and severity for the No-Build and Build Alternatives are shown in **Table 8-59** through **Table 8-60**.

Table 8-59: Freeway and Ramp Predicted Crash Frequency – No-Build

Output Summary							
General Information							
Project description:	Example Freeway						
Analyst:	FDOT	Date:	5/10/2019		Area type:	Urban	
First year of analysis:	2020						
Last year of analysis:	2040						
	Project-level crash data available?			No	Last year of crash data:		
Estimated Crash Statistics							
Crashes for Entire Facility		**Total**	**K**	**A**	**B**	**C**	**PDO**
Estimated number of crashes during Study Period, crashes:		1349.4	8.0	20.7	132.9	268.6	919.3
Estimated average crash freq. during Study Period, crashes/yr:		64.3	0.4	1.0	6.3	12.8	43.8
Crashes by Facility Component	**Nbr. Sites**	**Total**	**K**	**A**	**B**	**C**	**PDO**
Freeway segments, crashes:	5	1250.4	6.9	17.5	117.5	247.5	860.9
Ramp segments, crashes:	8	99.0	1.1	3.2	15.4	21.1	58.3
Crossroad ramp terminals, crashes:	0	0.0	0.0	0.0	0.0	0.0	0.0
Crashes for Entire Facility by Year	**Year**	**Total**	**K**	**A**	**B**	**C**	**PDO**
Estimated number of crashes during the Study Period, crashes:	2020	49.6	0.3	0.8	5.1	10.3	33.1
	2021	50.9	0.3	0.8	5.2	10.5	34.0
	2022	52.3	0.3	0.8	5.3	10.8	35.0
	2023	53.7	0.3	0.9	5.5	11.0	36.1
	2024	55.1	0.3	0.9	5.6	11.3	37.1
	2025	56.6	0.3	0.9	5.7	11.5	38.1
	2026	58.0	0.4	0.9	5.8	11.8	39.2
	2027	59.5	0.4	0.9	5.9	12.0	40.3
	2028	61.0	0.4	0.9	6.1	12.3	41.3
	2029	62.5	0.4	1.0	6.2	12.5	42.4
	2030	64.0	0.4	1.0	6.3	12.8	43.5
	2031	65.5	0.4	1.0	6.4	13.0	44.7
	2032	67.0	0.4	1.0	6.6	13.3	45.8
	2033	68.6	0.4	1.0	6.7	13.5	46.9
	2034	70.2	0.4	1.1	6.8	13.8	48.1
	2035	71.8	0.4	1.1	6.9	14.1	49.3
	2036	73.4	0.4	1.1	7.1	14.3	50.4
	2037	75.0	0.4	1.1	7.2	14.6	51.6
	2038	76.6	0.4	1.1	7.3	14.8	52.8
	2039	78.2	0.4	1.2	7.5	15.1	54.1
	2040	79.9	0.5	1.2	7.6	15.4	55.3
Distribution of Crashes for Entire Facility							
Crash Type	**Crash Type Category**	**Estimated Number of Crashes During the Study Period**					
		Total	**K**	**A**	**B**	**C**	**PDO**
Multiple vehicle	Head-on crashes:	3.6	0.0	0.1	0.7	1.4	1.4
	Right-angle crashes:	19.9	0.2	0.4	2.6	5.4	11.4
	Rear-end crashes:	651.9	3.8	9.6	64.3	134.6	439.6
	Sideswipe crashes:	223.9	0.9	2.3	15.4	32.3	173.0
	Other multiple-vehicle crashes:	25.6	0.2	0.4	2.8	5.8	16.3
	Total multiple-vehicle crashes:	924.9	5.1	12.9	85.8	179.5	641.7
Single vehicle	Crashes with animal:	5.8	0.0	0.0	0.2	0.3	5.3
	Crashes with fixed object:	309.5	2.1	5.7	33.9	64.1	203.8
	Crashes with other object:	40.5	0.1	0.3	2.0	4.0	34.1
	Crashes with parked vehicle:	6.3	0.0	0.1	0.7	1.3	4.2
	Other single-vehicle crashes	62.5	0.7	1.8	10.4	19.4	30.2
	Total single-vehicle crashes:	424.6	2.9	7.9	47.1	89.1	277.6
	Total crashes:	1349.4	8.0	20.7	132.9	268.6	919.3

Table 8-60: Freeway and C-D Road Predicted Crash Frequency – Build

Output Summary							
General Information							
Project description:	Example Freeway						
Analyst:	FDOT	Date:	5/10/2019		Area type:	Urban	
First year of analysis:	2020						
Last year of analysis:	2040						
Crash Data Description							
Freeway segments	Segment crash data available?		No	First year of crash data:			
	Project-level crash data available?		No	Last year of crash data:			
Ramp segments	Segment crash data available?		No	First year of crash data:			
	Project-level crash data available?		No	Last year of crash data:			
Ramp terminals	Segment crash data available?		No	First year of crash data:			
	Project-level crash data available?		No	Last year of crash data:			
Estimated Crash Statistics							
Crashes for Entire Facility		**Total**	**K**	**A**	**B**	**C**	**PDO**
Estimated number of crashes during Study Period, crashes:		1231.9	7.7	20.7	124.3	254.1	825.1
Estimated average crash freq. during Study Period, crashes/yr:		58.7	0.4	1.0	5.9	12.1	39.3
Crashes by Facility Component	**Nbr. Sites**	**Total**	**K**	**A**	**B**	**C**	**PDO**
Freeway segments, crashes:	3	901.7	5.2	13.3	89.1	187.7	606.4
Ramp segments, crashes:	6	330.2	2.4	7.4	35.2	66.4	218.8
Crossroad ramp terminals, crashes:	0	0.0	0.0	0.0	0.0	0.0	0.0
Crashes for Entire Facility by Year	**Year**	**Total**	**K**	**A**	**B**	**C**	**PDO**
Estimated number of crashes during the Study Period, crashes:	2020	46.1	0.3	0.8	4.7	9.7	30.6
	2021	47.3	0.3	0.8	4.8	9.9	31.4
	2022	48.5	0.3	0.8	5.0	10.1	32.3
	2023	49.7	0.3	0.8	5.1	10.4	33.1
	2024	50.9	0.3	0.9	5.2	10.6	33.9
	2025	52.1	0.3	0.9	5.3	10.8	34.8
	2026	53.4	0.3	0.9	5.4	11.1	35.6
	2027	54.6	0.3	0.9	5.5	11.3	36.5
	2028	55.9	0.4	0.9	5.7	11.6	37.4
	2029	57.2	0.4	1.0	5.8	11.8	38.3
	2030	58.5	0.4	1.0	5.9	12.1	39.1
	2031	59.7	0.4	1.0	6.0	12.3	40.0
	2032	61.1	0.4	1.0	6.1	12.6	40.9
	2033	62.4	0.4	1.0	6.3	12.8	41.9
	2034	63.7	0.4	1.1	6.4	13.1	42.8
	2035	65.0	0.4	1.1	6.5	13.3	43.7
	2036	66.4	0.4	1.1	6.6	13.6	44.6
	2037	67.8	0.4	1.1	6.8	13.9	45.6
	2038	69.1	0.4	1.2	6.9	14.1	46.5
	2039	70.5	0.4	1.2	7.0	14.4	47.5
	2040	71.9	0.4	1.2	7.2	14.7	48.5

Distribution of Crashes for Entire Facility

Crash Type	Crash Type Category	Estimated Number of Crashes During the Study Period					
		Total	**K**	**A**	**B**	**C**	**PDO**
Multiple vehicle	Head-on crashes:	4.4	0.0	0.1	0.7	1.5	2.1
	Right-angle crashes:	14.6	0.1	0.3	1.9	4.0	8.3
	Rear-end crashes:	550.5	3.5	9.3	57.8	118.7	361.2
	Sideswipe crashes:	204.6	0.8	2.1	13.2	27.2	161.3
	Other multiple-vehicle crashes:	38.4	0.3	0.8	4.5	8.8	24.0
	Total multiple-vehicle crashes:	812.5	4.7	12.6	78.1	160.2	556.9
Single vehicle	Crashes with animal:	4.9	0.0	0.0	0.1	0.3	4.4
	Crashes with fixed object:	308.7	2.1	5.8	33.1	67.3	200.5
	Crashes with other object:	36.1	0.1	0.3	1.9	4.0	29.8
	Crashes with parked vehicle:	6.0	0.0	0.1	0.6	1.3	3.9
	Other single-vehicle crashes	63.6	0.7	1.9	10.4	21.1	29.6
	Total single-vehicle crashes:	419.4	3.0	8.1	46.2	93.9	268.2
	Total crashes:	1231.9	7.7	20.7	124.3	254.1	825.1

8.4 Example 4: Adding a Median to an Urban Five-Lane Arterial with Two-Way Left Turn Lanes – Estimating the Change in Future Crashes and Crash Severity per Year with the Project

8.4.1 Background and Problem Statement

A PD&E study is being conducted to add raised median and left-turn lanes to a four-lane highway that has a center two-way left-turn lane (TWLTL). The project segment is one-mile long. The proposed treatments are being considered to reduce the left turn crashes and improve traffic operations on a highly congested corridor. The objective of the evaluation is to estimate the total change in the number and severity of crashes over the life of the project (2022-2042). The project team proposed to apply the HSM predictive method for both alternatives and then apply the FDOT crash severity distribution to estimate crash severity.

This example demonstrates estimating crashes and crash severity per year. Refer to Example 2 for guidance on applying the predictive method.

Step 1 - Estimate Total Number of Crashes per Year for the Build and No-Build Scenarios

During methodology development it was agreed that the HSM predictive method for urban and suburban arterials would be used to estimate safety performance for the No-Build and Build Alternatives in the 2022 (opening year) and 2042 (design year). For this example, the No-Build condition is a five-lane arterial including a center TWLTL; a 5T facility as defined in the HSM. The Build-condition converts the facility to a four-lane divided road; a 4D facility as defined in the HSM. FDOT calibration factors will be applied to both scenarios.

The objective of the evaluation was to understand the difference in the total number of crashes and crash severity over the life of the project after implementing the median. To do so, the project team applied the HSM predictive method to five different future years and then estimated individual years between these predictions using linear interpolation **(Table 8-61)**. Though crashes may not increase linearly within the five-year increments, with such a short period between predictions the team agreed any differences would not be substantial.

Predicted
Linear Interpolation

Table 8-61: Example – Predicted Crash Calculations per Year

Year	No-Build Urban 4-Lane Undivided Facility: Predicted Crashes	Build - Urban 4 Lane Divided Facility: Predicted Crashes
	Total	Total
2022	25.0	18.0
2023	25.3	18.3
2024	25.5	18.5
2025	25.8	18.8
2026	26.1	19.1
2027	26.9	19.4
2028	27.1	19.6
2029	27.4	19.9
2030	27.7	20.2
2031	28.0	20.4
2032	28.8	20.7
2033	29.0	21.0
2034	29.3	21.2
2035	29.6	21.5
2036	29.8	21.8
2037	30.6	22.1
2038	30.9	22.3
2039	31.2	22.6
2040	31.4	22.9
2041[5]	32.1	23.1
Total Crashes	**567**	**411**

Over the 20-year life of the project, in the No-Build Alternative it was estimated that there would be 567 crashes; and there would be 411 crashes in the Build Alternative. Crash frequency would decrease with the proposed project.

Step 2 - Estimate Crashes by Severity per Year

The crash severities are estimated by multiplying total crashes per year by the FDOT HSM crash severity distribution factors (**Figure 8-5**). **Table 8-62** and **Figure 8-6** show the results. The total number of crashes would decrease in the Build scenario; however, the number of fatal and injury crashes is forecast to increase due to the difference between the Build and No-Build crash severity distributions.

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5 *For this example, 2022 is the first full year of operations (assuming it would be opened in January); therefore, 2041 is the 20th year of operations and the last year for the 20-year design period benefit-cost analysis.*

Figure 8-5: HSM Crash Distribution for Florida

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Table 122.6.4 HSM Crash Distribution for Florida

Type Facility		Abbreviation	K	A	B	C	O
Rural Roadways	2-lane Undivided	R2U	0.028	0.094	0.181	0.187	0.509
	4-lane Undivided	R4U	0.033	0.093	0.164	0.186	0.524
	4-lane Divided	R4D	0.028	0.090	0.187	0.196	0.499
Urban & Suburban Arterials	2-lane Undivided	U2U	0.009	0.050	0.150	0.224	0.567
	3-lane TWLTL	U32LT	N/A				
	4-lane Undivided	U4U	0.004	0.031	0.110	0.204	0.650
	4-lane Divided	U4D	0.008	0.046	0.142	0.234	0.571
	5-lane TWLTL	U52LT	N/A				
Freeways	Rural		0.017	0.065	0.143	0.163	0.612
	Urban		0.006	0.035	0.113	0.206	0.641
	Ramps		0.004	0.032	0.107	0.210	0.647
All	All Roadways and Ramps		0.007	0.041	0.124	0.217	0.611

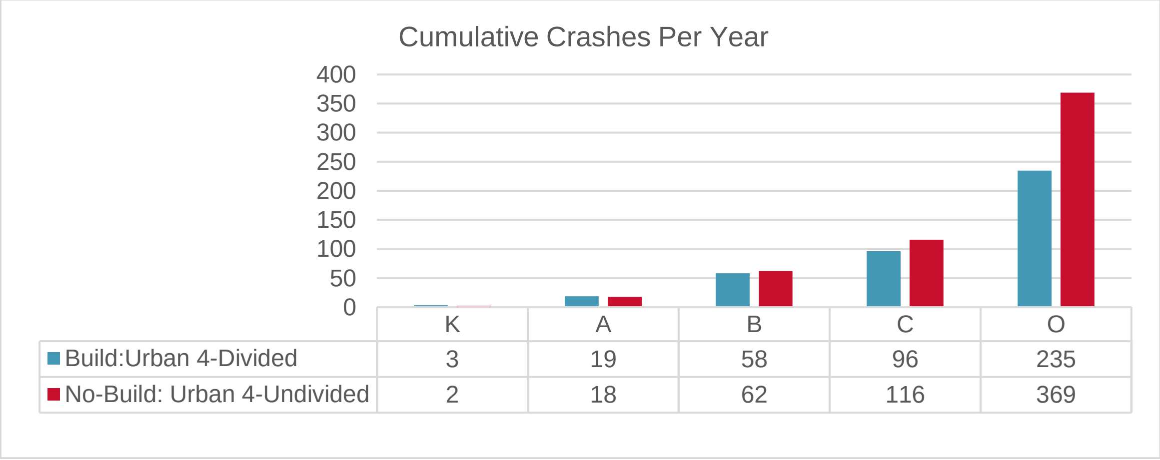
Notes:
K – Fatality
A - Incapacitating Injury
B - Non-incapacitating Injury
C - Possible (or minor) Injury
O - Property Damage Only

Predicted
Linear Interpolation

Table 8-62: Example – Predicted Crash Severity Breakdown per Year

Year	Build -Urban 4 Lane Divided: Crashes by Severity						No-Build -Urban 4 Lane Undivided: Crashes by Severity					
	Total	K	A	B	C	O	Total	K	A	B	C	O
2022	18.0	0.14	0.8	2.6	4.2	10.3	25.0	0.10	0.8	2.8	5.1	16.3
2023	18.3	0.15	0.8	2.6	4.3	10.4	25.3	0.10	0.8	2.8	5.2	16.4
2024	18.5	0.15	0.9	2.6	4.3	10.6	25.5	0.10	0.8	2.8	5.2	16.6
2025	18.8	0.15	0.9	2.7	4.4	10.7	25.8	0.10	0.8	2.8	5.3	16.8
2026	19.1	0.15	0.9	2.7	4.5	10.9	26.1	0.10	0.8	2.9	5.3	17.0
2027	19.4	0.15	0.9	2.7	4.5	11.0	26.9	0.11	0.8	3.0	5.5	17.5
2028	19.6	0.16	0.9	2.8	4.6	11.2	27.1	0.11	0.8	3.0	5.5	17.6
2029	19.9	0.16	0.9	2.8	4.7	11.4	27.4	0.11	0.8	3.0	5.6	17.8
2030	20.2	0.16	0.9	2.9	4.7	11.5	27.7	0.11	0.9	3.0	5.6	18.0
2031	20.4	0.16	0.9	2.9	4.8	11.7	28.0	0.11	0.9	3.1	5.7	18.2
2032	20.7	0.17	1.0	2.9	4.8	11.8	28.8	0.12	0.9	3.2	5.9	18.7
2033	21.0	0.17	1.0	3.0	4.9	12.0	29.0	0.12	0.9	3.2	5.9	18.9
2034	21.2	0.17	1.0	3.0	5.0	12.1	29.3	0.12	0.9	3.2	6.0	19.0
2035	21.5	0.17	1.0	3.1	5.0	12.3	29.6	0.12	0.9	3.3	6.0	19.2
2036	21.8	0.17	1.0	3.1	5.1	12.4	29.8	0.12	0.9	3.3	6.1	19.4
2037	22.1	0.18	1.0	3.1	5.2	12.6	30.6	0.12	0.9	3.4	6.2	19.9
2038	22.3	0.18	1.0	3.2	5.2	12.7	30.9	0.12	1.0	3.4	6.3	20.1
2039	22.6	0.18	1.0	3.2	5.3	12.9	31.2	0.12	1.0	3.4	6.4	20.3
2040	22.9	0.18	1.1	3.2	5.3	13.1	31.4	0.13	1.0	3.5	6.4	20.4
2041	23.1	0.19	1.1	3.3	5.4	13.2	32.1	0.13	1.0	3.5	6.6	20.9
Total Crashes	**411**	**3**	**19**	**58**	**96**	**235**	**567**	**2**	**18**	**62**	**116**	**369**

Figure 8-6: Example – Predictive Crash Severity Comparison



9 Key Terms

Annual Average Daily Traffic (AADT): Total volume on a roadway for an entire year divided by the number of days in the year. Represents the average daily traffic volume to account for fluctuations due to holidays, weather, seasonal patterns, etc.

Benefit-Cost Analysis (BCA): A formal economic analysis of the impacts of a measure or program such as a road safety program designed to assess whether the advantages (benefits) of the measure or program are greater than its disadvantages (costs).

Calibration Factor: Factor to adjust crash frequency estimates produced from a safety prediction procedure to approximate local conditions.

Countermeasure (i.e., treatment): A strategy intended to reduce the crash frequency or severity, or both, at a site.

Crash frequency: The number of crashes occurring at a particular site, facility, or network. Crash frequency may be characterized as observed, predicted, or expected crash frequency.

Crash modification factor (CMF): A multiplicative factor used to compute the long-term average crash frequency after implementing a given countermeasure at a specific site. Values of CMFs represent the long-term expected change in crashes relative to a set of base conditions. Under the base conditions, the value of the CMF is 1.0. A CMF of 1.0 indicates no expected change in crashes. A CMF less than 1.0 indicates an expected reduction in crashes and a CMF greater than 1.0 indicates an expected increase in crashes.

Crash modification function: A formula used to compute the CMF for a specific site based on its characteristics. It allows the CMF to change over the range of a variable or a combination of variables.

Crash reduction factor (CRF): The percentage crash reduction expected after implementing a given countermeasure at a specific site, equal to (1 - CMF) x 100.

Empirical Bayes (EB): Method of adjusting predicted crashes by utilizing existing crash data in conjunction with the predictive models or equations to better statistically approximate the number of predicted crashes. Can only be used in situations where the existing and predictive conditions for the roadway are unchanged.

Peak Hour: The peak hour (typically AM or PM) of traffic volume traversing a roadway segment or intersection to allow for the most critical period to be analyzed and used for operational and safety analysis.

Predictive Method: Use of equations (Safety Performance Functions) to estimate the predictive average crash frequency for a roadway segment or intersection utilizing the roadway attributes as input parameters.

Project costs: Project costs can relate to the design, construction, and maintenance costs of a project as well and the economic impacts of a project related to safety, environment, or right of way. The use of the term will be sensitive to the analysis context.

Roadway Characteristics: Term used to broadly relate to the cross-sectional elements of a roadway: number, type, and width of lanes; type and width of shoulder; type and width of median; or type of traffic control.

Safety performance function (SPF): An equation used to estimate or predict the average crash frequency per year at a location as a function of traffic volume and, in some cases, roadway or intersection characteristics (e.g., number of lanes, traffic control, or type of median).

10 Reference Documents

In addition to various reports and technical documents that are listed in Section 1.5, the following documents were referenced in preparation of this Guidebook. The analyst may review these documents for detailed information to gain a better understanding of the safety analyses and the tools used to perform such analyses.

Crash Data Analysis Manual, Version 1.0, Virginia Department of Transportation. November 2017. *http://www.virginiadot.org/business/VDOT_Crash_Data_Manual_Nov2017.pdf*

Crash Reduction Analysis System Hub (CRASH) User's Manual. April 2014 https://fdotewp1.dot.state.fl.us/trafficsafetywebportal/docs/SSO_Web_Portal_CRASH.pdf

FDOT Highway Safety Manual User Guide, Florida Department of Transportation: State Safety Office / State Roadway Design Office. 2015. http://www.fdot.gov/safety/11A-SafetyEngineering/TransSafEng/HighwaySafetyManual.shtm

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Standardization of Crash Analysis in Florida, Florida International University, Florida Department of Transportation. March 2012. *http://www.safetyanalyst.org/pdf/FloridaHSMandSafetyAnalystEvaluation.PDF*

Uniform Traffic Crash Report Manual, Florida Department of Highway Safety and Motor Vehicles. February 2019. *https://www.flhsmv.gov/pdf/courts/crash/CrashManualComplete.pdf*

Washington State Department of Transportation Safety Analysis Guide: Multimodal Development and Delivery. September 2017. http://www.wsdot.wa.gov/publications/fulltext/design/ASDE/Safety_Analysis_Guide.pdf

Safety Analysis Guidebook

for Project Development and Environment (PD&E) Studies

Office of Environmental Management
Florida Department of Transportation
605 Suwannee Street
Tallahassee, Florida 33299

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