Highway Safety Improvement Program Procedures And Techniques

aka 'Red Book'

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NEW YORK STATE OF OPPORTUNITY. | Department of Transportation

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4. ACRONYMS

AADT	Annual Average Daily Traffic
AOI	Area Of Influence
AWP	Annual Work Program
BCR	Benefit-Cost Ratio
CARDS	Centerline Audible Roadway Delineator
CMAQ	Congestion Management and Air Quality Improvement Program
CMF	Crash Modification Factor
DMV	Department of Motor Vehicles
FARS	Fatality Analysis Reporting System
FDE	Fundamental Data Elements
FDR	Final Design Report
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
GCWR	Gross Combined Weight Rating
GTSC	Governor’s Traffic Safety Committee
GVWR	Gross Vehicle Weight Rating
Haz Mat	Hazardous Materials
HPMS	Highway Performance Monitoring System
HRRR	High Risk Rural Roads
HSIP	Highway Safety Improvement Program
HSM	Highway Safety Manual
IPP	Initial Project Proposal
ITSMR	Institute for Traffic Safety Management and Research
LOSS	Level of Service of Safety
LRS	Linear Referencing System
LRSP	Local Road Safety Plan
MIRE	Model Inventory of Roadway Elements
MMUCC	Model Minimum Uniform Crash Criteria

MPO	Metropolitan Planning Organization
MTP	Metropolitan Transportation Plan
NHFP	National Highway Freight Program
NHPP	National Highway Performance Program
NHTSA	National Highway Traffic Safety Administration
NYSDMV	New York State Department of Motor Vehicles
NYSDOT	New York State Department of Transportation
ORT	Online Reporting Tool
PIL	Priority Investigation Location
PIR	Project Initiation Request
PNF	Project Notification Form
PP&MG	Program Planning and Management Group
PSAP	Pedestrian Safety Action Plan
PSI	Potential for Safety Improvement
PSR	Project Scoping Report
RHCP	Railway-Highway Grade Crossings Program
RSA	Road Safety Audit
RTE	Regional Traffic Engineer
SAFETAP	Safety Appurtenance Program
SDL	Safety Deficient Location
SEE	Safety Evaluation Engineer
SHARDS	Shoulder Audible Roadway Delineator
SHSP	Strategic Highway Safety Plan
SKARP	Skid Accident Reduction Program
SPF	Safety Performance Function
STBG	Surface Transportation Block Grant
STIP	Statewide Transportation Improvement Program
TAP	Transportation Alternatives Program
TIP	Transportation Improvement Program

TraCS	Traffic and Criminal Software
TRID	Transport Research International Documentation
USC	United States Code
VMT	Vehicle Miles Traveled

EXECUTIVE SUMMARY

The goal of the Highway Safety Improvement Program is to eliminate fatalities and serious injuries that occur on any public road and for all modes of travel. This is represented by NYSDOTs “Toward Zero Deaths” vision. In the recent 2023 Strategic Highway Safety Plan, New York State adopted the Safe Systems Approach to achieve this vision. While this represents an aggressive target, there simply is no acceptable number of deaths or serious injuries for New York State residents or those who travel here.

The Federal Highway Administration’s Highway Safety Manual outlines the steps to an effective safety program which NYSDOT supports and has built into the project development process. This offers an opportunity to include safety analysis and recommendations from low-cost safety improvements to large scale capital projects. This process begins with NYSDOTs network screening which prioritizes sites based on their “potential for safety improvement” (PSI). A safety Investigation, following the NYSDOT Safety Investigation Manual (aka Yellow Book), is performed for these sites and countermeasures are recommended where appropriate.

Once the countermeasures have been implemented, evaluations are performed to determine the effectiveness of the safety improvements and this information helps to calibrate the safety performance functions for future analyses.

While NYSDOT is focused on implementing engineering solutions as part of transportation projects, the success of this program is dependent on our partnerships with other NY State agencies, Metropolitan Planning Organizations and local municipalities who cover the other 3 ’E’s of Safety; Education, Enforcement, and Emergency Services.

NYSDOT is committed to following this data driven approach to safety and recognizes the need to incorporate equity into the planning process. As further guidance is developed by FHWA, NYSDOT will update this guide as appropriate.

CHAPTER 1. INTRODUCTION

1.1 HSIP Purpose

The Highway Safety Improvement Program (HSIP) is a state-administered, core Federal-aid program with the purpose of achieving a significant reduction in fatalities and serious injuries on all public roads. FHWA establishes the HSIP requirements via 23 CFR 924, and the States develop and administer a program to meet their needs. The HSIP requires a strategic, data-driven approach to managing safety on all public roads. Further, the HSIP focuses on performance, requiring States to establish and document long-term, outcome-oriented, safety performance targets and describe progress to achieve the targets in their annual HSIP report.

The purpose of the Highway Safety Improvement Program (HSIP) is to achieve a significant reduction in fatalities and serious injuries on all public roads.

New York State's HSIP is guided by the New York State Strategic Highway Safety Plan (SHSP), which outlines a vision of making roads in New York safer for all users. The plan sets specific goals for reducing fatalities and serious injuries on all public roads. These goals influence annual target-setting for the HSIP and other safety-related plans. The SHSP identifies general emphasis areas and cross-cutting considerations as well as specific strategies to help guide highway safety investment decisions. While the HSIP focuses on engineering improvements, the SHSP identifies a 4E approach to safety (i.e., engineering, education, enforcement, and emergency services). The other E's should be considered as appropriate in developing HSIP projects and solutions to address the underlying safety concerns.

The SHSP is important to the HSIP as it establishes priorities for investments in safety. Further, Federal law requires any expenditure of HSIP funds to be consistent with priorities established in the SHSP. For this reason, it is important to consider the SHSP in the HSIP process and account for future HSIP needs when updating the SHSP. The New York State Department of Transportation (NYSDOT or "the Department") updates the SHSP at least every five years in coordination with statewide, regional, and local safety partners.

1.2 Overview of HSIP Process

The HSIP comprises three components: planning, implementation, and evaluation as shown in Figure 2.

Planning	**Identify problems: collect, manage, and analyze data to identify opportunities to improve safety.** **Develop countermeasures: develop targeted strategies to address crash contributing factors.** **Prioritize projects: develop a balanced portfolio of projects that maximizes return on investment.**
Implementation	**Implement safety projects**: design projects, identify funding sources, allocate resources, program projects, and develop a plan to evaluate investments.

Evaluation	**Estimate effectiveness of projects and programs**: perform project-, countermeasure-, and program-level evaluations to understand the safety performance and cost-effectiveness of investments and to inform future decisions.

Figure 1. General HSIP process.

Hotspot and systemic safety are complementary and support a comprehensive approach to safety management.

These components can be further disaggregated into multiple steps within the traditional (hotspot) or systemic approaches to safety management as shown in Figure 2. The hotspot approach focuses on selecting and treating sites based on site-specific crashes. The systemic approach focuses on selecting and treating sites based on site-specific risk factors (i.e., geometric and operational attributes known to increase crash risk). These two approaches are complementary and support a comprehensive approach to safety management.

As illustrated in Figure 2, both approaches start by establishing the focus of the analysis, typically through the selection of a focus crash type and facility type. The focus crash type could be all crashes and the focus facility type could be the entire network, or the focus could be a specific crash type (e.g., fatal and serious injury crashes, roadway departure crashes) and/or facility type (e.g., intersections, rural two-lane roads). The primary difference between the two approaches is the order in which screening and diagnosis occur in the planning stage. The hotspot approach starts with network screening to identify sites with potential for safety improvement, followed by diagnosis to identify crash contributing factors at each location of interest. The systemic approach starts with diagnosis at the network level to identify risk factors associated with the focus crash type and focus facility type, followed by screening to identify and prioritize locations with the risk factors. The remainder of the steps are nearly identical for the two approaches. Countermeasure selection focuses on identifying appropriate countermeasures to target the underlying crash contributing factors. Economic appraisal helps to determine the most cost-effective countermeasure(s) for each location of interest. Agencies then prioritize among multiple potential projects, comparing both hotspot and systemic projects, to develop and implement an Annual Work Program (AWP). The final step is to evaluate the performance of implemented projects and programs to determine what is working well (and what is not).

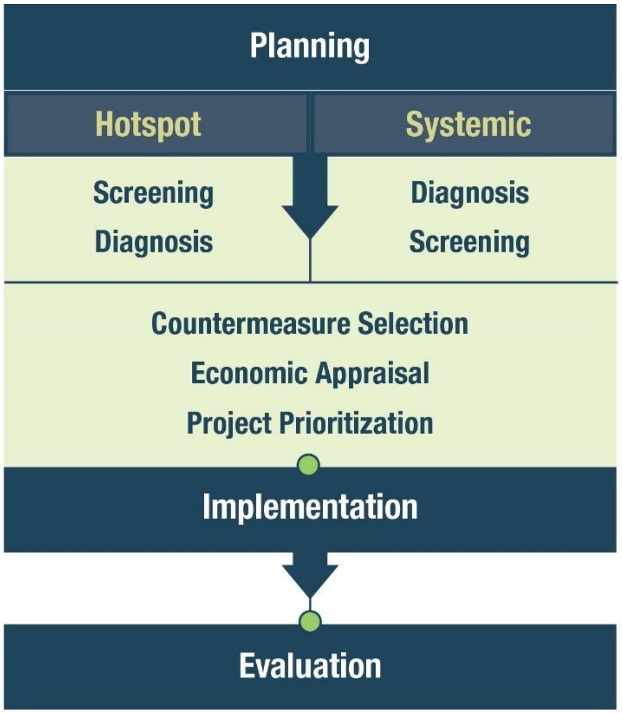


Figure 2. Roadway safety management process.

1.2.1 Hotspot Approach (Steps 1 – 2)

The hotspot approach typically focuses on sites with the highest potential for safety improvement and is often limited to one site or corridor per project. In New York, these are the Priority Investigation Locations (PILs) and Safety Deficient Locations (SDLs). The following is an overview of the first two components of the hotspot approach as implemented by the Department.

1. **Network Screening**: The Main Office conducts annual network screening to identify sites on the state system that have the highest potential for safety improvement. The focus crash type is fatal and serious injury crashes. The focus facility type is the state system. Main Office then provides the network screening results to the Regional Offices for review and consideration for the AWP. Regions select hotspot sites for further investigation and plan safety improvement projects. Local agencies work with metropolitan planning organizations (MPOs) and NYSDOT Regional Offices to identify sites on those roads under county or local municipal jurisdiction. Other opportunities to identify sites with potential for safety improvement include requests from other NYSDOT offices (e.g., Office of Design, Office of Maintenance) and the public.
2. **Diagnosis**: Analysts perform safety investigations to identify correctable crash patterns and contributing factors at hotspot sites produced from network screening. NYSDOT Regional Offices are required to investigate X percent of the list of sites with potential for safety improvement on an annual basis. Local agencies are responsible for managing safety on the roads under their jurisdiction and are required to submit the results of highway safety investigations when applying for HSIP funding.

1.2.2 Systemic Approach (Steps 1 – 2)

The systemic approach also focuses on sites with the highest potential for safety improvement but does so from a systemwide perspective. Specifically, the systemic approach focuses on crash types and contributing factors common to many sites across the network and typically involves multiple sites per project. As such, the systemic approach is proactive because it focuses on sites with risk factors; the sites are not required to have a history of crashes. The following is an overview of the first two components of the systemic approach as implemented by the Department.

1. **Diagnosis**: The NYSDOT Main Office performs systemic analysis for focus crash types such as pedestrian, roadway departure, and intersection crashes to identify focus facility types and risk factors associated with the focus crash type. Main Office documents the results either informally through memos or formally through safety action plans (e.g., Pedestrian Safety Action Plan and Roadway Departure Safety Action Plan) and provides the results to the Regional Offices for review and implementation. Regional Offices, MPOs, and local agencies can also perform systemic analysis to identify regional or local focus areas and risk factors.
2. **Network Screening**: Regional Offices use the list of risk factors to narrow down locations on the focus facility type as candidates for treatment. Local agencies work with MPOs and NYSDOT Regional Offices to identify sites on those roads under county or local municipal jurisdiction. While these candidate sites represent opportunities for systemic improvements, there is a need to select appropriate countermeasures in Step 3 and further investigate the locations to confirm each candidate is suitable for the treatment. There is no requirement for Regional Offices to investigate candidate systemic locations or implement systemic improvements; however, there is a separate set-aside of funding for systemic improvements and Regional Offices are required to perform or utilize the results of systemic analysis to apply for these funds. Local agencies are responsible for managing safety on the roads under their jurisdiction and are required to submit the results of systemic safety analysis when applying for systemic funding.

1.2.3 Hotspot and Systemic Approach (Steps 3 – 6)

The following is a brief overview of the final four components of the hotspot and systemic approaches, which are nearly identical, as implemented by the Department.

The key to countermeasure selection is targeting the underlying crash contributing factors (from diagnosis).

3. **Countermeasure Selection**: Once the crash contributing factors and patterns are understood, analysts identify appropriate countermeasures to target the issues while also considering the surrounding land use and context. Regional Offices identify potential countermeasures, considering insights from stakeholders including local agencies and the public. When targeting focus crash types such as pedestrian and roadway departure crashes, the respective safety action plans identify applicable countermeasures as a starting point.
4. **Economic Appraisal**: Regional Offices and local agencies perform economic appraisal to inform the selection of preferred countermeasures at a given location. Those seeking HSIP funding are required to perform and submit a benefit-cost analysis for capital improvement projects. A detailed benefit-cost analysis is not required for low-cost safety

improvements; however, a high-level benefit-cost analysis can help to select the preferred countermeasure.

5. **Project Prioritization**: While the Regional Traffic Engineer should prioritize capital improvement projects within their region, the NYSDOT Main Office performs project prioritization for the HSIP as a whole. Using a data-driven approach, the Main Office reviews HSIP project applications for eligibility and selects those projects that maximize the effectiveness of the program within the available budget. Main Office submits prioritized projects to the FHWA New York Division Office for concurrence and authorization. The Department then incorporates selected projects into the Statewide Transportation Improvement Program (STIP). Regional Offices develop and implement HSIP projects between steps 5 and 6.
6. **Safety Effectiveness Evaluation**: As projects are completed, the safety effectiveness evaluation is a shared responsibility among the Main Office and Regional Offices. The Regional Offices track the start and completion dates of construction, verify the actual improvements, and perform project-level evaluations. The Main Office aggregates the regional project-level evaluations to estimate the effectiveness of countermeasures and to evaluate the overall effectiveness of the HSIP and other safety programs. The results of the project-, countermeasure-, and program-level evaluations help to inform future decisions.

1.3 HSIP Investment Strategies

The Main Office is responsible for providing statewide strategy guidance for the HSIP. Those responsible for administering and delivering highway safety improvement projects (Regional offices) should consider the following strategies in developing and prioritizing HSIP project applications.

1. Create a balanced portfolio of state and local HSIP projects.
2. Create a balanced portfolio of hotspot, systemic, and other HSIP projects.
3. Consider data availability and quality.

1.3.1 Balanced Portfolio of State and Local HSIP Projects

The Department recommends a balance of state and local HSIP projects. Ideally, the distribution of state and local HSIP funding would reflect the proportion of fatal and serious injuries reported on the respective systems, but ultimately there are several factors that drive project prioritization and funding distribution. Regional offices should consider the following factors when developing a balanced portfolio of state and local HSIP projects:

- **State Highway System** roadways represents approximately 16% of the mileage for all public roads in New York (18,960 miles), with 32% of New York’s fatalities and serious injuries. The Department has more reliable data on the state highway system compared to off-system roads. Most of these roads can be analyzed with predictive methods.
- **Off-System** roadways represent 84% of the mileage for all public roads in New York (98,512 miles), with 68% of New York’s fatalities and serious injuries. Many of these roads lack complete data to apply more reliable analysis methods; however, with 68% of fatalities and serious injuries, off-system roads are a critical safety concern and require strategic investments.

1.3.2 Balanced Portfolio of Hotspot, Systemic, and Other HSIP Projects

The Department recommends a combination of the HSIP project types described below. Each project type addresses safety performance in a different way, creating a diversified portfolio of safety investments; however, the HSIP does not have to include projects of each type every year. Regional offices should use discretion to address their safety concerns with projects that provide the greatest opportunity to reduce fatalities and serious injuries.

- **Hotspot projects** focus on locations with the highest potential for safety improvement across the network. The Main Office performs annual network screening to identify sites with potential for safety improvement. Regional offices then investigate and address these poorly performing locations if an improvement project is feasible and cost-effective. Hotspot projects should address fatal and serious injury crash patterns and other contributing factors demonstrated by site-specific crash experience as well as geometric and operational characteristics. Hotspot projects are typically the most effective approach to address locations with the highest crash frequency or highest potential for safety improvement. Since hotspot projects only cover a small portion of the network and can be relatively costly, they should be reserved for improving the locations with the highest potential for improvement. Hotspot projects on off-system roads should be limited to high-volume sites experiencing serious crashes with clear opportunities for improvement. With so many off-system miles, hotspot projects on off-system roadways are generally not a cost-effective way to address statewide fatalities and serious injuries.
- **Systemic projects** focus on mitigating the factors associated with crash types that result in large numbers of fatalities and serious injuries across the network. The New York State SHSP identifies emphasis areas to establish focus crash types. Regional offices should select focus crash types that are most applicable to the region and identify the facility types where these crash types are most prevalent. The Main Office provides tools and support to help regions identify factors that contribute to the focus crash types and countermeasures that target the contributing factors. Systemic projects are typically the most cost-efficient approach to addressing statewide fatalities and serious injuries as well as the emphasis areas in the SHSP. Systemic projects also tend to be more cost-effective than other project types on off-system roadways.
- **Policy-based projects** are improvements to bring roadway design or operational features up to a standard. Policy-based countermeasures (also called nominal or systematic) often aim to reduce liability as well as crash risk, such as updating old roadside hardware to current designs or meeting sign retroreflectivity standards. These types of improvements should be implemented through non-HSIP projects to the extent possible but can qualify for HSIP funding if there is a demonstrated safety need and expected benefit. Policy-based improvements are typically implemented at all appropriate locations but may be prioritized by site-specific or regional safety performance. Policy-based improvements can help fill program budgets with scalable countermeasure implementation. Policy-based improvements can be an effective approach to addressing safety issues on off-system roads. Since crashes tend to be dispersed on off-system roads, an effective approach to risk management is to improve deficiencies or add safety features to all roads. Note these improvements can get costly across the entire off-system network and should focus on low-cost countermeasures in regions with pronounced infrastructure needs or relatively high fatalities and serious injuries.

- **Data and analysis projects** can help to add analytical capabilities, improve HSIP management, or meet legislative data requirements. The Department realizes comprehensive data and modern analytics can improve decision making, increase the effectiveness of resulting projects, and enhance the delivery of the HSIP. As such, the Department identifies strategic data and analysis improvements to help reduce fatalities and serious injuries.

1.3.3 Data Availability and Quality

The Department recommends using the most reliable methods to investigate safety performance issues, develop alternatives, and estimate the effectiveness of proposed projects. Ideally, all projects would be analyzed on a consistent basis using the same methods; however, the required data and methods are not available for every roadway. Regional offices should consider the following factors related to data availability and quality when developing HSIP projects:

- Some roads lack roadway inventory and traffic data.
- There is a general lack of pedestrian and bicycle inventory and exposure data.
- Predictive methods have not been developed for every roadway type and situation.
- Projects proposed at locations with more reliable data tend to result in more reliable investments.

1.4 Roles and Responsibilities

Figure 3 shows the general HSIP workflow for project programming across stakeholders. The detailed roles in administering and implementing the HSIP are described below. In general, the NYSDOT Main Office is responsible for managing the HSIP as well as providing strategy guidance, policies, and tools for implementation. Regional Offices, MPOs, and local agencies are responsible for administration and delivery of highway safety improvement projects within their jurisdiction. FHWA is generally responsible for overseeing all Federal-aid expenditures, including the HSIP.

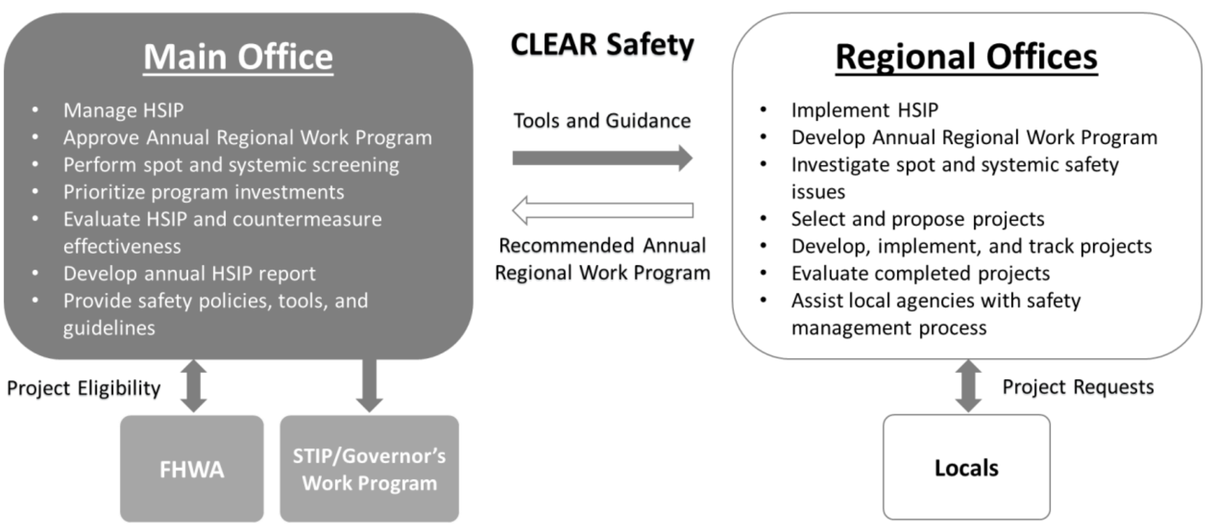


Figure 3. HSIP process workflow.

The **NYSDOT Main Office** manages the HSIP, conducts annual network screening for the state system, performs systemic analyses for focus programs, and evaluates the effectiveness of countermeasures and programs. The Main Office also reviews applications for regional safety projects, prioritizes program investments, and provides policies, tools, and guidelines to assist regional offices and local agencies with implementing the HSIP. While local agencies are not required to follow the NYSDOT HSIP process, the Main Office provides access to safety data as well as the HSIP policies, tools, and guidelines.

The **NYSDOT Regional Offices** are responsible for conducting highway safety investigations, developing highway safety improvement proposals, delivering highway safety improvement projects, tracking and reporting progress on regional safety investments, and evaluating completed projects. All regions have a Regional Director and most regions have a Regional Traffic Engineer (RTE), Safety Evaluation Engineer (SEE), and supporting staff that identify, plan, design, implement, and evaluate HSIP projects with support from the Main Office. Since a large portion of crashes occur on local roadways, it is important that Regions engage in local safety improvement initiatives. Each region can work with MPOs and local jurisdictions to assist them in improving safety within their region. Specifically, regional offices can help MPOs and local agencies to understand HSIP requirements, develop effective projects, and track the effectiveness of improvements.

The **Federal Highway Administration** (FHWA) assists with program strategy, oversees all Federal-aid expenditures, and assures the HSIP meets federal requirements. FHWA also offers technical assistance and training to NYSDOT and local agencies.

New York's **MPOs and local agencies** are integral to managing safety on all public roads. NYSDOT Main Office coordinates with MPOs to establish annual HSIP targets for at least the following five federally-required safety performance measures:

1. Number of fatalities
2. Rate of fatalities
3. Number of serious injuries
4. Rate of serious injuries
5. Number of non-motorized fatalities and non-motorized serious injuries

These targets are included in the Metropolitan Transportation Plan (MTP) and linked to investment priorities in the Transportation Improvement Program (TIP). Specifically, MPOs describe the anticipated effect of the TIP toward achieving HSIP targets in the MTP. MPOs and local agencies also coordinate with NYSDOT's Regional Offices to identify, propose, and implement effective off-system highway safety improvement projects. Local agencies develop and implement locally-administered projects as well as Local Road Safety Plans (LRSP) to improve safety in their jurisdictions. MPOs and local agencies can work with local safety stakeholders (e.g., police, emergency responders, and schools) to develop projects that address local safety needs.

Partner organizations serve as ambassadors of traffic safety and help promote the vision, mission, and goals established in the SHSP. Partners include the Governor's Traffic Safety Committee (GTSC), New York State Department of Motor Vehicles (NYSDMV), Institute for Traffic Safety Management and Research (ITSMR), National Highway Traffic Safety Administration (NHTSA), Federal Motor Carrier Safety Administration (FMCSA), state and local police, community groups, universities, and professional associations responsible for supplemental programs that improve safety beyond engineering.

New York's road users are the most important stakeholder in the HSIP. Each HSIP project aims to improve the safety and quality of life for road users. The HSIP is most effective when the public is engaged in safety, provides feedback during the development of HSIP projects, and actively reports safety concerns to NYSDOT and local government agencies.

1.5 NYSDOT Organization and HSIP Contacts

NYSDOT is decentralized with a Main Office and 11 Regional Offices. Table 1 lists the primary contacts for the HSIP. Please feel free to contact us for more information.

Table 1. Primary NYSDOT HSIP contacts.

Title	Phone Number	Website
HSIP Manager	(518) 485-0164	https://www.dot.ny.gov/divisions/operating/osss/highway/improvement-program
Safety Data Manager	(518) 457-9736 (518) 485-8406	https://www.dot.ny.gov/divisions/operating/osss/highway/accident-analysis-toolbox
Regional Traffic Engineer Region 1 Region 2 Region 3 Region 4 Region 5 Region 6 Region 7 Region 8 Region 9 Region 10 Region 11 (Director)	 (518) 457-5283 (315) 793-2459 (315) 428-4380 (585) 272-3460 (716) 847-3268 (607) 324-8512 (315) 785-2321 (845) 437-3320 (607) 721-8080 (631) 952-6020 (718) 482-4526	https://www.dot.ny.gov/regional-offices

1.6 How to Use This Manual

This manual focuses on the HSIP process. Chapter 1 provides an overview of the HSIP process, defines the roles and responsibilities of various stakeholders, and identifies key NYSDOT contacts with respect to the HSIP. Chapter 2 lists the HSIP funding eligibility requirements and describes the annual HSIP reporting requirements. Chapter 3 describes the relevant safety data systems that support the HSIP. Chapter 4 describes the planning component of the HSIP, including both the hotspot and systemic approaches to safety management. Chapter 5 describes the implementation component of the HSIP, including project prioritization and funding opportunities. Chapter 6 describes the evaluation component of the HSIP. The appendixes provide resources to support various aspects of the HSIP process.

While this manual focuses on the NYSDOT HSIP process, local agencies could adopt the manual, in part or in whole, to guide safety management efforts on the local system. Further, local agencies have access to CLEAR Safety and can use the tool to implement any or all components of the hotspot and systemic approaches for roads in their jurisdiction. For instance, local agencies could use CLEAR Safety to identify focus crash types, focus facility types, and risk factors in support of local road safety plans (LRSPs). This manual also provides templates to allow analysts to complete these procedures offline and outside of CLEAR.

A companion document, titled *Safety Investigation Procedures Manual* (The Yellow Book), serves as a step-by-step application guide for performing highway safety investigations as part of the Annual Regional Work Program and as part of the Department's project development process. The following is an overview of each component.

Annual Regional Work Program: Each region is required to perform highway safety investigations for at least X percent of locations identified as sites with promise on an annual basis. The Yellow Book supports diagnosis, countermeasure selection, and economic appraisal, which coincides with the planning component of the HSIP once network screening is complete.

Project Development Process: The project development process should include a safety review for every project (i.e., capital project or maintenance location). The Yellow Book supports a consistent process for integrating safety in the project development process. For example, the Office of Planning could use the Yellow Book to quantify and compare the safety performance of different options during alternatives analysis. The Office of Design could use the Yellow Book to quantify the safety impacts of design decisions and design exceptions (or variances). Chapter 5 of the Highway Design Manual presents a decision process to help determine what level of safety analysis is appropriate based on the scale and scope of the project. The following guidance indicates the minimum level of safety analysis for Safety and non-exempt Capital projects:

1. **Link all Safety and non-exempt Capital projects to an existing investigation** or begin an investigation in CLEAR Safety.
    a. If an appropriate investigation was already completed at project location, link the investigation to the proposed project if not already linked.
    b. If no investigation exists, initiate the investigation or contact the Regional Safety Evaluation Engineer to initiate the investigation.
2. **Perform basic safety analysis** (i.e., complete steps in Section 2.1 – 2.3 of the Yellow Book).
3. **Determine if intermediate or advanced safety analysis is required** based on Table 2.
    a. Identify all systemic and AWP sites within the project limits.
    b. Note general safety issues based on potential for safety improvement (PSI), which is a comparison of the site-specific safety performance compared to the statewide average using either observed or expected crashes depending on whether traffic volume is available. This performance measure is indicated in CLEAR Safety in the 'Crash Analysis' step of the 'Site Investigation' module.
    c. Note specific safety issues based on the test of proportions, which indicates over-represented crash types. This performance measure is indicated in CLEAR Safety in the 'Crash Analysis' step of the 'Site Investigation' module.

Table 2. Requirements for intermediate or advanced safety analysis.

Determinant	Category	Intermediate	Advanced
Annual Work Program (AWP)	No portion of project overlaps with a site on AWP	Optional	Optional
	Any portion of project overlaps with a site on AWP	Recommended	
Potential for safety improvement (PSI)	PSI ≤ 0	Optional	Optional
	PSI > 0	Recommended	
Test of proportions	No crash types over-represented	Optional	Optional
	One or more crash types over-represented		Optional

4. **Perform intermediate or advanced safety analysis**, if required, following the instructions in the Yellow Book. Note that when intermediate and advanced analysis are not required, there is still an option to address systemic safety issues by integrating proven safety countermeasures in the project, especially if risk factors are present. Further, it may be appropriate to perform a more robust safety analysis when "safety" is included in the project purpose and need, when a project application claims a safety benefit as part of the justification, or when there could be a substantial difference in safety for the alternatives.
    a. **Intermediate analysis** includes a review of systemic risk factors related to the over-represented crash types. Review published lists of risk factors for the over-represented crash type(s) and determine if any risk factors are present at the project location. If so, integrate proven safety countermeasures in the project to address the risk factor(s). Refer to section 3 of the Yellow Book for details.
    b. **Advanced analysis** includes the remaining steps of site investigation from section 2 of the Yellow Book (countermeasure selection, alternatives analysis, recommendations). Request help from the Regional Safety Evaluation Engineer as needed. Depending on the results of the analysis, determine if safety improvements are recommended and, if so, how they will be addressed as part of the overall project.

CHAPTER 2. HSIP FUNDING AND REQUIREMENTS

This chapter discusses legislative and regulatory requirements of the HSIP, including program funding, project eligibility, HSIP reporting requirements, and special rules.

2.1 Program Funding

The HSIP is a state-administered, federal-aid highway program with the purpose of reducing fatalities and serious injuries on all public roads. Funding is apportioned to New York per formulas explained on the FHWA website. In recent years, New York has received over $100M annually for the HSIP. Per 23 CFR 924.11, HSIP projects are funded with 90% Federal share of apportioned funds and 10% state match. Some exceptions may be funded at 100% Federal share as listed in 23 USC 120(c)(1).

HSIP funds lapse after four years. If the Department obligates fewer HSIP funds than the amount apportioned in a given year, the unobligated balance builds and can eventually lead to the funds lapsing. Lapsing funds are redistributed amongst other states in August each year. As such, it is important that the Department maintain an active HSIP program and a backlog of needs to prevent funds from lapsing.

It is important to maintain an active HSIP program and backlog of projects to prevent HSIP funds from lapsing.

Safety improvements or features routinely included in broader Federal-aid projects (e.g., guardrail) should be funded from the same source funds as the broader project whenever possible. HSIP funds are primarily reserved for standalone safety projects, targeting sites with potential for safety improvement as cost-effectively as possible. However, when it would yield efficiencies in funding due to construction mobilization, workforce management, or other factors, project managers may consider using HSIP funds to add safety countermeasures or hardware to non-HSIP projects. When applying HSIP funds to non-HSIP projects, HSIP funding should be limited to countermeasures that meet HSIP eligibility requirements and are expected to reduce fatalities and serious injuries.

2.2 Project Eligibility

Proposed projects must meet the following minimum requirements to be considered for HSIP funding:

1. Supports the New York State SHSP (i.e., consistent with an emphasis area, strategy, or activity)
2. Represents an eligible activity as specified in United States Code (USC) Section 148
3. Provides a minimum estimated BCR of 1.0

2.2.1 Support the State SHSP

Per 23 CFR 924.7, every state is required to develop an SHSP that identifies key highway safety priorities (emphasis areas) and strategies to address those priorities within the state. The New York State SHSP is the statewide safety plan for accomplishing the vision: “Roads in New York will be safer to travel for all users.” The SHSP lays the foundation for

HSIP projects must be consistent with priorities established in the SHSP.

the State HSIP by identifying key emphasis areas and crash contributing factors as well as effective strategies to target the contributing factors and reduce the related crashes, injuries, and deaths.

NYSDOT updates the data-driven SHSP at least every five years in coordination with federal, state, regional, and local safety partners. The New York SHSP focuses on the following six emphasis areas, which reflect historic and ongoing highway safety issues in New York:

- Intersections
- Lane Departure
- Vulnerable Users (bicyclists, pedestrians, motorcyclists, and individuals working/traveling in a work zone)
- Age-Related (young drivers and older drivers)
- Road User Behavior (impaired driving, occupant protection, distracted and drowsy driving)
- Speed

The New York SHSP also includes the following three emphasis areas based on cross-cutting considerations and emerging highway safety concerns:

- Emergency Response
- Data
- Connected and Autonomous Vehicles

Key strategies related to each emphasis area are multidisciplinary and align with the “4Es” – engineering, education, enforcement, and emergency services. The SHSP also defines a framework for implementation activities to be carried out through coordination with safety partners, including federal, state, local, and tribal agencies.

2.2.2 Eligible HSIP Activities

23 USC 148(a) provides a sample listing of eligible highway safety improvement project types. In general, HSIP projects must implement safety infrastructure countermeasures or improve safety data collection, integration, and analysis such that HSIP stakeholders can better plan, implement, and evaluate highway safety improvement projects in the future. Projects should also address a serious crash risk or safety problem identified through a data-driven process and demonstrate the potential to produce a reduction in fatalities and serious injuries.

Non-eligible activities include education, public outreach, and enforcement (such as those previously allowed under MAP-21).

2.2.3 Benefit-Cost Ratio

The federal rule does not require a minimum BCR for HSIP projects; however, the FHWA HSIP Eligibility Guidance does note that agencies should consider the cost-effectiveness of HSIP projects during project selection and prioritization. Further, HSIP funds should be used to maximize opportunities to advance highway safety improvement projects that have the greatest potential to reduce roadway fatalities and serious injuries in New York. HSIP projects should also support New York’s safety performance targets established in accordance with 23 U.S.C. 150(d).

NYSDOT requires a minimum BCR of 1.0. This helps to account for the variability in estimating project costs and safety benefits. If the project costs are underestimated or if the estimated safety benefit is not realized, then the minimum threshold of 1.0 helps to absorb these differences and ensure a positive return on investment.

2.3 HSIP Reporting

The NYSDOT Central Office submits an HSIP Annual Report to FHWA by August 31 each year using the HSIP Online Reporting Tool (ORT). The HSIP report describes progress in implementing HSIP projects, assesses the effectiveness of those improvements, and describes the extent to which the improvements contribute to the goals of reducing the number of fatalities and serious injuries on public roads. Collectively, all states' HSIP Reports inform Congress of the progress to reduce fatalities and serious injuries nationally. More information is available on the HSIP ORT website.

CLEAR Safety produces standard reports to support the development of the HSIP Annual Report.

2.4 HSIP Special Rules

The FAST Act includes two special rules for the HSIP, emphasizing High Risk Rural Roads (HRRR), older drivers, and pedestrians. More recently, FHWA established the Safety Performance Management Measures and HSIP Final Rules, which affect the administration of the HSIP. The following subsections discuss these rules and associated penalties.

2.4.1 Special Rule for High-Risk Rural Roads

Programming HRRR projects as part of the annual HSIP will minimize changes to the program should this Special Rule apply.

The HRRR Special Rule defines HRRRs to include any rural major, minor collector, or rural local road with "significant safety risks." NYSDOT defines "significant safety risks" as having a "crash rate per mile above the average crash rate per mile established for the Region." FHWA uses five-year rolling average fatality rates based on data from the Highway Performance Monitoring System (HPMS) and the Fatality Analysis Reporting System (FARS) to assess HRRR Special Rule applicability. NYSDOT is not responsible for assessing its performance for this Special Rule but will continue to monitor the HRRR performance measures annually to assure compliance with the rule.

As per 23 U.S.C. 148(g)(l), the HRRR Special Rule takes effect if the fatality rate on rural roads in a State increases over the most recent two-year period for which data are available. If the HRRR Special Rule applies in any year, NYSDOT must obligate $6,191,372 (200 percent of its FFY2009 HRRR set-aside funds) to HRRR improvements in the next fiscal year. If this occurs, FHWA will notify the Department to begin programming HRRR projects and NYSDOT Central Office will outline a plan to spend the penalty funds in the HSIP Annual Report. It is imperative to spend all HRRR penalty funds in the first year they apply. If funds set aside as part of the HRRR Special Rule are not spent in the next fiscal year, then remaining funds are returned to FHWA and subject to redistribution. Programming HRRR projects as part of the annual HSIP will minimize changes to the program should this Special Rule apply.

2.4.2 Special Rule for Older Drivers and Pedestrians

The Older Drivers and Pedestrians Special Rule defines older drivers and pedestrians as road users over the age of 65. The Special Rule applies if the five-year rolling average rate of older driver and pedestrian fatalities and serious injuries increases across the most recent two-year period. NYSDOT Central Office is responsible for reporting the number of fatalities for drivers and pedestrians 65 years of age and older from FARS and the number of serious injuries for drivers and pedestrians 65 years of age and older from the State's data system. FHWA uses the fatality and serious injury information, along with population data obtained from the U.S. Census, to calculate the older driver and pedestrian fatality and serious injury rate per capita and determine if the Special Rule applies.

The Model Minimum Uniform Crash Criteria (MMUCC) defines a serious injury as "Severe laceration resulting in exposure of underlying tissues/muscle/organs or resulting in significant loss of blood; Broken or distorted extremity (arm or leg); Crush injuries; Suspected skull, chest or abdominal injury other than bruises or minor lacerations; Significant burns (second and third degree burns over 10% or more of the body); Unconsciousness when taken from the crash scene; or Paralysis." New York is in compliance with the MMUCC definition for "Suspected Serious Injury (A)".

If the Special Rule applies, the state is required to include strategies in the SHSP to address the increases in those rates. The Department will continue to monitor these performance measures annually to comply with the rule; however, the NY SHSP already includes an emphasis area and specific strategies for 'Age-Related' (young drivers and older drivers). If this Special Rule applies in the future, NYSDOT will review and adjust the strategies within the existing emphasis area as appropriate. If future versions of the SHSP do not include an Age-Related emphasis area and this Special Rule applies to New York, the FAST Act requires it be reintroduced in the next version of the SHSP.

2.4.3 Safety Performance Management Measures Final Rule

The Safety Performance Management Measures Final Rule established the following five performance measures for the HSIP, effective April 14, 2016.

1. Number of fatalities.
2. Rate of fatalities per 100 million vehicle miles traveled (VMT).
3. Number of serious injuries.
4. Rate of serious injuries per 100 million VMT.
5. Number of non-motorized fatalities and non-motorized serious injuries.

The NYSDOT Central Office sets targets and reports on these measures as five-year rolling averages in the HSIP Annual Report. MPOs may adopt the Department's targets or establish their own. The Department's performance measures and targets for HSIP must be identical to those in the GTSC Highway Safety Plan. More information is available on the HSIP Rulemaking website.

Annually, FHWA determines whether New York meets the targets or performs better than the baseline for at least four of the five measures. If New York does not meet at least four of the five targets, then the Department must reserve HSIP obligation authority for HSIP projects (i.e., cannot transfer HSIP funds) and submit an annual implementation plan with actions the Department will take to meet targets in the future.

2.4.4 HSIP Final Rule

The HSIP Final Rule, effective April 14, 2016, updates the existing HSIP requirements under 23 CFR 924 to be consistent with MAP-21 and the FAST Act and clarifies existing program requirements. There are no established penalties associated with this rule.

Specifically, the HSIP Final Rule added the following requirements:

1. The SHSP must be updated at least once every five years.
2. The HSIP Annual Report is due August 31st, states must use the HSIP ORT to submit the report, and the Annual Report must include a description of progress toward achieving safety performance targets.
3. States must collect and use the Model Inventory of Roadway Elements (MIRE) fundamental data elements (FDE) on all public roads to support enhanced safety analysis by September 30, 2026. The MIRE FDE are a subset of roadway data elements representing the minimum data to conduct advanced safety analysis, which includes basic geometric and location data to assign a facility type plus its annual average daily traffic (AADT).

More information is available on the HSIP Rulemaking website.

2.4.5 Transferability of Apportioned Funding

Per 23 USC 126, the Department may transfer up to 50% of its apportionment to the HSIP from the National Highway Performance Program (NHPP), Congestion Management and Air Quality Improvement Program (CMAQ), National Highway Freight Program (NHFP), Surface Transportation Block Grant (STBG)—except from the portion sub-allocated to areas by population, and Transportation Alternatives Program (TAP)—but only from the portion available for use anywhere in New York. Up to 100% of the Railway-Highway Grade Crossings Program (RHCP) apportionment may be transferred to the HSIP if the Department demonstrates to FHWA that it has met all needs for installation of protective devices at railway-highway crossings.

The Department may also transfer apportionments out of HSIP to the NHPP, NHFP, STBG, CMAQ, or TAP. However, this should only be done if HSIP funding would otherwise lapse. The HSIP supports safety, which is the top priority at NYSDOT.

For ease of administration, the law also allows the Department to request that FHWA transfer funds among entities to fund eligible projects (e.g., between FHWA and the Federal Transit Administration, and from one State to another or to FHWA). In these instances, the transferred funds are still used for the original purpose; they are just administered by a different entity. The Department may use this allowance to fund pooled fund studies and other initiatives.

CHAPTER 3. SAFETY DATA AND GOVERNANCE

This chapter describes the relevant safety data systems that support the HSIP and the overarching data governance. Figure 4 shows the most applicable safety data systems and illustrates how the data are integrated in CLEAR. The key safety data systems are described below.

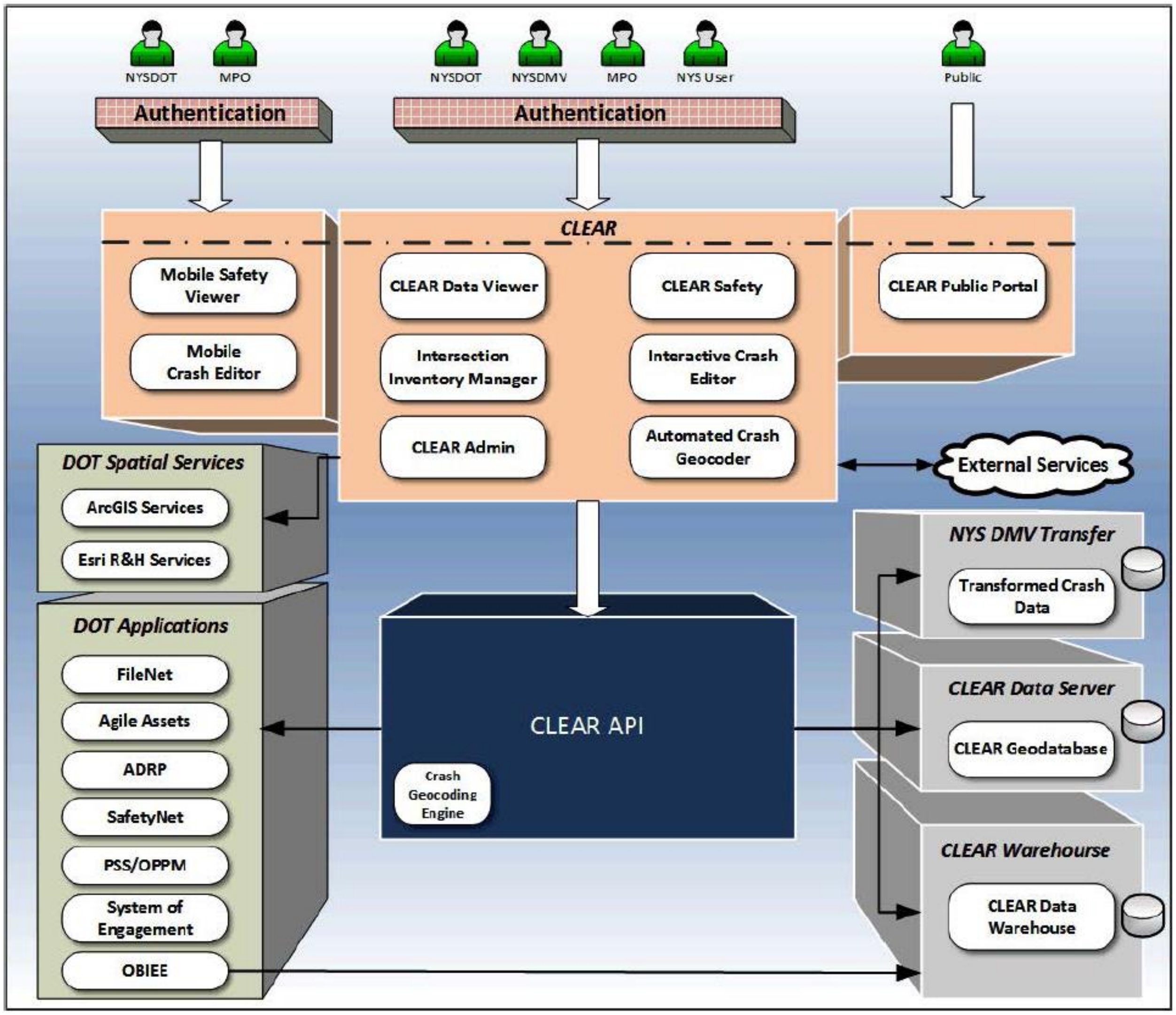


Figure 4. HSIP safety data systems and integration.

3.1 Crash Data

Crash data are the basis for many safety analyses such as network screening (i.e., identifying sites with potential for safety improvement), diagnosis (i.e., determining underlying crash contributing factors), and evaluation (i.e., assessing the safety effectiveness of implemented projects and programs). The collection, management, and dissemination of crash data is the joint responsibility of several safety stakeholders, including law enforcement, Department of Motor Vehicles (DMV), and DOT among others. Crash data originate from law enforcement officers, who use form MV104A (MV-104AN in New York City) to document crashes. Law enforcement agencies submit these forms to DMV for review and approval. Law enforcement agencies use the Traffic and Criminal Software (TraCS) solution as the primary method of electronic data capture; however, there are still some law enforcement agencies using hardcopy crash reports.

As shown in Figure 5, crash data begins with ingestion of crash reports at the DMV. Data entry personnel review crash reports as part of their daily responsibilities. They review these reports sent from the various law enforcement agencies for completeness and accuracy before marking as ready for transfer to DOT. Once crash information has been accepted by DMV, it is transferred during nightly processing into databases within the DOT staging environment. As part of this ETL transfer process from DMV to DOT, the data goes through several transformation routines to arrange or convert the data into the CLEAR-specific crash data structures.

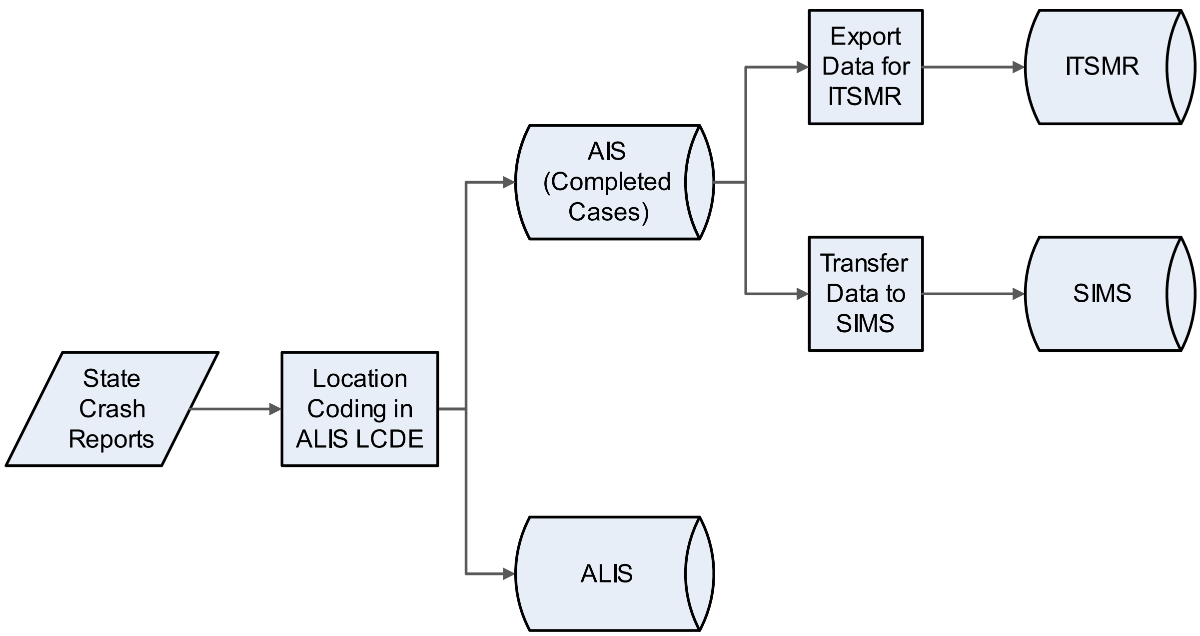


Figure 5. Summary of crash data flow.

CLEAR helps to streamline crash data distribution and eliminate the potential for multiple instances of crash data extracts by providing a single source of crash data for various agencies (e.g., DOT and ITSMR). The crash data are updated anytime there is a change (e.g., a user requests a change to a specific crash), so all users are working from the same dataset at any given time. CLEAR also improves accessibility to the officer narrative in a text-searchable field. The officer narrative is critical for verifying the accuracy of the other fields on the police crash report and understanding the crash contributing factors during site analysis and investigation.

Crash data, generally speaking, is essential for proper safety analysis of crashes as well as all data related to crashes, such as vehicles and persons involved. The transfer and storage of accurate data from DMV to DOT is critical to good crash analysis and, in turn, leads to potential roadway improvements for safer roads. The foundation of the crash database, and crash analysis in general, is built around the three core tables of crash, vehicle, and person as shown in Figure 6 and described below.

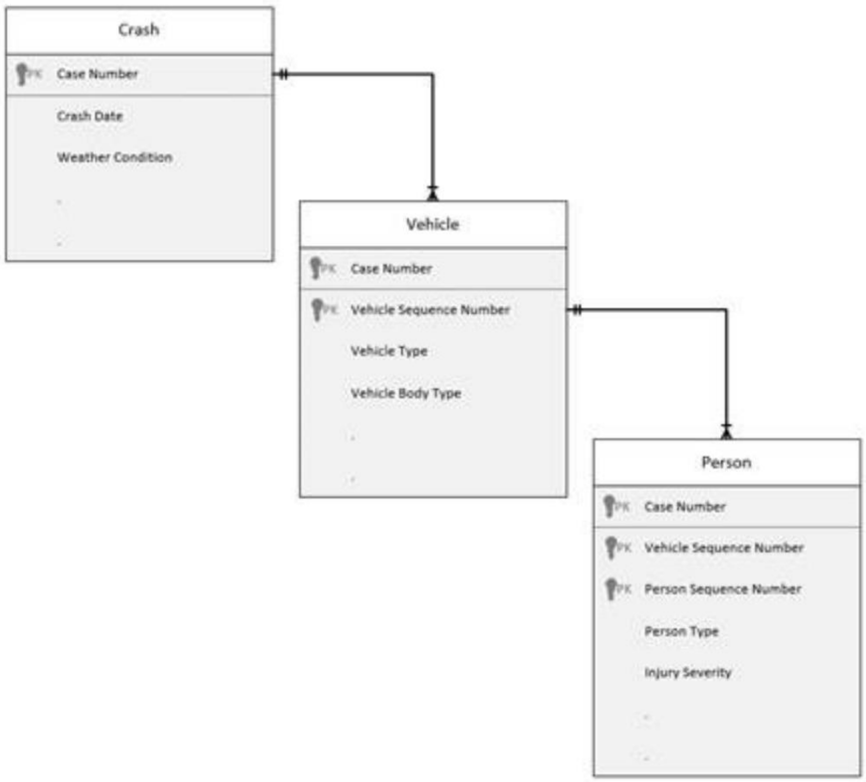


Figure 6. Core crash data tables with sample attributes.

3.1.1 Crash-level Data

Crash-level data contain the reported crash characteristics such as location details, road characteristics at the crash location, and weather or light conditions at the time of the crash. These are all critical to comprehensive crash analysis.

Each crash, otherwise known as a case, goes through a complex process to locate the crash to a correct coordinate location. While most of the crash-level data are stored in a single file, the location-based data are stored in separate tables. This helps normalize the database structures by arranging location data in separate tables adjacent to the core crash data. DMV personnel also conducts a crash location process; however, this is accomplished after the crash has been transferred to DOT and is done using CLEAR applications accessible by DMV coders. The reasoning behind this is that DMV is the owner of the authoritative crash data, but DOT takes on the responsibility and ownership over the crash location. With DMV's assistance locating crashes, DOT is able to provide an accurate spatial assessment of all crashes stored in the CLEAR crash data repository. When it comes to crash data, the successful partnership between DMV and DOT relies on this two-way communication and maintenance of crash data stored by each agencies respective crash data systems.

Reported Location

The reported location is provided with the crash data transferred from DMV. This information is useful but is not a true spatial location until it is processed through the CLEAR location coding workflow and a candidate location is accepted. At that point, it becomes a spatial feature in the crash database. The reported location consists of the best possible location details available to the law enforcement officer at or near the scene of the crash. It is possible that the input location fields were not correctly filled out or there is more location detail interspersed in the narrative or diagram portion of the crash report. If that is the case, it is the job of the location coder at DMV to use all possible information available in the report to identify an accurate crash location. DOT personnel have the opportunity, later on, to review a case and relocate if necessary.

CaseNumber	Region	CountyFIPS	MuniFIPS	OnStreet	CrossStreet	StreetNumber	ExitNumber	Milepost	ReferenceMarker	Landmark	Latitude	Longitude	Distance	DistanceUnitsCode	DirectionCode
36725284	8	36027	360276135761346	MONTGOMERY ST	[Route] 308	NULL	NULL	NULL	9 82053155	NULL	0.0000	0.0000	125.0000	1	1

Figure X. Sample reported location record.

Computed Location

The computed location is stored in the Computed Location table once a candidate location is found, reviewed, and accepted as the most accurate location available. This process is accomplished by location coders at DMV, as described above, but may also be accomplished by an analyst during a safety investigation. For instance, if the analyst determines the crash location is inaccurate and the correct location is known, the analyst can edit the crash location using the same geocoding methods used by location coders. Additionally, crashes go through an initial batch processing effort when they are first brought into DOT's CLEAR environment. This batch processing helps geolocate a large percentage of crashes that pass obvious location checks and lightens the workload of the location coders at DMV. The Computed Location record is a core component of CLEAR and is crucial to any spatial analysis of crashes.

CaseNumber	CountyFIPS	MuniFIPS	MPO_ABBR	OnStreet	ClosestCrossStreet	MasterIntersectionId	RampID	DistanceFromIntersection	DirectionFromIntersection	ReferenceMarker	UTMEasting	UTMNorthing	IntersectionIndicator
36684750	36111	3611145458	NULL	COTTEKILL RD	Rybak Ln	0	NULL	128.00000000	W	NULL	571951.52952821	4634261.74909118	0

Figure X. Sample computed location record.

Computed Routes

When a candidate location is accepted, a post-processing routine is run to retrieve any routes the crash occurred on. The purpose of this function is to store the route name and measure for all routes underlying the crash location. Route name and measure are required attributes for analyzing crashes along specified road network corridors. As shown in Figure 7, there can be multiple overlapping route locations collected for an individual crash location. In some cases, there may be multiple routes on the same segment. In other cases, this is an error and the crash should be assigned to only one of the routes.

CaseNumber	RouteKey	RouteID	Measure	SegmentID	RoadInventoryYear
37074401	US1 SB	100011022	0.09435475	161856	2020
37074401	I-87 NB	100495011	3.49385626	161856	2020
37074401	I-95 SB	100706022	0.09435475	161856	2020

Figure 7. Computed route records showing multiple overlapping route locations.

Computed Road Attributes

Road attributes are another critical component to crash analysis. As such, there is a need to identify and understand the available roadway attributes at the site of a crash. The Roads & Highways linear referencing system (LRS) provides for a variety of network attributes through event layers. These event layers, described in the Roadway Data section, are made available to extract and store road attribution with the crash, using the Computed Road Attributes table at the time of location coding. These attributes are especially useful when conducting systemic analysis by allowing the analyst to focus on risk factors at a system level in order to identify sites of similar characteristics that could benefit from installing countermeasures on a more broad scale. It is expected that the physical road characteristics would be identical for any overlapping routes at the site of the crash. Therefore, unlike the Computed Routes table described above, there is only a single Computed Road Attributes record for any accepted computed crash location.

3.1.2 Vehicle-level Data

DMV typically transfers crash data to DOT with one or more vehicles records included. Vehicle-level data are stored in the Vehicle table within CLEAR. While DMV stores the driver details in the vehicle record, these data are separated into a person record for the driver when transferred to DOT. This allows CLEAR to perform person-based queries for all crashes while maintaining a link between the vehicle and the driver. Vehicles may have additional related records, such as supplemental events, when the vehicle is classified as a commercial vehicle. Apparent contributing factors may also be linked to a vehicle which help determine which vehicles involved contributed to the crash and how. Figure 8 provides a diagram of the relationships among the vehicle-level files. Further details on commercial vehicles, supplemental events, and apparent factors are provided in the sections below.

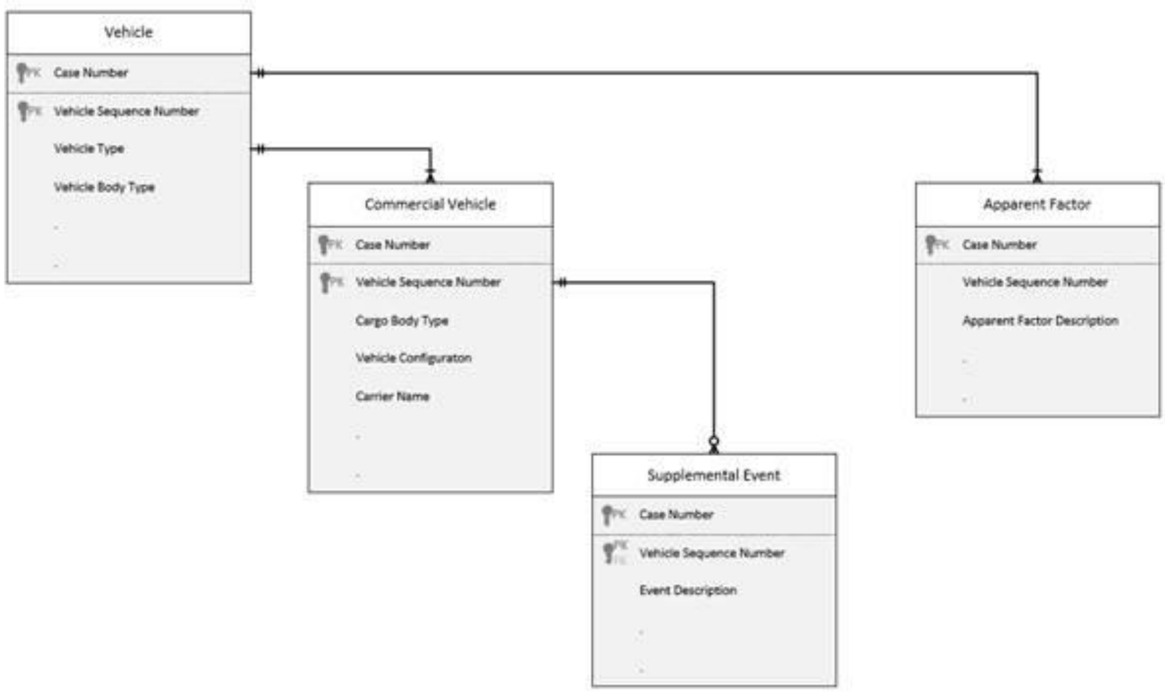


Figure 8. Table structures for vehicle-level data with sample attributes.

Commercial Vehicles

The Commercial Vehicle table stores the information specific to large trucks and buses. This is information that comes from an MV-104S form attached to the main MV-104 crash report. This form identifies further details about the large vehicle as well as carrier information, when applicable. When a vehicle meets the following criteria, the officer will include an MV-104S with the report.

- Any commercial truck having a Gross Vehicle Weight Rating (GVWR) or Gross Combined Weight Rating (GCWR) greater than 10,000 pounds;
- Any vehicle displaying a hazardous materials (Haz Mat) placard; or
- A bus designed to carry 9 or more persons, including the driver.

AND, one of the following events occurred:

- At least one vehicle was towed/transported from the scene (other than for a flat tire);
- At least one person sustained fatal injuries; or
- At least one person was transported for immediate medical treatment.

SafetyNet: DOT is responsible for reporting all qualifying commercial vehicle crashes to the Federal SafetyNet system. Once reported, a federally-reportable case number is saved with the commercial vehicle record so DOT has record that the vehicle was properly reported.

Supplemental Events

The supplemental Event table contains any extra events that occur for a large truck or bus crash. Up to four supplemental events can be recorded per supplemental form.

Apparent Factors

Every crash must have at least one apparent contributing factor captured in the report. However, up to two per vehicle or person record may be captured. The factor(s) may be human, vehicular, or environmental in nature. If additional contributing factors for a vehicle or person occurred, they may be found in the officer's notes section. Storing these factors in a separate Apparent Factor table allows DOT to conduct more efficient analyses and focus on select apparent factor patterns if desired.

3.1.3 Person-level Data

Person-level data include details related to the people involved, which can support more robust crash analysis. DMV stores person records as vehicles or, in the case of a driver, with the vehicle. When crash data are transferred from DMV to DOT, person-related data is transformed into a Person record. Most importantly for crash analysis, person type and injury status are saved with the person record along with age. Any other person details that may be stored are typically used in FOIL requests only, such as names, addresses, and license numbers, for example.

Non-Motorists

Non-motorists are somewhat unique in how they are captured and stored in the DMV database. They are captured as vehicles of a specific body type that represent non-motorists only. When non-motorist data are transferred to DOT, it is transformed from vehicles into person records with only a key identifier linking the person record back to the original vehicle record at DMV, if tracing it back is ever necessary.

Apparent Factors

If the crash was attributable to human factors, up to two of these human factors may be linked to the person record transferred from DMV to DOT and stored within CLEAR.

3.1.4 Crash Reports

Crash reports are sent to DMV by law enforcement agencies in two formats, either scanned paper reports or as electronic XML uploads. A motorist may submit a paper report as well and that is currently scanned into DMV. NYS is moving towards predominantly electronic reports but it is still not 100% paperless. For that reason, DMV collects both formats and the transfer process between DMV and DOT also accommodates both formats.

Crash reports are considered the source of truth for all cases transferred and stored in CLEAR. Users having the proper permissions may always refer to the original crash reports to verify crash details. Figure 9 shows how a crash report is stored in the CLEAR database along with the corresponding metadata and, in the case of an electronic report, the actual report XML. The following sections describe the different types of reports.

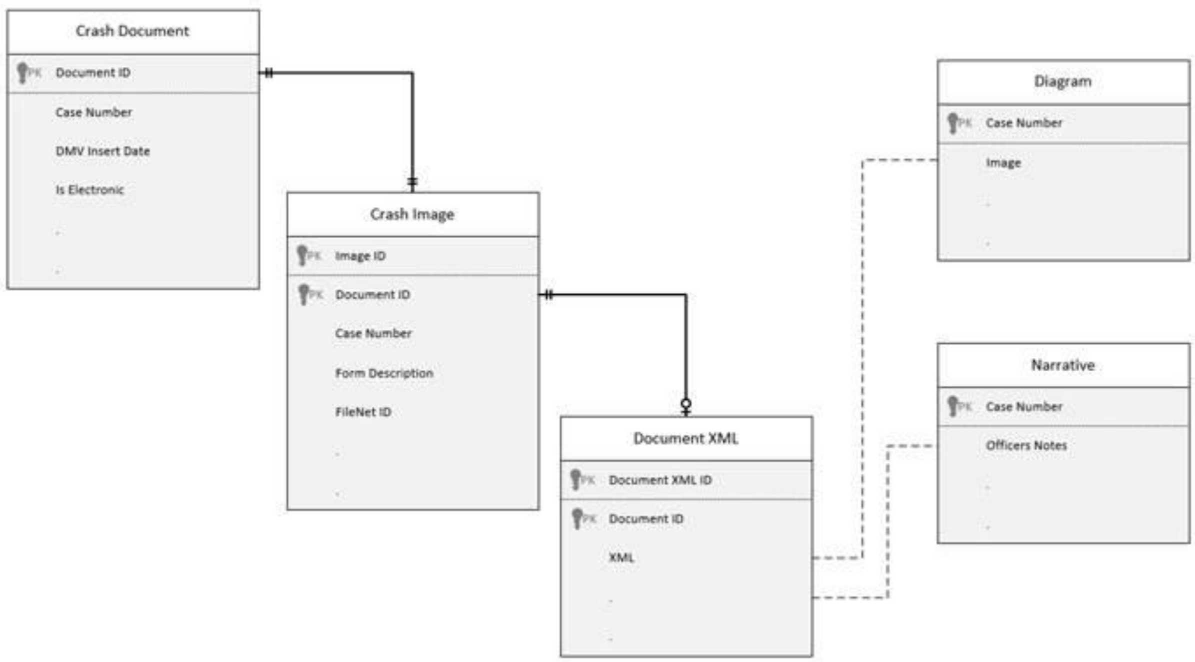


Figure 9. Table structure for storing crash report metadata with sample attributes.

Paper Reports

Paper reports are transferred for each new or updated case and entered into the FileNet Document Management Repository. From here, users with the appropriate permissions can call up these records for viewing in the CLEAR Crash Report Viewer. Most CLEAR users have the necessary permissions to view crash reports but if a user does not, they may request reports through the FOIL request mechanisms already in place at NYSDOT. If a report is in paper form and stored in FileNet, the Crash Document record will denote that it is not electronic and a FileNet ID will be stored in the Crash Image record. There will be no Document XML record in the case of a paper report.

Electronic Reports

Electronic reports are also sent to DOT from DMV during the nightly transfer along with the rest of the crash data. These reports are parsed for report type and are stored in the Document XML table containing an XML-capable attribute field for rendering by the CLEAR Crash Report Viewer upon request. The Crash Report Viewer application calls on the stored XML and renders it into the appropriate PDF template based on its report type (e.g., MV-104, MV104S). The same permissions are required for viewing electronic reports as are required for viewing paper reports, as noted above. Additionally, the CLEAR database has a separate table for both officer notes and the diagram. During the transfer, these two parts of an electronic report are parsed out and stored as standalone data elements in the database so they may be shown inline by any of the CLEAR applications requiring quick access to the information.

Standard Reports

The main reports containing the core crash details are referred to as the MV-104, MV-104A, and MV-104AN. The MV-104 represents a motorist report. The MV-104A and MV104-AN represent a police report.

Fatal Reports

If one or more fatalities have occurred, an MV-104D form is attached to the main report and includes person details of the deceased.

Truck/Bus Reports

If one or more vehicles assigned to the case fit the classification of a large truck or bus, an MV-104S form is included for each qualifying vehicle. This form describes the commercial vehicle in detail to include information such as carrier information and sequence of events.

3.2 Roadway and Traffic Data

Roadway data support safety analyses from the simple identification of different roadway facility types to the advanced adjustment of predicted crashes. Traffic data are critical to safety analyses as traffic volume is the primary predictor of crashes. The Department uses Esri's Roads & Highways as the primary platform for roadway and traffic data.

Roads & Highways is made up of a core route and mile point dataset that represents the linework for all public roads in New York. This basic network is supplemented by several dozen event layers each representing unique attribution collected and maintained by NYSDOT. Refer to the following link for an overview of Esri's Roads & Highways product.

The roadway data are maintained and supplied by the Department's GIS and Highway Data Services Units and support the road inventory in CLEAR. Once per year, a request is made by the maintainers of the CLEAR solution for this externally maintained road network data in order to create a new annual version of a customized road inventory. It is important to note that 99% of all CLEAR functionality works from a static and highly processed version, or snapshot, of the Department's real-time LRS. While a real-time LRS can be useful for some transportation analyses, a static snapshot of the road network is generally more appropriate for networkwide safety analyses and to help normalize the data year-over-year. For instance, one common task in highway safety is to identify sites with potential for safety improvement based on annual safety performance measures. These annual safety performance measures are based on general roadway characteristics and the annual average daily traffic volume. Not only would it be challenging to aggregate safety performance measures from a real-time LRS with several hundred thousand road segments all updating asynchronously, but it would add little value to understanding the general safety performance.

The Roads & Highways data comprises segment data, intersection data, ramp data, and traffic volume data, which are described in the following sections.

3.2.1 Segment Data

A segment-based road network dataset is created for the unique purpose of supporting CLEAR Safety. These data are the cornerstone of all system functionality and, when crashes are properly assigned to the network, allows for safety analyses based on location and underlying roadway characteristics. Using the approach described in the above section, a periodic request to the Department's GIS unit is made for a snapshot of the Roads & Highways LRS data. This snapshot is run through a series of segmentation scripts to create the unique linear datasets described below. When a snapshot is processed and a new road inventory is created, the road inventory from the previous year remains intact and is used when historical versions are necessary to correct a crash location. These segmentation routines are conducted and maintained under the domain of the CLEAR solution with the intent of supporting CLEAR's unique and highly customized system functionality. The various components of the processed LRS segmentation include:

- **Road Segments**: This element represents the LRS route linework segmented from intersection to intersection and assists in the location coding process for all crashes that come into the CLEAR system.
- **Street List**: This element represents another processed version of the linework that focuses on segments spanning as long as the route name does not change within a county but is clipped at county boundaries. This allows the user to search for a route within a county or region without extending into adjacent counties and pulling unwanted crashes into query results. These segments support CLEAR in the following ways:
    - Used by geocoding to determine the street name at the crash location.
    - Used as a visual map reference layer.
    - Used as an interactive map layer allowing the user to select streets when searching for crashes.
- **Route List**: Similar to the Street List dataset but instead of being identifiable by street name, these segments are identifiable by route name and direction. This segmentation is mainly useful for larger routes when a roadway is better known by route name than street name or has no street name at all. These segments support CLEAR in the following ways:
    - Used by geocoding to determine the route name(s) at the crash location.
    - Used as a visual map reference layer.
    - Used as an interactive map layer allowing the user to select routes when searching for crashes.
- **Screening Segments**: This segmentation has a significant role in the safety functions within CLEAR. The segments are based on the core attributes that define the segment-based facility types (e.g. functional class, number of lanes, dividedness, and access control). Further, the segmentation uses these attributes to create contiguous roadway line features, categorized by facility type, that can be analyzed against the overlaying or assigned crashes. Screening segments were created with the intent of supporting a screening engine that has the ability to traverse the road network identifying potential for safety improvement. When the engine "walks" the network, it does so by facility type looking for segments that meet a certain safety performance threshold, appending them into new line features until they no longer meet the threshold. These new screened

features, called PILs, are a derivative of this core screening segments dataset. Screening segments support CLEAR in the following ways:

- Through development and maintenance processing, screening segments are used to develop safety performance functions (SPFs) for specific facility types.
- Providing this data as a layer on an interactive map allows the end-user to select screening segments as study sites for further investigation and potential mitigation.
- These data are used to identify specific countermeasure locations and perform benefit/cost analysis specific to the segment facility type.

- **Event Segments**: Similar to the Screening Segments data, this is a segmented representation of the road network where linework is split based on pre-selected roadway characteristics. Event Segments are a more granular representation than Screening Segments, using a broader set of roadway characteristics to define segments. The Department has provided a list of LRS event layers, or road characteristics, that the annual road data processing routine uses to segment the core linework. These segments support CLEAR in the following ways:
    - When a crash is location coded and a coordinate is assigned to the crash, the coordinate is then used to pull all available road characteristics at the crash location. These road characteristics can assist analysts in individual crash analysis as well as systemic analysis of all or portions of the road network.

3.2.2 Intersection Data

Over the last decade, the Department has undertaken an effort to create an intersection inventory to support intersection-based safety analyses. The latest evolution of the inventory incorporates the Roads & Highways data, associating the intersection points with information for individual legs or approaches. This supports the creation and use of an "area of influence" in finding crashes associated with an intersection. A CLEAR application supporting the maintenance of the intersection inventory was built and made available to the Traffic Safety Unit. This intersection maintenance application works hand-in-hand with the Department-maintained Roads & Highways data to discover new intersection points based on the route linework as well as providing the capability to re-evaluate existing intersections when physical changes have been made and the intersection data needs to be updated accordingly.

A key distinction between the intersection inventory and the road inventory described above is the real-time nature of the intersection data. The Traffic Safety Unit maintains the authoritative intersection data. The Traffic Safety Unit is also the product owner of the CLEAR solution that integrates these intersections with other safety data. As such, the intersections are used as real-time data and are not processed in the same manner as routes from Roads & Highways, which need to be processed to create a static road inventory. The Traffic Safety Unit will continue to maintain the intersection data and will also provide it to the GIS unit on a periodic basis to be used by other business units and external systems outside of CLEAR. The various components of the intersection data model are described below.

- **Master Intersection**: The core dataset for the intersection inventory, this data element carries general attribution and provides an identification number for the intersection that is used to associate with crashes as a computed intersection location ID. Because some intersection attributes are only needed at the high-level intersection perspective, the process of creating or maintaining an intersection programmatically determines the dominant leg and pulls the associated attributes into this main intersection table. The table can then be used for more general intersection safety analysis as well as for searching for intersections by these higher level characteristics.

- **Master Intersection Area of Influence (AOI)**: This spatial dataset contains the ‘area of influence’ created from joining and buffering an intersection’s legs or approaches. These data are most commonly used to find crashes within a given buffer distance to any of an intersection’s contained points.
- **Intersection Legs**: Also a spatial dataset, the intersection legs data is created through special processing routines that utilize the Roads & Highways LRS. The route network from Roads & Highways provides the line features representing the statewide route network that the intersection processing routines use to buffer and extract intersection legs. The leg feature data has two primary purposes in creation and maintenance of intersections. First, the legs are used as the basis for the intersection area of influence. From the legs, the tool creates a buffered area around and outward from all intersection points involved. Second, the legs are used to derive event data from the LRS for many roadway characteristics that support comprehensive safety analysis of intersections. Characteristics are associated with the calculated leg features and rolled up to the intersection-level if the leg is determined to be the dominant leg and the characteristics are used primarily as intersection-level attribution.
- **Intersection Leg Detail**: Each leg, as mentioned previously, is processed to pull event data from the Roads & Highways LRS. This leg or approach-level data supports analyses that use major and minor road characteristics. As an example, traffic volume and functional class determines which leg or approach should be considered a major leg versus a minor leg. Knowing the major versus minor legs of an intersection is critical for estimating safety performance and identifying safety concerns and opportunities for improvement.
- **Intersection Points**: This is the foundation of the intersection inventory. The Department has collected intersection points going back several years, which has allowed for the construction of a robust intersection inventory. The points help to identify intersection legs and leg attribution. The points also serve as the basis for a more complex intersection structure, referred to as the ‘area of influence’, for spatial crash queries and analysis. Crashes have been associated with intersection points for several years, which allows analysts to query and analyze crashes identified as “at-intersection” or “intersection-related” and associated with an intersection by ID. The difference now is that the Department is associating intersection crashes to a main intersection ID as opposed to an individual intersection point ID.
- **Intersection View**: A custom view was created to pull together various components of the intersection. This view is used in the development of intersection-based SPFs, which support predictive analysis.

3.2.3 Ramp Data

A ramp inventory was created to support CLEAR Safety based on very specific safety needs. In order to conduct safety analyses on ramp-related crashes, The Department’s Traffic Safety Unit assessed each individual ramp to determine key characteristics such as ramp facility type, whether the ramp was related to a ramp terminal or not, and whether the ramp was an on-ramp or off-ramp. These data enhance analysis capabilities in CLEAR Safety by allowing for the use of more advanced methods. While ramp data were created for the purpose of supporting

CLEAR Safety, the Traffic Safety Unit has provided the data back to the business unit maintaining Roads & Highways. Ramp data are now a permanent part of that platform. Going forward, when an annual snapshot is requested for regenerating the CLEAR road inventory, the ramps will be included and any ramp updates will flow back into CLEAR. Ramp data are used to support CLEAR in the following ways:

- Used to produce ramp-specific SPFs that support predictive analysis.
- Used by geocoding to determine if a crash is located on a ramp segment and, if so, associate the ramp ID to the crash for more efficient analysis per ramp.
- Used as a visual map reference layer.
- Used as an interactive map layer allowing the user to select ramps when searching for crashes.

3.2.4 Traffic Data

The Traffic Count Event Layer is key to many functions in CLEAR both as a visible reference layer for hands-on or real-time analysis of crash locations, and as a core component in the advanced screening methods used within CLEAR. Traffic counts, or AADT specifically, is a required data element for advanced safety performance measures such as Excess Expected Average Crash Frequency. While traffic volume data are not available for all public roads, the Department is working to collect or estimate traffic volume for all roads by 2026. Traffic counts are maintained by the Department's Traffic Monitoring Group within Highway Data Services and are updated continuously within the Department's Roads & Highways platform. These data are mapped to the Roads & Highways LRS network using the traffic station event layer. With the traffic count data integrated with Roads & Highways, this information is provided as part of the yearly Roads & Highways snapshot request. As such, CLEAR Safety contains static year-by-year traffic volume data. CLEAR Safety utilizes traffic data when available to employ more rigorous methods; otherwise, CLEAR Safety reverts to more simplistic performance measures that do not rely on traffic volume.

3.3 Maintenance and Roadside Asset Data

Agile

3.4 Capital Project Data

OPPM

3.5 Pedestrian and Bicycle Data

The Department does not maintain a statewide inventory of pedestrian and bicycle facilities. This presents an opportunity for future data capability improvements. Specifically, it would support both hotspot and systemic approaches to safety management, allowing analysts to identify locations and types of facilities that are over-represented in fatal and serious crashes. While this would be a large undertaking, there is an opportunity to rely on input and support from counties, cities, and MPOs. There is a wealth of information generated and collected now, and some agencies already have sidewalk and bike route inventories. This could be an added layer or feature class in Roads & Highways that evolves over time. It could start with basic information on the type and location of the facility. It could then be expanded to include details on the width, offset to roadway, and condition. It may also serve as a repository for pedestrian and bicycle counts or results from demand models. Further, this could help to improve consistency and uniformity in the collection of pedestrian and bicycle counts among MPOs and local agencies.

3.6 Data Governance

Data governance is the corporate approach to collecting and managing data. CLEAR supports data governance by providing a framework to integrate disparate datasets for safety analysis. The Department has begun discussions of how to implement data governance practices. Refer to XXX for further details on the NYSDOT data structure, agency responsibilities, change management processes, and dependencies. Knowing this information will promote coordination among divisions within NYSDOT and stakeholders external to NYSDOT.

CHAPTER 4. SAFETY PLANNING

There are two general approaches to developing projects during the planning stage of the safety management process: the **hotspot approach** and the **systemic approach**. The hotspot approach focuses on selecting and treating sites based on site-specific crashes. The systemic approach focuses on selecting and treating sites based on site-specific risk factors (i.e., geometric and operational attributes known to increase crash risk). These two approaches are complementary and support a comprehensive approach to safety management.

The primary difference between the two approaches is the order in which screening and diagnosis occur in the planning stage. The **hotspot approach** starts with network screening followed by diagnosis (at the site level). The **systemic approach** starts with diagnosis (at the network level) followed by screening. While there are differences in the application of the two approaches, both focus on preventing future crashes and reducing fatalities and serious injuries. Another commonality is focusing on sites with the greatest potential for safety improvement. In either case, it is important to use reliable, data-driven methods to inform these decisions. Table 3 provides a general characterization and comparison of the hotspot and systemic approaches.

Table 3. General characterization of hotspot approach and systemic approach.

Category	Hotspot Approach	Systemic Approach
General	Effective means to identify sites and implement countermeasures at those sites with the highest potential for site-specific safety improvement.	Effective means to identify sites and implement countermeasures at those sites with the highest risk across a road network.
Underlying safety issue(s)	Typically vary at each site (i.e., based on site-specific diagnosis).	Common risk factors for a group of sites (i.e., based on network diagnosis).
Countermeasures	Typically vary at each site (i.e., address specific issue(s) based on diagnosis).	Target common underlying safety issues across sites (i.e., implement similar projects across a network to address high priority crash types and risk factors).
Project types and cost	Range from low-cost improvements (e.g., enhancing signing or striping, trimming vegetation, or modifying signal phasing) to capital improvement projects (e.g., constructing roundabout, modifying intersection skew angle, or realigning horizontal curve).	Typically low-cost improvements (e.g., enhancing signing or striping, installing rumble strips, or upgrading signal heads), but higher-cost improvements are candidates if the improvement is cost-effective.
Project impact	Aim to achieve reductions in crash frequency and severity at treated locations given the focus on site-specific issues and targeted countermeasures.	Aim to achieve reductions in crash frequency and severity across a large portion of the system given the focus on priority crash types and risk factors rather than site-specific crash history.

Implementation	Standalone HSIP projects or add-ons to existing 3R, Work Program, or other non-HSIP projects.	Standalone HSIP projects or add-ons to existing 3R, Work Program, or other non-HSIP projects.

The following sections describe the hotspot and systemic approaches in more detail, including more reliable methods to support decisions and the data requirements to use more reliable methods. Beyond the first two steps of the process, both approaches are nearly identical, but the respective sections discuss each approach through countermeasure selection to note the subtle differences. The two approaches converge for economic appraisal and project prioritization where projects are compared side-by-side based on economic merit (i.e., return on investment).

4.1 Hotspot Approach

The hotspot approach is a six-step process, excluding implementation, as outlined in the Highway Safety Manual (HSM) and shown in Figure 10. Following the figure is a summary of the first four steps of the hotspot approach, including opportunities to use more reliable methods to improve decisions.

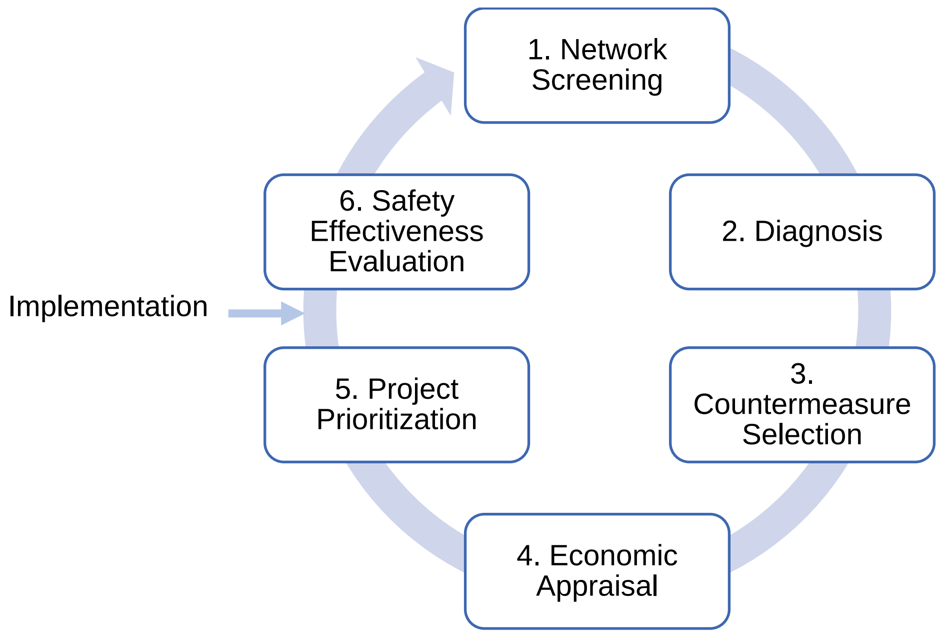


Figure 10. 6-step hotspot approach to safety management.

4.1.1 Network Screening

Statewide network screening serves as a starting point for Regional offices to develop their Annual Work Program.

The goal of network screening is to identify sites with potential for safety improvement (i.e., sites worth investigating further). PSI is the primary performance measure for network screening, which is based on a comparison of the site-specific safety performance to the statewide average (i.e., Excess Expected Crash Frequency). The focus crash type for statewide network screening is fatal and serious injury crashes and the focus facility type is the State system. Annually, the NYSDOT Main Office performs statewide network screening in CLEAR Safety and provides Regional offices with an initial list of sites with potential for safety improvement. This list serves as a starting point for Regional offices to develop their AWP. The Main Office also identifies a workable quantity of locations for each Region to investigate as part of the AWP. The Region must address at least the minimum quantity of locations but has flexibility in preparing the AWP based on the suggested list from Main Office and special requests for investigations made within the Region. The Region and Main Office then agree on a common list for the AWP.

SPFs are mathematical equations used to predict annual crash frequency at a location as a function of traffic volume and other roadway or intersection characteristics.

There are several potential performance measures for conducting network screening as described in the Highway Safety Manual and other resources (Reference). These methods differ in reliability where the less reliable methods only require basic data (e.g., crash data) and the more reliable methods require more complete data (i.e., crash, roadway, and traffic volume data). The more reliable measures use the Empirical Bayes method, incorporating crash predictions from SPFs and site-specific crash history. The more reliable methods can account for potential bias due to regression-to-the-mean (i.e., random fluctuations in crashes over time), changes in traffic volume, the nonlinear relationship between crash frequency and traffic volume, and differences in crash severity (Reference). When detailed roadway and traffic volume data are not available to employ the Empirical Bayes-based measures, research has shown that crash frequency may serve as a suitable performance measure for network screening (Reference).

The Department uses the most reliable data-driven approach feasible to identify sites with potential for safety improvement. The feasibility depends on the availability of crash, roadway, and traffic volume data across a given facility type, particularly traffic volume as crash and basic roadway attributes are available for the entire system. Where traffic volume data are available across a facility type of interest, network screening is based on excess expected crash frequency (see below for definition). Where traffic volume data are not available, network screening is based on average observed crash frequency (see below for definition).

Excess Observed Crash Frequency: Screening the network by means of excess observed crash frequency is based on a comparison of the difference between the crash frequency at a given location and the average crash frequency for the respective facility type. Equation 1 shows the calculation of potential for safety improvement (or PSI) based on excess observed crash frequency.

$$PSI_{observed} = N_{observed} - N_{average} \tag{1}$$

Where:

$PSI_{observed}$ = potential for safety improvement based on excess observed crash frequency

$N_{observed}$ = observed crash frequency at a given location

$N_{average}$ = average crash frequency for the respective facility type

Sites are ranked from high to low based on the average difference; in this case the average difference between the fatal and serious injury crash frequency at a given location and the average fatal and serious injury crash frequency for the respective facility type over the last five complete years of applicable data.[1] The crash frequency is based on a simple average of observed crashes across the facility type of interest. For segments and ramps, the crash frequency is computed as the number of crashes per mile. For intersections, the crash frequency is computed as the number of crashes per intersection. This measure does not account for potential bias due to regression-to-the-mean, differences in traffic volume among sites, and the nonlinear relationship between crash frequency and traffic volume.

Excess Expected Crash Frequency: Screening the network by means of excess expected crash frequency is based on a comparison of the difference between the expected crashes and the predicted crashes. Equation 2 shows the calculation of potential for safety improvement (or PSI) based on excess observed crash frequency.

$$PSI_{expected} = N_{expected} - N_{predicted} \tag{2}$$

Where:

$PSI_{expected}$ = potential for safety improvement based on excess expected crash frequency

$N_{expected}$ = expected crash frequency at a given location

$N_{predicted}$ = predicted crash frequency for the respective facility type

Sites are ranked from high to low based on the excess expected crash frequency; in this case the average difference in expected and predicted fatal and serious injury crashes over the last five complete years of applicable data.[1] This measure establishes a threshold using the SPF to provide an indication of when sites are performing relatively well (or not so well) with respect to other similar sites. It accounts for potential bias due to regression-to-the-mean, differences in traffic volume among sites, and the nonlinear relationship between crash frequency and traffic volume.

The expected crash frequency is computed using the Empirical Bayes method, which combines the observed crash frequency (i.e., number of historical crashes) with the predicted crash frequency for a given site. The following is a brief overview of the EB method:

1. Identify Reference Group: Identify a group of sites representative of the facility and site type of interest for network screening. The reference group should reflect the major factors affecting crash risk, including traffic volume and other site characteristics. NYSDOT has defined 70 facility types for network screening as listed in Appendix A.
2. Develop SPFs: Using data from the reference sites, estimate an SPF relating crashes to independent variables such as traffic volume and other site

[1] Up to five consecutive years of roadway and crash data reflecting current conditions are used in screening. If there are major changes to a site over time, then the network screening only uses the most recent years of data that correspond to current conditions. For example, if an intersection was converted from stop-control to signal-control within the study period, then the network screening only includes data from years under the current condition (signal control).

characteristics. NYSDOT has developed SPFs for network screening as shown in Appendix B.

3. Estimate Predicted Crashes: Use the SPFs and traffic volume data for each site included in the network screening to estimate the predicted number of crashes for each year in the study period.
4. Estimate Expected Crashes: Use the Empirical Bayes method, shown in equation 3, to compute the expected crashes for each site-year in the study period as the weighted sum of predicted crashes from the SPF and observed crashes. For further details, refer to Hauer or the Highway Safety Manual (Reference).

$$N_{expected} = w * N_{predited} + (1 - w) * N_{observed} \quad (3)$$

Where:

$N_{predicted}$ = number of crashes predicted by SPF

$N_{observed}$ = number of crashes observed for study period

w = SPF weight, computed using equation 4

$$w = \frac{1}{1 + k * N_{predicted}} \quad (4)$$

Where:

k = dispersion parameter of SPF

Once the appropriate performance measures are computed for each site across the network, it is necessary to rank the sites. Intersections and ramps are ranked based on the simple ranking method (i.e., sort from high to low based on the performance measure). Analysts can choose to rank segments based on either the simple ranking or sliding window method (Reference). For the sliding window method, it is necessary to enter the window length (typically 0.3 miles) and sliding increment (typically 0.1 miles).

Regional offices should provide a reason for excluding high-priority sites from the AWP.

Main Office provides the network screening results to the Regional offices. Again, the Main Office uses the excess expected crash frequency (or excess observed crash frequency) to prioritize locations and develop the statewide network screening list. Regional offices then use the network screening list as a starting point and may confirm or remove sites from the initial list in developing the AWP. It is useful to visualize the screening results in CLEAR Safety to identify nearby sites that could be combined into potential corridors or areas for further study and remediation. For instance, if there are multiple high-priority intersections and segments in close proximity, it may be appropriate to study and consider corridor-level issues and countermeasures, rather than investigating and treating each priority location in isolation.

Regional offices should provide a reason for excluding high-priority sites from the AWP. The following is a list of factors to consider, and potential reasons to exclude sites, when reviewing network screening results for consideration in the AWP:

- Is the identified safety concern from the screening valid (e.g., are the data correct, is there an apparent safety issue, etc.)? If not, is there another safety concern worth addressing?
- Do any of the sites have projects already planned or in progress? If so, is the project expected to address the underlying issue or is there an opportunity for additional safety improvements through a jointly-funded project?
- Have any of the locations had previous planning or corridor studies noting safety concerns or potential future preferred safety improvements? If so, consider using these results as a starting point for the current diagnosis.
- Are there sites on the list that are in close proximity? If so, consider combining nearby sites for investigation as a corridor or area. Visualizing and mapping network screening results can help identify corridors or areas with nearby sites with promise.
- Is it likely that preferred improvements will be out of scope for HSIP (e.g., full interchange reconstruction)? Consider how the project could be funded and whether short-term improvements may be a good starting point while planning a more substantial capital improvement.
- Were any of the sites recently improved? If so, consider omitting those sites and continue to monitor those locations to see if safety performance improves.

Regional offices are not required to select sites from the network screening list—other methods for project identification are acceptable, but there is a need for proper justification. Regional offices may add sites to the AWP based on:

1. **Specialty PIL lists**: specialty PILs include wet-weather, fixed-object, single-vehicle, and pedestrian crashes. As with the statewide network screening based on fatal and serious injury crashes, the specialty PIL lists identify locations with potential for safety improvement. The difference is that the potential for improvement is based on specific crash groups that represent statewide areas of concern. CLEAR Safety generates specialty PIL lists for select crash groups and Regional offices can use CLEAR Safety to generate other specialty PIL lists as desired.
2. **Regional systemic network screening**: Regional offices may perform systemic network screening to identify groups of sites with high potential for safety improvement. These analyses could be based on specific crash types and contributing factors of regional significance. For instance, Regional offices could apply systemic screening methods to supplement the annual site-specific network screening from Main Office. Refer to *Section 4.2 Systemic Approach* for further discussion of systemic screening. Regions could also use the site-specific network screening list as a starting point for systemic analysis. For instance, visualizing network screening results on maps of the roadway network can help identify regions or corridors where a systemic safety project could be warranted to efficiently address common safety problems.
3. **Regional site-specific network screening**: Regional offices may perform additional site-specific network screening to identify locations with high potential for safety improvement. These analyses could be based on specific crash types and contributing factors of regional significance. Other crash-based network screening performance measures available in CLEAR Safety include:

   Average Observed Crash Frequency: Screening the network by means of average observed crash frequency is based on a comparison of the number of observed crashes among sites. Observed crash frequency is determined by the number of historical crashes occurring during a specified time period. Sites are ranked in descending order by the number of crashes; in this case by the average number of fatal and serious injury crashes over the last five complete years of applicable data. This measure does not account for potential bias due to regression-to-the-mean or differences in traffic volume among sites.

Expected Crash Frequency: Screening the network by means of expected average crash frequency is based on a comparison of the number of expected crashes among sites. The expected crash frequency is computed using the Empirical Bayes method, which combines the observed crash frequency (i.e., number of historical crashes) with the predicted crash frequency for a given site. The average expected crash frequency is the average of the expected crashes over the study period; in this case the last five years. Sites are ranked in descending order by the expected average number of crashes; in this case by the expected average number of fatal and serious injury crashes over the last five complete years of applicable data. This measure accounts for potential bias due to regression-to-the-mean, differences in traffic volume among sites, and the nonlinear relationship between crash frequency and traffic volume.

Level of Service of Safety (LOSS): Screening the network by means of LOSS employs an SPF to compare either observed or expected crash frequency for a given site to the predicted crash frequency for the given traffic volume. LOSS stratification boundaries are defined to create four categories of sites with respect to the difference between the observed or expected crashes and the predicted crash frequency. In CLEAR Safety, the following stratification boundaries are used to define the four LOSS categories:

- Level 1: > 90th percentile.
- Level 2: 50th to 90th percentile.
- Level 3: 10th to 50th percentile.
- Level 4: < 10th percentile.

As described in the first edition of the Highway Safety Manual, this measure does not account for potential bias due to regression-to-the-mean because it is based on a comparison of observed and predicted crashes. More recent research shows how the method can be adapted to account for regression-to-the-mean by replacing the observed crash frequency with the expected crash frequency. This essentially becomes the excess expected crash measure but incorporates levels of safety. In either case, the LOSS measure does account for differences in traffic volume among sites and the nonlinear relationship between crash frequency and traffic volume because it is based on SPFs. Based on the more recent research (Kononov et al., 2015), the 10th- and the 90th-percentile LOSS boundaries are estimated by using the inverse gamma distribution function and the parameters shown in equations 7 and 8.

$$alpha = \frac{1}{k} \tag{7}$$

$$beta = \frac{N_{predicted}}{alpha} \tag{8}$$

Where:

alpha = alpha value for inverse gamma function in Excel

beta = beta value for inverse gamma function in Excel

k = dispersion parameter associated with SPF

$N_{predicted}$ = number of crashes predicted by SPF

4. **Other Safety-Related Studies**: Other planning and engineering studies from various sources often incorporate a safety review that may identify potential safety improvements to the studied locations. These studies rely on data-driven analysis or anecdotal information to assess safety concerns. Regions may elect to initiate HSIP projects from these types of studies after verifying the presence of a data-driven need.
5. **Local Agency or Citizen Requests**: Another source of HSIP projects is from local agency or citizen requests. Local road safety plans often indicate specific projects, countermeasures, or strategies of interest to local stakeholders. Regions can approach local agencies to make them aware of a safety issue, and local agencies can request assistance from the Region to investigate locations of concern. These locations may not show up on the statewide network screening list due to lower PSI or data issues. While requests can help to identify potential locations for further investigation, all local agency and citizen requests should be reviewed to confirm the locations are appropriate candidates for the HSIP, demonstrate a data-driven opportunity for safety improvement, and determine if cost-effective improvements are feasible.

4.1.2 Diagnosis

The goal of diagnosis is to understand the crash patterns and identify the underlying factors contributing to crashes at sites identified from network screening. It is critical to diagnose crash patterns and underlying safety issues before selecting countermeasures. Otherwise, resources may be misallocated if the selected countermeasure does not properly or effectively target the underlying issues. Diagnosis can also help to identify potential safety issues that have not yet manifested in crashes.

It is critical to diagnose crash patterns and underlying safety issues before selecting countermeasures.

For the State highway system, documented procedures exist under which the Department's eleven Regional offices annually select, investigate, and recommend crash reduction measures for locations with potential for safety improvement within their jurisdictions. NYSDOT's Traffic and Safety Division published the *Safety Investigation Procedures Manual* (the Yellow Book) to document the methodology to investigate sites with potential for safety improvement, diagnose crash contributing factors, identify and develop targeted countermeasures and alternatives, and perform alternatives analysis.

For the local highway system, the process of investigating sites with potential for safety improvement, developing countermeasures, and implementing safety improvement projects is the responsibility of the individual municipalities with jurisdiction over those specific roads. The direct involvement of the State largely ends with the crash reporting and data services discussed in Chapter 3, Safety Data Systems. State engineers and staff are available to advise and assist local officials in their efforts through the Community Assistance Officer in each Region. Assistance is also available for funding of safety improvements. However, since each municipality defines and carries out its own program, only the procedures concerned in the NYSDOT HSIP are described here.

Traditional methods for diagnosing safety issues include crash summary statistics and collision diagrams. More reliable methods include tests of proportions. These methods help to identify crash contributing factors, particularly those that are over-represented compared to other similar locations. The data required to support these more reliable methods include detailed crash data for the location of interest. The test of proportions also requires summary crash data (i.e., average crash proportions) for other similar locations. Roadway and traffic data are useful in the diagnosis process to help identify roadway geometric and operational factors that may be contributing to crashes.

Diagnosis involves a review of site-specific crash history, traffic operations, and general site conditions. This may include more traditional engineering studies (e.g., site reviews, policy checks, and speed studies) and/or multidisciplinary road safety audits (RSAs). Diagnosis may also include a desktop data analysis and/or field visit to review site conditions and identify crash contributing factors. Field visits are particularly useful to observe road user behaviors and site conditions not observable from the office. It is useful to conduct a field review under multiple conditions (e.g., day and night, peak and off-peak travel times, dry and wet) to investigate potential issues that may arise under different conditions and to confirm crash contributing factors identified from the crash history.

The following are steps for conducting site diagnosis.

1. **Review crash data**: The first step is to review and confirm the crashes during the study period within the study area. Confirming crashes helps to ensure the subsequent analysis is based on accurate information. Analysts confirm each crash by reviewing and accepting its attributes and location or editing (or requesting edits) to crash attributes and/or location before confirming.
2. **Review crash summary data**: The second step involves a detailed review of crash data to identify crash patterns and contributing factors. This involves a review of crash summaries by collision type, crash severity, time of day, day of week, weather condition, light condition, and more. Tabular summaries, bar charts, and pie charts are useful for displaying these descriptive statistics. In addition to descriptive statistics, tools such collision diagrams and statistical tests can help to identify crash patterns and over-represented safety issues. CLEAR Safety provides crash summaries and related tools to support this step. Refer to the NYSDOT Yellow Book for further details on the use of summary statistics, collision diagrams, and statistical tests.
3. **Assess supporting documentation**: This next step involves a review of documented information about the site along with interviews of local stakeholders (e.g., transportation professionals, community groups, local board members) to obtain additional perspectives on the crash data review from step 2. Supporting documentation may include traffic volumes, condition diagrams, construction plans and design criteria, photos and maintenance logs, weather patterns, and recent traffic studies.
4. **Assess field conditions**: Field observations are useful for supplementing the information gathered in steps 1 – 3 and can help to understand the behavior and interactions among road users. The field review should include observations of traffic operations such as turning movements, conflicts, and operating speeds, as well as accommodation for pedestrians, cyclists, and special road users such as senior

pedestrians or young pedestrians (e.g., children near schools). In addition, the field review should include observations of highway and roadside design to determine whether the design and location of roadway and roadside features are consistent with road user expectations. The roadside review can also help to determine if roadside recovery zones are clear and traversable.

For further discussion of the diagnosis process, including detailed prompts, refer to the Highway Safety Manual and FHWA's Road Safety Audit Guidelines.

4.1.3 Countermeasure Selection

Consider multiple potential alternatives before selecting a final countermeasure.

The goal of countermeasure selection is to identify and assess potential countermeasures and select the most effective countermeasure(s) to address the crash contributing factors identified in diagnosis. The first part of countermeasure selection is to develop one or more countermeasures to target the underlying safety issues. It is advisable to consider a number of potential alternatives rather than a single countermeasure. This helps to compare feasible alternatives and to document reasons for advancing or eliminating certain alternatives, which is particularly desirable for capital projects.

CLEAR Safety provides a countermeasure selection tool that generates a list of suggested countermeasures based on crash patterns and/or crash contributing factors. Appendix C provides a snapshot of the countermeasure list by facility type. Other resources such as FHWA's Proven Safety Countermeasures, NCHRP Report 500 series, and the NHTSA's Countermeasures that Work also identify targeted countermeasures to address or mitigate underlying contributing factors. Analysts can use these resources to develop a list of potential countermeasures for further consideration in economic appraisal (see Section 4.3 below).

Countermeasures may produce different results when implemented at different sites with different geometric and operational characteristics. As such, there is a need to consider the safety impact of countermeasures, individually and in combination, for the scenario of interest. Subsequent steps of the roadway safety management process (economic appraisal and project prioritization) include the consideration of parameters such as constructability, environmental impacts, and cost. The following is a summary of three methods, listed in order of increasing reliability, for comparing countermeasures: judgment-based, data-driven behavioral-based, and data-driven crash based.

1. **Judgment-based**: Professional judgment is critical for all aspects of safety management, including the selection of countermeasures (e.g., selecting appropriate countermeasures to address or mitigate a given issue based on past experience). While judgment is important, a purely judgment-based method is the least reliable for assessing potential countermeasure effectiveness because it is limited by personal experience (that may be relatively limited) and susceptible to personal bias. One benefit of using a multidisciplinary team to diagnose issues and select countermeasures is that it draws on multiple experiences and perspectives.
2. **Behavior-based (data-driven)**: A data-driven behavior-based method draws on research results to assess countermeasure effectiveness. Performance measures may include speed, conflicts, lane keeping, and compliance with traffic control devices. While the results do not provide a direct estimate of the expected change in crashes, these

types of performance measures can help estimate the expected effect on road user behavior.

3. **Crash-based (data-driven)**: A data-driven crash-based method also draws on research results but provides a direct estimate of safety performance impacts. Crash modification factors (CMFs) are the typical focus of crash-based methods and can help to quantify and compare the safety effects of potential countermeasures under specific site conditions. CLEAR Safety provides CMFs for select countermeasures as shown in Appendix C. The CMFs are based on safety effectiveness evaluations, either national or NY-specific, and are updated periodically using findings from the Department's post-implementation evaluations. Refer to the NYSDOT Yellow Book for further details on CMF application and refer to the CMF Clearinghouse for a complete list of national CMFs.

4.2 Systemic Approach

The systemic approach is a six-step process as shown in Figure 11. Following the figure is a summary of the first three steps of the systemic approach, including opportunities to use more reliable methods to improve decisions.

The systemic approach is complementary to the hotspot approach.

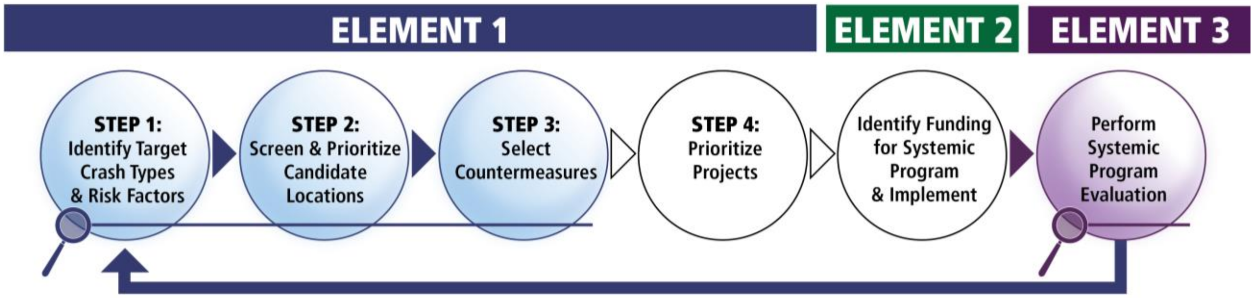


Figure 11. 6-step systemic approach to safety management.

4.2.1 Identify Focus Crash Types, Facility Types, and Risk Factors

The first step in the systemic approach is to identify the focus crash type(s), facility type(s), and risk factors. This is similar to the second step in the hotspot approach (diagnosis).

- **Focus crash types** reflect prevalent severe crash types for a given jurisdiction. The New York State SHSP is a good starting point to identify focus crash types. For those agencies with a regional, county, local, or tribal road safety plan, it is useful to identify focus crash types from these plans instead of the SHSP because these plans reflect the local emphasis areas.
- **Focus facility types** typically include the locations where the target crash types are most prevalent (e.g., rural, two-lane, undivided segments or urban, four-leg, signalized intersections). Analysts can use CLEAR Safety to generate crash trees for the focus crash type(s) to determine where they are most prevalent. The analyst can filter crashes on focus facility groups by general facility type category (e.g., segment, intersection, ramp) and specific facility type (e.g., rural, two-lane, divided, free access).
- **Risk factors** are those characteristics that are common among the locations on the focus facility type(s) and are associated with an increased risk of the focus crash type(s). Risk factors may include site-specific crash history, roadway and roadside attributes, operational characteristics, and socioeconomic and demographic factors. Analysts can use CLEAR Safety to perform statistical analyses and evaluate potential risk factors. Refer to the FHWA Systemic Safety Project Selection Tool and NYSDOT Yellow Book for further information on the identification of focus crash types, focus facility types, and risk factors.

4.2.2 Screen and Prioritize Candidate Locations

The second step of the systemic approach is to develop a prioritized list of potential locations for systemic improvement. This is similar to step one in the hotspot approach (network screening). Using risk factors as the basis for screening, analysts identify sites on the focus facility types with these specific geometric and operational characteristics as candidate locations. To prioritize candidate locations, analysts assign a level of risk to each site based on the site-specific risk factors (e.g., geometric characteristics, operational attributes, and crash history).

Analysts can assign equal weight to each risk factor or apply thresholds or weights to each risk factor to reduce the list of sites based on available resources and program objectives. Refer to the FHWA Systemic Safety Project Selection Tool and NYSDOT Yellow Book for further information related to the screening and prioritization of candidate locations.

4.2.3 Select Countermeasures

Countermeasures should target the underlying risk factors.

The third step in the systemic approach is to select one or more targeted countermeasures to address the underlying risk factors. Given the list of risk factors for the focus crash type(s), analysts can develop targeted countermeasures to address or mitigate the specific risk factors at the specific locations across the focus facility type. This is similar to the third step in the hotspot approach (countermeasure selection). Note that not all locations would necessarily receive the same treatment. Instead, the list of risk factors present at a specific location and the general site conditions for that location should help to determine the appropriate countermeasure. For implementation, it is useful to group sites with common characteristics or with common recommended countermeasures to create economies of scale. Refer to the FHWA Systemic Safety Project Selection Tool and NYSDOT Yellow Book for further information related to the selection of countermeasures.

CLEAR Safety provides a countermeasure selection tool that generates a list of suggested countermeasures based on crash patterns and/or crash contributing factors as described above in Section 4.1.3. Appendix C provides a snapshot of the countermeasure list by facility type. Other resources such as FHWA's Proven Safety Countermeasures, NCHRP Report 500 series, and the NHTSA's Countermeasures that Work also identify targeted countermeasures to address or mitigate underlying contributing factors. Analysts can use these resources to develop a list of potential countermeasures for further consideration in economic appraisal (see Section 4.3 below). While CLEAR Safety supports countermeasure selection, analysts should consider site-specific and contextual factors in selecting the preferred countermeasure because there are many factors that contribute to the success or failure of safety improvement projects.

4.3 Economic Appraisal

All capital improvements require a full benefit-cost analysis.

A common tradeoff in project planning and countermeasure selection is whether it is more appropriate to select a more expensive treatment that is more likely to reduce a greater number of crashes per site, or to select a less expensive treatment that may reduce a lower number of crashes per site. Given that some sites experience a much higher crash frequency than others, it is usually more appropriate to implement higher cost treatments at sites with higher crash frequency, and lower cost treatments at sites with lower crash frequency. Beyond these general guidelines, there is a quantitative approach to identify the most economically efficient option.

The goal of economic appraisal is to assess the cost-effectiveness of alternatives by estimating and comparing the economic benefits and costs. Benefit-cost analysis is required for all proposed capital improvement projects. It is also applicable to proposed projects from both the hotspot and systemic approaches.

Economic appraisal involves several components, including safety benefits, crash costs, discount rates, service life values, and project costs. The following subsections describe each component.

4.3.1 Safety Benefits

The estimated safety benefits (or disbenefits) of a countermeasure are based on the difference between the expected crashes without the countermeasure and the expected crashes with the countermeasure. CLEAR Safety automatically computes these values along with the annual benefit for the countermeasure(s) of interest based on the observed crash history, SPF (where applicable), and associated CMF(s) (default or user-defined). Further, CLEAR Safety provides a breakdown of the benefits based on total crashes as well as fatal and injury crashes. Refer to the NYSDOT Yellow Book or FHWA's Highway Safety Benefit-Cost Analysis Guide for further details on estimating safety benefits.

If there is no applicable CMF available in CLEAR Safety, the analyst can consider the following options to estimate the safety benefit of proposed countermeasures and enter the result in CLEAR Safety as a user-defined CMF.

1. **Identify a CMF from FHWA's CMF Clearinghouse or Safety Literature**: The CMF Clearinghouse is a repository of CMFs sponsored by FHWA. A star rating is used to indicate the relative quality of CMFs. While the CMF Clearinghouse is intended to provide a complete list of national CMFs, there may be CMFs from recent literature that have not yet made it into the Clearinghouse. To identify the latest research on a given topic or countermeasure of interest, refer to the Transport Research International Documentation (TRID).
2. **Estimate a CMF from SPFs or Average Crash Rates**: In general, it is reasonable to assume that a proposed improvement would bring a location into line with the average crash experience of similar type facilities. Under this assumption, the analyst could develop a pseudo CMF by comparing the average safety performance based on SPFs or average crash rates. For instance, if the proposed improvement was to convert a three-legged minor road stop-controlled intersection to a three-legged roundabout, and there is not an applicable CMF, it is possible to develop a pseudo CMF by:
    a. Using the corresponding SPF or average crash rate to estimate the average safety performance for a similar three-legged minor road stop-controlled intersection.
    b. Using the corresponding SPF or average crash rate to estimate the average safety performance for a three-legged roundabout.
    c. Dividing the result for the proposed condition (in this case the roundabout) by the result for the existing condition (in this case the stop-controlled intersection).

   This method is most appropriate for upgrade and reconstruction projects where the general facility type (e.g., number of lanes, median type, intersection control) is expected to change. Further, this method may be appropriate in cases where there are numerous proposed improvements that are difficult to capture with CMFs. In such cases, numerous overlapping improvements at a single site may make it impossible to apply improvement-specific CMFs without duplicating benefits. Appendix B provides SPFs and average crash rates for various facility types.
3. **Estimate a CMF from Professional Judgment**: This method is only used in instances where there is no other crash-based research related to the countermeasure of interest.

Considerable judgment must be exercised in this approach, but it allows for a correspondingly high degree of flexibility. It can range from a review of crash reports to the use of safety surrogate measures.

a. **Review Crash Reports**: The analyst could perform a detailed review of individual crash reports for the location of interest to determine which crashes may have been prevented by the proposed improvement. Similar to the steps in option #2 above, there is an opportunity to estimate a pseudo CMF by dividing the estimated number crashes with treatment by the observed number of crashes without treatment.
b. **Use Safety Surrogates**: A surrogate measure of safety is an observable non-crash event, behavior, performance measure, or index that is related to crash occurrence or crash severity. Ideally, to use surrogates in this type of safety analysis, there should be a practical method for converting the changes or differences in surrogates to corresponding changes or differences in crash frequency. However, this has historically been a limitation and one reason why surrogate research has not made its way into safety management practice. While there are limitations to using surrogates as a direct measure of countermeasure effectiveness, FHWA's A Guide to Developing Quality CMFs identifies surrogates as one possible approach to estimating safety benefits.

4.3.2 Crash Costs

To complete an economic appraisal, there is a need to convert the estimated change in crash frequency to a dollar value based on the average cost of a crash. The crash cost values for New York are based on the FHWA guide Crash Costs for Highway Safety Analysis. The values in Table 4 represent the 2016 values from the FHWA guide, updated to 2022 and adjusted to reflect the state-specific cost of living and injury-to-crash ratios. The costs are updated periodically using the Consumer Price Index. Refer to CLEAR Safety for the most recent crash cost values.

Crash cost values should be adjusted annually using the Consumer Price Index.

Table 4. Average crash cost values.

Severity	Costs by Severity
K	$15,727,025
A	$866,561
B	$275,534
C	$173,401
O	$16,957

4.3.3 Discount Rate

The discount rate helps to adjust for inflation and the time value of money and resources. The standard discount rate for HSIP projects in New York is 3%. CLEAR Safety uses this as the default value for alternatives analysis.

4.3.4 Service Life Values

Service life is the number of years that a countermeasure should have a noticeable effect on crashes at a site (Reference). Factors that influence service life include the environment, maintenance and rehabilitation practices, replacement cycles, operational and design context, and manufacturer specifications and warranties. CLEAR Safety includes standard service life values for select countermeasures as shown in Appendix C. Refer to FHWA's Countermeasure Service Life Guide for further details on values and application of service life in economic appraisal.

4.3.5 Countermeasure Costs

Countermeasure costs include the cost to implement and maintain over the designated service life. CLEAR Safety provides default costs for select countermeasures by facility type. When costs are not provided for a given countermeasure or facility type, or the cost does not appear reasonable, analysts can update the costs as needed. It is recommended to update costs, when possible, to better reflect the estimated project cost for the specific scenario. An additional contingency cost factor may be added to the annualized project cost to account for unexpected considerations and possible errors in estimation. The more precise the estimate of project costs, the lower the contingency factor is likely to be. Annual maintenance, operation, energy, and other non-capital costs are then added to cost estimates to arrive at total annualized cost. Refer to the Department's Weighted Average Item Price Report for further details on average prices.

It is recommended to update costs, when possible, to better reflect the estimated project cost for the specific scenario.

4.3.6 Economic Analysis Method

It is important to compare costs and benefits over the same time period for economic analysis. CLEAR Safety uses annual values for comparison. For annual safety benefits, the values represent the monetary value of the difference between the annual estimated crashes without the countermeasure and the annual estimated crashes with the countermeasure, as shown in equation 9.

$$Annual\ Safety\ Benefit\ (\$) = Crash\ Cost_i * (N_{annual\_expected\_without\_i} - N_{annual\_expected\_with\_i}) \quad (9)$$

Where:

Annual Safety Benefit = monetary value of the estimated change in annual crashes between the condition without the countermeasure and the condition with the countermeasure

$Crash\ Cost_i$ = average crash cost associated with severity level i

$N_{annual\_expected\_without\_i}$ = annual estimated crashes of severity level i without the countermeasure

$N_{annual\_expected\_with\_i}$ = annual estimated crashes of severity level i with the countermeasure

The annual countermeasure cost is based on annualized value of initial construction costs plus the value of any annual maintenance costs, as shown in equation 10.

$$Annual\ Cost\ (\$) = \frac{Initial\ Construction\ Cost}{M} + Annual\ Maintenance\ Cost \quad (10)$$

Where:

Annual Cost = annual cost of construction and maintenance costs

M = factor to convert present value costs to annual costs, as shown in equation 11

$$M = \frac{(1+r)^s - 1}{r * (1+r)^s} \tag{11}$$

Where:

r = discount rate (3% as noted previously)

s = service life of countermeasure

The benefit-cost ratio (BCR) is the estimated annual benefits divided by the estimated annual costs, where a BCR greater than 0 indicates the project is expected to generate safety benefits and a BCR greater than 1.0 indicates the return is greater than the investment. CLEAR Safety provides the BCR for both total crashes and fatal and injury crashes. By focusing on the BCR for fatal and injury crashes, there is an opportunity to prioritize those projects with the greatest potential to reduce deaths and injuries.

Analysts may also include estimates of other monetized benefits in the BCR, including energy, travel time, and vehicle operational savings. Refer to the NYSDOT Yellow Book or FHWA's Highway Safety Benefit-Cost Analysis Guide for further details on economic appraisal.

4.4 Project Prioritization

There are more opportunities to improve safety across a highway network than funds available to implement the projects. As such, safety program managers are challenged with selecting projects and allocating resources to maximize the program's return on investment. **Regional offices** are responsible for identifying, developing, and proposing effective highway safety improvement projects that address the safety needs of the region. The **Main Office** is responsible for prioritizing proposed projects from all of the regions to maximize the opportunity to advance safety in New York.

It is useful to consider a mix of hotspot and systemic, state and local, and education and enforcement projects as part of a comprehensive approach to safety management.

While Regional offices are ultimately responsible for deciding how to address safety issues in the region, all HSIP projects must meet HSIP eligibility requirements and maximize the opportunity to reduce fatalities and serious injuries in New York. It is also recommended that Regions consider a balanced portfolio of projects, including a mix of hotspot and systemic improvements and a mix of projects on state and local roads. It is important for Regional offices to coordinate with local agencies and encourage local road safety improvements because 68% of fatal and serious injury crashes occur off the State system in New York. Further, there is an opportunity to consider and recommend education and enforcement strategies as part of a comprehensive approach to safety management.

Regions should use CLEAR Safety to document the results of alternatives analysis and related recommendations. The Main Office then groups those recommendations into the following four general categories as described below:

1. No Action
2. Capital Improvements
3. Maintenance Improvements
4. Other Initiatives

4.4.1 No Action

This is the classification of projects where no improvements are recommended after a detailed safety investigation. Analysts should document the results of all alternatives considered, including those not selected for implementation with a statement to document the reasons for no action.

4.4.2 Capital Improvements

The estimated BCR is required for all capital improvement projects.

When, in the judgment of the Regional Traffic Engineer, low-cost projects have been unable or are unlikely to resolve an underlying safety problem, a capital project is considered. Due to the larger scope and cost, capital projects are subject to more rigorous review and require documented justification than other projects. The exact nature of the development process depends on various factors, including the source of funding and the anticipated cost-effectiveness of the proposed improvement. The cost-effectiveness, as indicated by the safety BCR, is the most important determinant of project development requirements. Depending on the estimated safety BCR, the development of a capital improvement project follows one of two paths:

Project Initiation Request (PIR): Projects with a safety **BCR less than 1.0** may be justifiable when other benefits are considered in addition to safety, but these projects receive careful scrutiny, especially when dedicated safety funds are involved. In addition to the benefit cost analysis, extensive project and plan reviews and approvals are required within the Department to assure that funds are used in an appropriate manner. The following elements may be required in the project development process:

1. Project development report (see below)
2. Main Office reviews
3. Program management actions
4. Environmental impact review
5. Design reports
6. Plans, specifications and estimates
7. Traffic and Safety review
8. FHWA review (if a proposal calls for Federal funds)

Project Development Report: The Regional Planning and Development Group may undertake preliminary development work on a project when necessary to supplement the PIR. This work might include such items as: need for the project; specification of project objectives; definition of project limits; traffic data and projections; identification of alternative solutions; compatibility of alternative land use plans; identification of possible adverse effects of the solutions; conflicts of alternative solutions with other existing or proposed highway projects; documentation showing lack of feasibility of certain solutions; and more detailed estimates of the costs and operational impacts of the alternative solutions than would be available in the Project Initiation Request.

The preliminary development work done by this group would be described in the Project Development Report. This report verifies the type of solution appropriate for the identified problem and, if a highway solution is recommended, the range of highway solutions appropriate for further consideration and for the development of design alternatives.

The Program Planning and Management Group (PP&MG) reviews the PIR and Project Development Report, and also coordinates review of the PIR by other Department program areas. This review process involves consideration of the merits of the project, its compatibility with other department projects and programs, and funding availability. Since the proposed safety capital project is targeted at a safety problem, the Traffic and Safety Division's recommendations are especially important.

Project Notification Form (PNF): For proposed improvements showing an expected safety **BCR of 1.0 or more**, a streamlined process is available to expedite project development. For such projects, the Regional Director has the authority to place the project on the work program without Main Office review, subject to the availability of funds. However, if the project is to use Federal funds, it may still be necessary to obtain FHWA approval through the Main Office, which also remains responsible for overall program performance.

4.4.3 Maintenance Improvements

These improvements include routine non-regulatory measures as well as traffic control improvements.

1. **Non-Regulatory Measures**: Routine non-regulatory measures include the installation, replacement, or moving of warning signs, the removal of brush impeding sight distance, the application of certain pavement markings, and resurfacing or pavement grooving. These improvements are generally implemented by Regional maintenance forces (Resident Engineers). Regional signal crews are used for such purposes as installing flashing beacons on stop ahead or yield ahead signs. Larger scale maintenance projects, such as roadway widening and adding turn lanes or guiderail, may require additional justification.
2. **Traffic Control Improvements**: Traffic control improvements include signing or signal installations or modifications that entail a change in traffic regulations (e.g., stop signs, yield signs, speed limit signs, traffic signals, and certain pavement markings). These improvements are implemented by Regional maintenance forces, Regional signal crews, or private contractors, depending on the nature of the improvement and the workforce available in each Region. New signals are installed either by Regional signal crews or by private contractors. Most signal modifications are performed by Regional signal crews. Since a change in traffic regulations is involved, the Department's Traffic and Safety Division Director must submit official orders (form TE 3e) to the Secretary of State, who files the order and notifies the Main Office to proceed. The Regional Traffic Engineer is then informed of the filing and, in cases of signing or pavement marking changes, prepares a work order and forwards it for execution by the appropriate Resident Engineer. Once the project is completed, the Resident Engineer informs the Regional Traffic Engineer, and the date assigned and completion date are recorded on the Log of Safety Projects (form TE 133-1). New traffic signals and some signal changes also require filing with the Secretary of State. Once notification of filing has been received from the Main Office, Regional Traffic Engineers complete the Signal Operations Specification (form TE 4c).

4.4.4 Other Initiatives

Implementation of "other" recommendations usually involves correspondence and follow-up. These recommendations typically include requests for selective enforcement by State Police and informing appropriate jurisdictions of findings relating to non-State highways. Requests for additional information from other Department groups may also be involved, such as requests for skid tests and special traffic counts. Once results have been received from these tests and surveys, the Regional Traffic Engineer decides whether to implement follow-up measures such as improving skid resistance or modifying traffic control devices at the location.

The Main Office prioritizes and selects capital improvement projects for inclusion in the STIP. These projects then proceed through the project development process to complete project scoping, planning, and design. Note that some safety improvements may be identified after a project has already gone through part of the project development process as safety should be considered at each stage (scoping, planning, preliminary design, and final design). Refer to Appendix D for a flow chart of the Department's project development process.

In general, the Main Office ranks capital improvement projects by BCR_{FI} (the BCR associated with fatal and injury crashes). In addition to the BCR_{FI} and available funding limits, the Main Office considers the following factors in prioritizing and selecting projects.

- **Other planned projects at the location**: Projects could be given a higher priority when other projects are planned at the location (for safety improvement or otherwise) when the projects could, for example, save on mobilization and materials costs if constructed together. For instance, there is an opportunity to address high priority crash types by adding cost-effective countermeasures to existing 3R, Work Program, or other non-HSIP projects. On the other hand, projects may be given a lower priority if other projects are planned at the location and the proposed safety improvement is redundant or the other project should be evaluated before further improvements are made.
- **Vulnerable Road User Projects**: It may be difficult to justify pedestrian and bicycle safety improvement projects due to limitations in current predictive methods. As such, pedestrian and bicycle projects may be approved in the HSIP without a BCR or with BCR under 1.0 with the understanding that providing safe mobility to non-motorized users is a priority.
- **Funding equity**: It is neither practical nor a good investment strategy to use all HSIP funds in one region of New York—all regions experience traffic fatalities and serious injuries. The Department will adjust priorities as necessary to distribute available funding among regions.
- **Environmental impacts and mitigation**: Projects with substantial environmental impacts may be given lower priority than similar projects with no environmental impacts.
- **Right-of-way needs and acquisition**: Projects requiring right-of-way acquisition may be given lower priority than similar projects with no right-of-way needs. This is due to the potential complications in acquiring right-of-way, not the costs. The associated right-of-way costs should already be accounted for in the BCR.
- **Project readiness**: Projects that are "shovel-ready" may be given higher priority than projects that are in development and design stages.
- **Public acceptance**: Projects with favorable public perception may be given higher priority than projects that are highly controversial.

For unfunded projects, the Main Office documents the reasons and shares the information back to the regions. Regional offices should maintain a listing of unfunded safety needs and potential projects. Annually, the regions can consider these unfunded needs and reprioritize with the list of new potential projects.

CHAPTER 5. IMPLEMENTATION

The goal of this step is to implement the proposed (and approved) recommendations. This can occur through standalone HSIP projects, standalone capital or maintenance projects, or jointly funded projects (e.g., adding HSIP funds to a capital project). There are many opportunities to add safety improvements to other existing or planned projects. The Regions should regularly consider opportunities to add safety countermeasures to planned projects outside of the HSIP when there is a data-driven need to improve safety. As described in Section 4.1.1, cross-referencing the annual network screening list with existing and planned projects is an effective way to identify opportunities to implement safety improvements through other projects. Adding safety improvements to other projects is an efficient way to improve safety because it minimizes mobilization costs and impacts on operations.

Visualizing proposed project locations on maps can help identify opportunities for project bundling.

Another way to gain efficiencies in project management and implementation costs is to bundle similar smaller projects into one or more larger projects. For instance, while the hotspot approach typically produces projects at individual locations, there may be an opportunity to bundle recommendations from similar hotspot improvement projects such as rumble strips or high friction surface treatment for implementation. Similarly, systemic projects typically involve the implementation of low-cost strategies at multiple locations with similar characteristics, which may be conducive to project bundling. Visualizing proposed project locations on maps of the roadway network can help to identify areas or corridors where project bundling could be an efficient means to implement similar projects and address common safety problems.

Regions can use CLEAR Safety to manage their recommendations and suggest an implementation category for each recommendation. The Main Office then confirms one of the following implementation categories as described in the previous section:

1. Capital improvement
2. Maintenance
3. Initiative

At this point, the projects and initiatives diverge from CLEAR Safety. Capital improvement projects enter the next stage of the project development process. Maintenance activities and other initiatives also follow their respective implementation paths. The following is an overview of the process for each project type. Refer to XXX for further information.

5.1 Capital Improvement Projects

Recommendations advancing through the Department’s Capital Program are transmitted for formal executive approval and, if approved, an action memo is issued by PP&MG adding the project to the Capital Program. The Capital Projects Coordination Bureau then issues a design authorization. If Federal funds are involved, the Traffic and Safety Division transmits the PIR to FHWA for review. FHWA reviews the PIR primarily for environmental impacts, but FHWA may also consider non-environmental issues, suggest alternative solutions, or point out possible substandard features of the proposed project. For most Federally-funded safety capital projects, FHWA transfers responsibility for design approval to the State via certification acceptance procedures. The Traffic and Safety Division may also be responsible for obtaining the required FHWA certification or approval for PNF-advanced projects that use Federal funds.

5.1.1 Environmental Impacts

Capital Projects are divided into three categories: simple, moderate, and complex. Exhibit 2-1 of the Department's *Project Development Manual* provides a summary of these three types of projects and gives examples for each project category. Further, the preliminary NEPA and SEQR classification is an important decision to be made during the Project Scoping Stage. Section 2.3.1 of the Department's *Project Development Manual* defines the NEPA Class and SEQR Type based on the "significance" of the anticipated social, economic, and environmental issues (impacts) of the project. The NEPA classes and SEQR types then determine which section of the procedural steps to use. Federally aided projects follow the procedures for their NEPA environmental class and 100% State funded projects follow the procedures shown for their SEQR type.

The evolutionary nature of the transportation project development process requires that determination of a project's NEPA class and SEQR type should not be viewed as absolute and final. In many cases, as a project advances through the various stages of project development toward implementation, new or more specific information is obtained, a project's circumstances may change, or additional alternatives may be developed. Any of these changes may require changes in the project's scope, NEPA class, or SEQR type.

Refer to the Department's *Project Development Manual* for further discussion of requirements.

Exhibit 2-3 Federal-Aid Design Approval Document Formats (see Notes on Page 2-17)

Project Complexity	NEPA Class[1]	SEQRA Type[2]	Document Formats Required		
			Project Scoping Stage	Design Phase I	Design Phase IV
Simple	Class II Automatic CE or Programmatic CE	Type II	A separate Project Scoping Stage document is not prepared for simple projects	A separate Draft Design Report is not prepared for simple projects	Project Scoping Report/ Final Design Report (PSR/FDR)
Moderate	Class II Programmatic CE or CE w/doc. Class III[4] (EA)	Type II & Non-Type II[3] (EA)	Project Scoping Report (PSR) in format of Design Report	Draft Design Report (DDR) (fulfills NEPA/SEQRA EA requirements)	Final Design Report (FDR) (fulfills NEPA/SEQRA EA requirements)
Complex	Class I (EIS)	Non-Type II (EIS)	Project Scoping Report (PSR) in format of Design Report	Draft Design Report/ Environmental Impact Statement (DDR/DEIS)	Final Design Report/Env. Impact Statement (FDR/FEIS)

Exhibit 2-4 100% State-Funded Project Reports

Project Complexity	SEQRA Type[2]	Document Formats Required		
		Project Scoping Stage	Design Phase I	Design Phase IV
Simple	Type II	A separate Project Scoping Stage document is not prepared for simple projects	A separate Draft Design Report is not prepared for simple projects	Project Scoping Report/Final Design Report (PSR/FDR)
Moderate	Type II & Non-Type II (EA)	Project Scoping Report in format of Design Report	Draft Design Report (DDR) (fulfills SEQRA EA requirements)	Final Design Report (FDR) (fulfills SEQRA EA requirements)
Complex	Non-Type II (EIS)	Project Scoping Report (PSR) in format of Design Report	Draft Design Report/ Environmental Impact Statement (DDR/DEIS)	Final Design Report/ Env. Impact Statement (FDR/FEIS)

Notes for Exhibits 2-3 and 2-4:

1. The NEPA Class as per 23 CFR 771.115 must be documented in the appropriate section of the project report in sufficient detail for DAD readers to understand the project's classification.
2. The SEQRA Type as per 17 NYCRR Part 15 must be documented in the appropriate section of the project report and the particular SEQRA 17 NYCRR Part 15 section that is the basis for the SEQRA Type determination must be stated in sufficient detail for DAD readers to understand the project's classification. This requirement applies to Federal-aid as well as 100% State-funded projects.
3. Projects that are Federal-Aid and SEQRA Non-Type II (EA) must follow the procedural steps found in PDM Sections 4.4.2 and 4.5.2. This includes the filing of a DONSE (in Section 4.5.2) if it is determined that there are no significant effects.
4. See PDM Section 2.3.1.2.B for detailed information on NEPA Class III project types.

5.1.2 Project Design

The Capital Projects Coordination Bureau transmits the Project Design Authorization to the Department's Regional Offices as well as to Main Office program areas. Regional Design may decide at that point to commence project design, or it may choose (for Federally funded projects) to await FHWA's notification of concurrence with the categorical exclusion for applicable projects.

Project Design involves a detailed analysis of location alternatives, if appropriate, and the establishment of design criteria and alternatives within the limit of the selected location band. All feasible design alternatives are assessed on the basis of engineering, social, economic, and environmental considerations. These are documented in the design report and final design report as described below.

1. **Design Report**: This report describes the initial findings of project design. It summarizes the nature and results of public and agency comments and criticisms, "no action" and maintenance alternatives, supplementary studies, environmental assessments, and

earlier reports, if any. If the Department determines that a proposed project may have a significant effect on the human environment, the Design Report will be processed as a draft Environmental Impact Statement. If the proposed project will not have such an effect, the report will be prepared as an Environmental Assessment, leading to a finding of no significant impact.

2. **Final Design Report**: The Design Report is reviewed by the public and functional areas within the Department. Regional Design evaluates recommendations for design modifications or alternatives received from the public or from other functional areas in the Department and selects the preferred alternative, giving special attention to design features that may avoid or minimize identified adverse effects. Design features which differ from established standards are identified, and their use justified. The final Design Report may serve as either the final Environmental Impact Statement or the finding of no significant impact for applicable projects.

Advance detail plans, which contain about 75% of the information needed to commence the safety capital project, are then prepared and submitted to traffic engineering design review. All comments resulting from this review must be resolved before plans may be completed. Plans, specifications, and estimates are then completed, reviewed and sent to the Main Office Final Plan Review Bureau for funding authority and contract letting.

5.1.3 Traffic and Safety Reviews

The Regional Traffic and Safety Group provides technical advice and assistance to the Regional Planning Group, the Regional Design Group, and the Regional Construction Group during the development of all highway construction reports and plans. The Traffic and Safety Group reviews such reports and plans to assure that traffic engineering principles and techniques have been properly incorporated. All projects, regardless of their BCR, NEPA class, or SEQR type, are reviewed by the Regional Traffic and Safety Group.

The Regional Planning and Development Group and the Regional Design Group are responsible for the distribution of project reports and plans to the Regional Traffic and Safety Group for review. The Regional Construction Group is responsible for the distribution of orders-on-contract and field change sheets for this review.

The Traffic and Safety Division Main Office Design Review unit, on request by the Regional Traffic Group, provides advice and assistance during the traffic engineering design review of reports and plans at the various stages of project development. The Design Review unit monitors traffic engineering design reviews conducted by the Regional Traffic and Safety Group to ensure compliance, to evaluate their completeness, and to determine the need for developing training, policies, directives, and standards pertaining to traffic operations.

Major review comments are resolved at the earliest possible stage in project development to avoid unnecessary delays in completion of the project. If the engineering material submitted at a particular stage contains information in greater detail than normally expected at that point, all of the submitted material is subjected to a traffic engineering design review. If the material submitted at a particular stage is not sufficient for an adequate traffic engineering design review, the Regional Group responsible for the preparation of the material is notified and requested to forward the necessary data.

5.2 Maintenance Activities

Highway Maintenance and Simple project types that are NEPA Class II and/or SEQRA Exempt or Type II may use the Initial Project Proposal (IPP)/Final Design Report (FDR) format as noted in the *Project Development Manual* Appendix 7, Exhibit 7-1. The Project Scoping Report (PSR)/FDR may also be used for these projects, where the project scope warrants. If a Simple Project is SEQRA Non-Type II (EA) the PSR/FDR format must be used (except when it is Non-Type II (EA) only because it exceeds 17 NYCRR 15.14(d)(6), i.e., there is a Section 106 No Adverse Effect determination). Contact the Main Office Project Liaison with questions regarding the applicability of report formats for specific project situations.

Refer to Sections 4.3.3.2 and 4.3.3.3 in the Department's *Project Development Manual* for more information on projects that have been defined as Maintenance or Simple projects.

5.3 Other Initiatives

XXX

CHAPTER 6. EVALUATION

Evaluations of projects, countermeasures, and programs provide the feedback needed to guide future decision-making.

The final element of the Department's HSIP is evaluation. This involves measuring the effectiveness of individual projects, specific countermeasures, and overall programs in reducing crash frequency and severity. This can also involve activity-level evaluations to measure and assess the productivity and efficiency of various efforts. In general, the regions are responsible for tracking project-level data and performing project-level evaluations. The Main Office is responsible for countermeasure- and program-level evaluations.

Evaluation activities assume a variety of forms. The most common type is the "before and after" study, which measures and compares the performance of projects, countermeasures, and programs before and after implementation. Depending on the subject of the evaluation and the purpose for which the results are to be used, the result may be a CMF (measuring change in safety performance), a BCR (measuring cost-effectiveness), or a comparison of budget planned vs. budget spent (measuring program efficiency). The following are three categories of performance measures described in this chapter:

1. **Safety** performance measures focus on the change in crash frequency and severity as well as the corresponding rates per measure of exposure. Examples include the change in fatal and serious injury crashes or an estimate of lives saved and injuries prevented over a defined period.
2. **Economic** performance measures focus on the cost-effectiveness (i.e., cost to change a certain number of percent of crashes) and return on investment (i.e., BCR). Examples include the BCR of a given rumble strip project or a group of similar rumble strip projects.
3. **Efficiency** performance measures focus on project management activities comparing actual to planned values such as level of implementation, budget, and schedule. Examples include comparisons of the actual miles, cost, and schedule of shoulder rumble strip projects compared to the planned miles, cost, and schedule of projects for a given year.

Whatever the focus of an evaluation, it serves an important purpose beyond the simple monitoring of the program. Evaluations of past performance provide the feedback needed to guide future decision-making. Future efforts can be channeled into those strategies or specific countermeasures that have been proven most effective. Evaluations also demonstrate accountability. HSIP evaluation can help the Department to measure and demonstrate progress toward achieving long-term safety goals and annual safety performance targets. Finally, evaluations help to meet Federal requirements, which started with the 1966 Highway Safety Act. The following are current (as of the date of publication) requirements related to HSIP evaluation.

- 23 CFR Part 924.5(a) requires each State to develop, implement, and evaluate on an annual basis a HSIP that has the objective to significantly reduce fatalities and serious injuries resulting from crashes on all public roads.
- 23 CFR Part 924.13(a)(1) requires each State's HSIP evaluation process to include a process to analyze and assess the results achieved by the program of highway safety

improvement projects in terms of contributions to improved safety outcomes and the attainment of safety performance targets established as per 23 U.S.C. 150.

- 23 CFR Part 924.13(a)(2) requires each State's HSIP evaluation process to include an evaluation of the SHSP as part of the regularly recurring update process to 1) confirm the validity of the emphasis areas and strategies based on analysis of current safety data, and 2) identify issues related to the SHSP's process, implementation, and progress that should be considered during each subsequent SHSP update.
- 23 CFR Part 924.13(b) requires each State to use the HSIP evaluation results for 1) updating safety data used in the planning process, 2) setting priorities for highway safety improvement projects, 3) assessing the overall effectiveness of the HSIP, and 4) reporting.

This chapter is structured in five sections, covering three different levels of evaluations: 1) project, 2) countermeasure, and 3) program. All three build on the legacy Post-Implementation Evaluation System (PIES) and related before-after methodology. Project-level evaluations form the basis for both countermeasure- and program-level evaluations, so project-level tracking is critical to the success of all evaluations. Accordingly, the first section of this chapter focuses on project tracking needs and responsibilities. The program-level evaluation section is divided into two subsections: 1) crash-based, and 2) activity-based. Crash-based program-level evaluations focus on the statewide safety targets. Activity-based evaluations focus more on process and procedures, measuring factors related to output and productivity. The chapter concludes with a section on reporting and communicating evaluation results. This includes the role of evaluations in improving the efficiency of the Department's safety program, along with the procedures established to ensure their continued influence.

All of the evaluation activities discussed in this chapter contribute to optimizing program, policy, and procedure development.

6.1 Project Tracking

Project tracking should begin during the planning and implementation stages to prepare for evaluations later in the safety management process. By preparing for evaluation early in the project development process, there is an opportunity to save time later in the process and enhance the reliability of results. **The Regions are responsible for collecting the applicable project information to support evaluations and entering the data in CLEAR Safety**. The regions should coordinate with local agencies that use HSIP funds to collect and enter the data in CLEAR Safety.

Project tracking should begin during the planning and implementation stages to prepare for evaluations later in the safety management process.

The following sections describe information that should be documented during the planning, implementation, and post-implementation (i.e., evaluation) stages of the project development process.

6.1.1 Planning

During the planning stage, it is important to document details related to site selection and the conditions before implementation. The first thing to note is the justification or method for selecting the project location. This is done early in the Site Investigation stage in CLEAR Safety where the analyst can select an 'Investigation Type' and one or more 'Investigation Reasons' as shown in the lists below.

- Investigation Type:
  - HSIP: Highway Safety Improvement Program
  - SAFETAP: Safety Appurtenance Program
  - Ad hoc crash analysis
- Investigation Reasons:
  - Priority Network Segments
  - Safety Deficient Segments
  - Priority Intersections
  - Wet Road Specialty (HAL)
    SKARP
  - Utility/Light Support (HAL)
  - All Fixed Object Specialty (HAL)
  - Pedestrian Specialty (HAL)
  - Bicycle Specialty (HAL)
  - High Risk Rural Road (HRRR)
  - Road Safety Audit (SAFETAP)
  - Collision with Animal Specialty (HAL)
  - Right Angle Specialty (HAL)
  - Rear End Specialty (HAL)
  - Large Truck Specialty (HAL)
  - Other Specialty (HAL)
  - Cluster
  - Police Hazard Report
  - Response to Complaint or Inquiry
  - Regionally Initiated
  - Other

Next, it is important to document the safety performance before implementation. This includes reviewing and confirming the crash history and underlying crash contributing factors in the before period. Analysts can accomplish this in CLEAR Safety during the 'Crash Review' and 'Crash Analysis' steps of the Site Investigation stage.

Finally, it is important to document the site conditions before implementation. This includes the traffic volume, traffic control, roadway, roadside, and land use characteristics prior to implementation. It may be useful to take site photos and include those in the project record by attaching a file to the 'Site Conditions' during the Site Investigation stage.

6.1.2 Implementation

As each project is implemented, it is critical to document the specific countermeasure(s) implemented, specific treated locations, implementation period (begin and end dates), and final project costs. The specific locations is particularly important for systemic projects where similar treatments may be implemented at multiple locations as part of the same project or contract. Project costs should include preliminary engineering, right-of-way, and construction.

Tracking individual projects supports project-level evaluations, and subsequently countermeasure- and program-level evaluations. As such, there is a need to **link individual projects with specific countermeasures** and also to **link individual projects with specific programs and subprograms**. When an analyst selects or assigns a countermeasure in CLEAR Safety to a proposed project, the system creates the link between the project and countermeasure. CLEAR Safety can also create a link between projects, programs, and subprograms based on input from the user. Specifically, the user can select the proposed program for implementation when proposing a capital project. The categories include:

- PSAP: Pedestrian Safety Action Plan
- CARDS/SHARDS: Centerline/Shoulder Audible Roadway Delineator
- Roadway Departure
- SKARP: Skid Accident Reduction Program
- SAFETAP: Safety Appurtenance Program
- Intersections
- Empire State Trail

6.1.3 Evaluation

After projects have been implemented for an extended period of time (e.g., three years), it is time to document or confirm the conditions after implementation and then perform the evaluations. The first step in the evaluation stage is to define the scope of the study (i.e., location(s) and study period) and then review any crashes that were not confirmed during the planning stage. Similar to the planning stage, confirming crashes helps to ensure the subsequent analysis is based on accurate information. Analysts confirm each crash by reviewing and accepting its attributes and location or editing (or requesting edits) to crash attributes and/or location before confirming. This is facilitated in CLEAR Safety under the 'Crash Review' tab within the Site/Project Evaluation module. If a crash is skipped and not explicitly confirmed or ignored, it will be included in the analysis, but a disclaimer will be applied to any determinations.

Finally, it is important to confirm and document the site conditions after implementation. This includes the traffic volume, traffic control, roadway, roadside, and land use characteristics after implementation. If there were any changes to the proposed project, then this should be noted as part of the evaluation.

6.2 Project-Level Evaluation

Project-level evaluations support countermeasure- and program-level evaluations.

Project-level evaluation focuses on individual projects and measures the effectiveness by changes in the frequency and severity of crashes from the before period to the after period. Project-level evaluations serve as the basis for more aggregate evaluations at the countermeasure and program level. **The Regions are generally responsible for performing project-level evaluations using CLEAR Safety**. The following are general considerations related to project evaluation.

1. **Performance measures**:
    a. **Crash-based measures**: Crash-based performance measures for individual projects typically include localized safety impacts (e.g., site-specific change in crashes, injuries, and fatalities). In addition, it is useful to evaluate target and correctable crashes, particularly if a project targets specific crash types or crash contributing factors. For instance, centerline rumble strips target cross-centerline crashes, so it would be useful to evaluate the change in cross-centerline crashes in addition to other common measures (e.g., total and fatal plus injury crashes).
    b. **Non-crash-based measures**: While crash-based measures are preferred for safety effectiveness evaluations, there is the potential to use non-crash-based performance measures to assess the implementation process and intermediate effectiveness of completed improvement projects. Non-crash-based performance measures may include project management factors (e.g., schedule and budget) and changes in non-crash safety measures (e.g., operating speed, driver compliance, driver response).
    c. **Economic measures**: BCR is a potential economic performance measure, but this is better suited for countermeasure- and program-level evaluations. At the project level, economic measures are susceptible to influence from a few severe crashes, particularly when using simple before-after methods to evaluate the change in crashes. For example, just one fatal crash in the before or after period can have a substantial impact on the estimated benefit.
2. **Study period**: Analysts should use a minimum of three full years of before data and three full years of after data to evaluate projects. At the analysts discretion, there may be a need for more years of data to better understand the long-term averages. This is particularly true for projects that target rare or seemingly random crash types (e.g., pedestrian or bicycle crashes). While a longer study period generally provides a larger sample of crashes for analysis, it also increases the chances for other changes over time (e.g., roadway or operational changes, driver behavior, or vehicle fleet). As such, analysts should balance the study period with the potential for other changes over time.
3. **Methodology**: CLEAR Safety uses a simple before-after analysis for evaluating projects using crash-based performance measures. While more rigorous methods can produce more reliable results, this is generally not necessary at the project level. Instead, the analyst should focus on whether the project appears to have addressed the crashes and/or risk factors that were the impetus of the project.

The following sections provide more details on the methods and associated data requirements as well as potential applications of the evaluation results.

6.2.1 Project-Level Evaluation Methods and Data Needs

This section focuses on crash-based performance measures, but the same methods can generally be applied using other non-crash-based performance measures. For crash-based project-level evaluations, the simple before-after method and test of proportions are appropriate. While the simple before-after method is susceptible to potential sources of statistical bias, and small sample sizes can limit the transferability of project-level evaluation results, these concerns can be left for countermeasure-level evaluations. At the project level, the intent is to determine if the project achieved its objective and if there are any remaining crash patterns that could be addressed.

Simple before-after evaluations should use 12-month increments (or whole calendar years) and use the same duration for the before and after period.

The **simple before-after method** compares crashes before and after implementation of the project. Using the Site/Project Evaluation module in CLEAR Safety, an analyst can directly compare the crash frequency by severity in the before and after periods. Project-level evaluations should include 12-month increments to avoid seasonal impacts and it is preferred to use the same duration for the before and after period (e.g., three years before and three years after). If the duration of the before and after period are different, it is important to normalize the analysis by comparing crashes per year. Note this method does not account for changes in traffic volume from the before to the after period, which can impact the results.

Table 5 provides an example project-level evaluation using the simple before-after method. In this example, the study period is seven years, which includes three years before and after implementation, and excludes the one year of implementation. For this example, the sample data indicate a 6.7 percent increase in total crashes and a 60 percent reduction in fatal and injury crashes.

Table 5. Example project-level evaluation using simple before-after method

Crash Category	Crashes Before Implementation (3-year period)	Crashes During Implementation (1-year period)	Crashes After Implementation (3-year period)	Change (before-after)	% Change
Total	15	Excluded	16	-1	6.7% increase
Fatal and injury	5	Excluded	2	3	60% reduction

The **test of proportions method** compares the proportion of target crashes to total crashes before implementation and after implementation. For example, an analyst may want to compare the proportion of fatal and serious injury crashes before and after converting a two-way stop-controlled intersection to a roundabout. This method is particularly useful, and generally more appropriate than the simple before-after method, when the traffic volume changes from the before to the after period. Similar to the simple before-after method, evaluations should include 12-month increments to avoid seasonal impacts and it is preferable to include at least three years before and after implementation in the study period. Unlike the simple before-after method, the test of proportions method is not affected by different durations of before and after periods.

The test of proportions method is useful to evaluate projects where the traffic volume changes over time or when the before and after periods are different durations.

Table 6 provides an example project-level evaluation using the test of proportions method. Similar to the prior example, the study period is seven years, including three years before implementation, three years after implementation, and excluding the implementation year. The target crashes will depend on the project of interest and is specified by the analyst in CLEAR Safety. In this example, the proportion of target to total crashes is 0.67 before implementation and 0.33 after implementation. The result is a difference of -0.33 from the before to the after period, indicating a 50 percent reduction in the proportion of target crashes.

Table 6. Example project-level evaluation using test of proportions method

Total Crashes Before (3-year period)	Target Crashes Before (3-year period)	Proportion of Target to Total Crashes Before	Crashes During Implementation (1-year period)	Total Crashes After (3-year period)	Target Crashes After (3-year period)	Proportion of Target to Total Crashes After
18	12	0.67	Excluded	9	3	0.33

Collision diagrams are another method to assess the change in target crashes. Specifically, analysts can use the Site/Project Evaluation module in CLEAR Safety to develop and compare collision diagrams for the before and after periods. This could help to quickly determine if a project achieved its initial objective (i.e., to address a specific crash type or crash contributing factor). It could also help to identify cases where total crashes increased or remained unchanged while target crashes decreased. If a project does not address the target crashes, or if other crash types increased unexpectedly, then alternative or supplemental countermeasures may be necessary.

Comparing collision diagrams before and after implementation could help determine if a project achieved its objective.

The example in Figure 12 illustrates the use of collision diagrams to compare crash patterns and target crash types for the before and after periods.

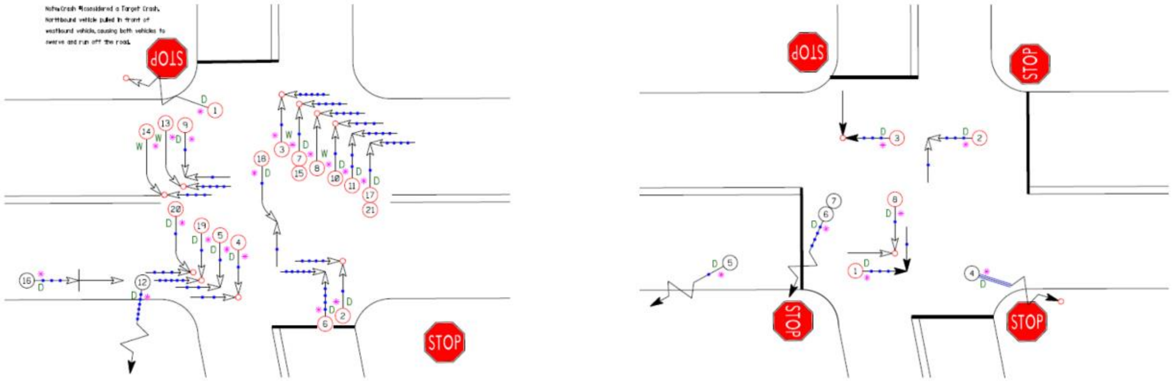


Figure 12. Example of collision diagrams to compare crash patterns

6.2.2 Project-Level Evaluation Results

CLEAR Safety produces a project evaluation report that includes the evaluation details (e.g., study period and location), list of crashes included in the before and after periods, collision diagram(s) (if applicable), simple before-after results, test of proportion results (if applicable), and any project evaluation notes entered by the analyst. Figure 13 provides an excerpt of the before-after evaluation results from a sample project evaluation report. Note that crash data is presented by severity, divided into total, fatal, incapacitating injury, non-incapacitating injury, possible injury, and property damage only (PDO) crashes. These categories refer to the number of crashes, not the number of people or vehicles involved, and reflect the maximum severity of each crash (i.e., a crash involving three vehicles, with five injuries and one fatality would be listed as one fatal crash).

Before/After Counts

	Total			Fatal			Incapacitating Injury			Non-incapacitating Injury			Possible Injury			Property Damage Only		
Crash Type	Before Total	After Total	Total % Change	Before K	After K	K % Change	Before A	After A	A % Change	Before B	After B	B % Change	Before C	After C	C % Change	Before O	After O	O % Change
COLLISION WITH MOTOR VEHICLE	0	35		0	0		0	0		0	1		0	6		0	28	
COLLISION WITH PEDESTRIAN	0	2		0	0		0	1		0	0		0	1		0	0	
COLLISION WITH BICYCLIST	0	1		0	0		0	0		0	1		0	0		0	0	
COLLISION WITH BUILDING/ WALL	0	1		0	0		0	0		0	0		0	0		0	1	
OTHER NON-COLLISION	0	1		0	0		0	0		0	0		0	0		0	1	

Figure 13. Example of project evaluation report

Analysts should consider project-level evaluation results with caution because they may not represent the general countermeasure effect. For instance, not all safety improvement projects result in a safety performance benefit, but this does not mean the countermeasure is generally not effective. There may be site-specific characteristics or other factors that contribute to an ineffective project. While project-level evaluations may not represent the general countermeasure effect, the results can help to understand the change in safety performance at a specific site or group of project locations. The following are specific applications of project-level evaluation results.

- **Identify and Address Safety Opportunities**: Project-level evaluations can help to identify investments that did not perform as intended. If a project did not address the target crash type(s) or crash contributing factors as intended, there may be an opportunity to address the situation by modifying design or operational elements, installing supplemental strategies, or in rare cases removing the countermeasure (e.g., when unintended crash types arise that degrade safety performance). In CLEAR Safety, analysts can flag a project for future monitoring if there is a concern that the completed project did not address the target crash type(s) or that the completed project may be contributing to unintended crash types.

- **Justify or Support Similar Projects**: While the results of one project evaluation do not guarantee the same results at another location, the results can help to inform other decisions. For instance, other regions and local agencies can use the results to decide if a similar project might work in their area or to demonstrate the benefits of past projects when justifying proposed projects to the public. XXX
- **Support Countermeasure-Level Evaluations**: Countermeasure-level evaluations attempt to estimate the safety effectiveness of one or more countermeasures, in isolation or in combination, with the goal of producing a CMF. In these evaluations, the results from individual project evaluations are aggregated using more rigorous methods to account for potential sources of bias. Further there is a need for the analyst to select those projects that are most similar and represent general installations of the countermeasure. As such, **it is important for analysts to flag potential projects that should not be included in countermeasure-level evaluations**. This can be accomplished in CLEAR Safety during project-level evaluations by checking the box to "Recommend that this project is excluded from higher level evaluations." While it is not appropriate to exclude certain sites just because the results are not favorable, it may be appropriate to exclude a site from the analysis if the conditions (e.g., site characteristics or treatment application) are different than the other sites included.

Project-level evaluations support countermeasure- and program-level evaluations.

- **Support Program-Level Evaluations**: Program-level evaluations generally include all relevant projects and assess safety performance at a macro level. As such, the details of any one project typically would not skew the results of a program-level evaluation. If it is necessary to flag projects that should not be included in program-level evaluations, this can be accomplished in CLEAR Safety during project-level evaluations by checking the box to "Recommend that this project is excluded from higher level evaluations."

Refer to FHWA's *HSIP Evaluation Guide* for further details on project-level evaluation.

6.3 Countermeasure-Level Evaluation

Countermeasure-level evaluation focus on the effectiveness of similar projects by measuring changes in the frequency and severity of crashes from the before period to the after period, often with the intention to develop a CMF. Countermeasure-level evaluations can help to inform future decisions, particularly when estimating the expected benefits of other similar proposed projects. As countermeasures are proven effective, there is also an opportunity to integrate those measures in planning and design policies and to update the CMFs in CLEAR Safety. **The Main Office is generally responsible for performing countermeasure-level evaluations and updating CLEAR Safety with resulting CMFs**. The following are general considerations related to countermeasure evaluation.

1. **Performance measures**: Crash-based measures should be used for countermeasure-level evaluations, particularly if the intent is to develop a CMF. CLEAR Safety provides CMFs by severity, including total crashes, fatal and injury (FI) crashes, and property damage only (PDO) crashes. This supports future benefit-cost analysis where the net benefits are based on CMFs by severity. There is also the option to evaluate the effect of countermeasures by crash type. This can be useful to assess programs or countermeasures that target specific crash types (e.g., centerline rumble strips targeting cross-centerline crashes).
2. **Sample size**: The sample size required to obtain statistically significant results depends on many factors, including the desired level of confidence and the magnitude of the countermeasure effect. There is no method to estimate the minimum sample size requirements for an Empirical Bayes before-after study, but there is a method for estimating minimum sample size requirements for a before-after with comparison group study, which can serve as a conservative sample size estimate for an Empirical Bayes study. Table 7 presents the minimum number of crashes required for select CMFs (analysts best guess at how effective the countermeasure will be) and common levels of significance. For example, if the expected CMF is 0.80 and the desired level of significance is 0.10 (90 percent confidence), then the required number of crashes is 193. These estimates assume the number of comparison sites is equal to the number of treated sites and the duration of the before and after periods are equal. So this indicates a minimum sample of 193 crashes in both the before and after periods for both the treatment and comparison groups. For scenarios not listed in the table, refer to the spreadsheet template in Appendix E. Do not use linear interpolation or extrapolation to estimate sample sizes for other levels of significance or levels of effect from the numbers in the table because the trends are nonlinear.

Table 7. Sample size requirements (number of crashes) for before-after with comparison group method

Expected Levelof Effect (CMF)	0.10 Level of Significance (90% Confidence)	0.05 Level of Significance (95% Confidence)
0.90	1155	1858
0.80	193	279
0.70	67	95
0.60	29	41

As the desired level of confidence increases (e.g., from 90% to 95%), so does the minimum sample size. Similarly, a larger sample is required to detect smaller changes in safety (e.g., a larger sample is required to detect a 10% change in crashes—a CMF of 0.90—compared to the sample needed to detect a 40% change in crashes). While larger sample sizes generally provide more statistically reliable results, there is a need to balance the desired reliability with the resources required to collect and analyze the data. CLEAR Safety automates much of the data collection and analysis process for safety evaluations, so the focus on sample size should be whether there is a sufficient sample to produce meaningful results. This can also be determined after the evaluation by comparing the magnitude of the standard error to the magnitude of effect (the CMF). If the standard error is relatively small compared to the CMF, then the results are more reliable.

3. **Study period**: As described in the prior bullet, the minimum required sample size depends on many factors. Once the minimum sample size is determined in terms of the required number of crashes, the analyst can determine the number of years needed to accumulate the minimum crashes given the sample of projects available for countermeasure evaluation. In general, the study period should include at least three years before and after implementation and exclude the implementation period from the analysis. It is possible to use different durations for the before and after period (e.g., five years before and three years after); however, the before and after periods should represent 12-month increments to avoid seasonal bias. As such, it is common to use full calendar years for ease of assembling data. For some countermeasures, it may be difficult to collect the required sample size. For example, pedestrian and bicycle countermeasures may involve relatively few pedestrian and bicycle crashes per intersection or per mile. Similarly, systemic improvements often target crashes over a wider area, and some locations within that area may experience few or no crashes. Increasing the duration of the study period is one option to increase the number of crashes for analysis, but there is the potential to introduce bias if other changes occur over time as discussed previously. When other options to increase sample size are unavailable, an alternative is to accept a lower level of significance (e.g., 0.15 or 0.20) as opposed to the typical value of 0.05 or 0.10 as an interim step.
4. **Grouping projects**: To increase the statistical reliability of countermeasure evaluations, there is a need to include multiple similar projects in the analysis rather than a single project. While countermeasure-level evaluations could be based on a few sites, this will typically result in a large standard error and lower confidence in the result. When grouping multiple locations for countermeasure-level evaluation, there is a need to consider the consistency among projects (e.g., strategies and site characteristics) and the potential for different effects under different conditions. Different combinations of countermeasures and site characteristics along with variations in vehicles and driver behavior can result in different countermeasure effects. When developing CMFs, CLEAR Safety presents a disaggregate analysis, in addition to the aggregate results, to identify potential differences by region or facility type. If a CMF includes data from multiple regions or facility types, and the countermeasure effects differ by region or facility types, then this can lead to larger standard errors and less certainty in results.
5. **Methodology**: CLEAR Safety focuses on the Empirical Bayes before-after method for countermeasure-level evaluations, but this manual provides templates and discussion to implement other methods if desired. If the intent is to develop a CMF for use in future investigations, then analysts should use more reliable methods such as the Empirical Bayes before-after method or before-after with comparison group method. The more reliable methods account for potential sources of bias such as regression-to-the-mean, changes in traffic volume, and the non-linear relationship between crashes and traffic volume.

The following sections provide more details on the methods and associated data requirements as well as potential applications of the evaluation results.

6.2.1 Countermeasure-Level Evaluation Methods and Data Needs

This section focuses on the use of observational before-after methods and crash-based performance measures to evaluate countermeasures and develop CMFs. In before-after studies, some change occurs during the study period (i.e., projects are implemented), and analysts compare the safety performance of treated locations over time. There is also the potential to use information from a comparison or reference group (i.e., untreated locations) to adjust for other changes over time that affect safety performance.

While countermeasure-level evaluations may focus on total crashes, it is often useful to evaluate specific crash types and severities because countermeasures can have differential effects by crash type and severity (e.g., a median barrier may increase PDO and minor injury crashes while reducing fatal and serious injury crashes). CLEAR Safety provides options to stratify the analysis by crash type and severity. Crash severity is more common for stratifying an evaluation because there are fewer discrete injury categories than crash type categories.

The following sections provide detailed information on four variations of before-after methods. As shown in Table 8, the Empirical Bayes before-after method is the more reliable method for developing quality CMFs because it can properly account for potential sources of bias. In some cases, other methods may be an acceptable alternative to the Empirical Bayes before-after method as noted in the sections below. Refer to the appendix for templates to conduct various before-after evaluations.

Table 8. Overview of before-after methods

Method	Accounts for Regression-to-the-Mean	Accounts for Changes in Traffic Volume	Accounts for Nonlinear Relationship between Crashes and Traffic Volume	Accounts for Other Changes Over Time
Simple				
Simple with linear traffic volume correction		●		
Comparison group		●		●
Empirical Bayes	●	●	●	●

6.2.1.1 Empirical Bayes Before-After

The Empirical Bayes before-after method is one of the more reliable methods for developing CMFs because it can properly account for potential sources of bias, including regression-to-the-mean, changes in traffic volume, and other changes over time. The basic premise is to estimate the expected crashes that would have occurred had there been no project and compare that with the actual observed crashes that occurred after implementation.

The Empirical Bayes before-after method is one of the more reliable methods for developing quality CMFs.

Methodology

The following steps describe how to estimate the expected crashes that would have occurred had there been no change, and how to estimate the CMF and associated standard error. Refer to Appendix F for a template to conduct an Empirical Bayes before-after evaluation.

1. **Identify a Suitable SPF (or develop or calibrate SPF)**: The Department has developed planning-level SPFs that could serve as the basis for countermeasure-level evaluations using the Empirical Bayes before-after method. If there is not an applicable SPF

available, it will be necessary to develop or calibrate an SPF. To develop or calibrate an SPF:

a. **Identify a reference group**: Identify a group of sites without the countermeasure, but similar to the treated sites, including traffic volume and other site characteristics.
b. **Develop/calibrate SPF**: Using data from the reference group, estimate or calibrate an SPF relating crashes to independent variables such as traffic volume and other site characteristics. The network screening SPFs in CLEAR Safety could serve this purpose. Refer to FHWA's *SPF Development Guide: Developing Jurisdiction-Specific SPFs* for further details on how to develop SPFs.

2. **Compute Predicted Crashes**: Use the applicable SPF(s) and traffic volume data for the treated sites to estimate the predicted number of crashes for each year in the study period (both the before and after periods).
3. **Compute Ratio of Predicted Crashes**: Using the results of step 2, compute the ratio of predicted crashes after implementation to predicted crashes before implementation. This helps to adjust for differences between the before and after period, including different durations.
4. **Compute Expected Crashes Before Implementation**: Using the Empirical Bayes method, shown in equation 12, compute the expected crashes in the before period at each treated site as the weighted sum of observed crashes before implementation and predicted crashes before implementation from step 2.

$$Expected_{before} = w * Predicted_{before} + (1 - w) * Observed_{before} \quad (12)$$

Where:

- $Expected_{before}$ = expected crashes before implementation
- w = weighting factor computed by equation 13
- $Predicted_{before}$ = sum of predicted crashes from SPF for each year in before period
- $Observed_{before}$ = sum of observed crashes for each year in before period

$$w = \frac{1}{1+(k*Predicted_{before})} \quad (13)$$

Where:

- k = dispersion parameter given with SPF
- $Predicted_{before}$ = sum of predicted crashes from SPF for each year in before period

5. **Estimate Expected Crashes After Implementation**: For each treated site, estimate the expected crashes after implementation as the product of the expected crashes before implementation (step 4) and the ratio of predicted crashes (step 3), as shown in equation 14. This is the expected number of crashes that would have occurred had there been no project. In addition, estimate the variance of this expected number of crashes, as shown in equation 15.

$$Expected_{after} = Expected_{before} * \frac{Predicted_{after}}{Predicted_{before}} \tag{14}$$

Where:

- $Expected_{after}$ = expected crashes after implementation
- $Expected_{before}$ = expected crashes before implementation
- $Predicted_{after}$ = sum of predicted crashes from SPF for each year in after period
- $Predicted_{before}$ = sum of predicted crashes from SPF for each year in before period

$$Variance(Expected_{after}) = Expected_{after} * \frac{Predicted_{after}}{Predicted_{before}} * (1 - w) \tag{15}$$

Where:

- $Variance(Expected_{after})$ = variance of expected crashes after implementation
- $Expected_{after}$ = expected crashes after implementation
- $Predicted_{after}$ = sum of predicted crashes from SPF for each year in after period
- $Predicted_{before}$ = sum of predicted crashes from SPF for each year in before period
- w = weighting factor computed by equation 13

6. **Compute CMF**: The CMF is approximately equal to the observed crashes in the after period divided by the expected crashes in the after period. As shown in equation 16, there is a small adjustment based on the expected crashes in the after period and the associated variance.

$$CMF = \frac{Observed_{after} / Expected_{after}}{1 + \left(Variance(Expected_{after}) / Expected_{after}{}^2 \right)} \tag{16}$$

Where:

- CMF = crash modification factor
- $Observed_{after}$ = sum of observed crashes for each year in after period
- $Expected_{after}$ = expected crashes after implementation
- $Variance(Expected_{after})$ = variance of expected crashes after implementation

7. **Compute Standard Error of CMF**: The standard error of the CMF is computed by equation 17.

$$Standard\ Error(CMF) = \sqrt{\frac{CMF^2 * \left[\left(1 / Observed_{after} \right) + \left(Variance(Expected_{after}) / Expected_{after}{}^2 \right) \right]}{\left[1 + \left(Variance(Expected_{after}) / Expected_{after}{}^2 \right) \right]^2}} \tag{17}$$

Where:

- Standard Error(CMF) = standard error of crash modification factor

- CMF = crash modification factor
- $Observed_{after}$ = sum of observed crashes for each year in after period
- $Variance(Expected_{after})$ = variance of the expected crashes after implementation
- $Expected_{after}$ = expected crashes after implementation

Data Requirements

The primary data requirements for the Empirical Bayes before-after method include:

- **Treatment locations:** Select the sites of interest for inclusion in the evaluation. For countermeasure-level evaluations, this should include all sites that represent typical conditions and applications of the treatment of interest.
    - **Note:** No cherry-picking! It is not appropriate to exclude certain sites because the results are not favorable. This can bias the resulting CMF and lead to misinformed future investment decisions. It may be appropriate to exclude a site from the analysis if the conditions (e.g., site characteristics or treatment application) are different than the other sites included. If there is a need to exclude a site from the analysis, return to the project level analysis, find the location of interest, and select "Recommend that this project is excluded from higher level evaluations."
- **Crash data:** It is recommended to use three to five years of crash data before and after implementation of the countermeasure. It is important to confirm the crash details (e.g., location, type, and severity) for the before and after periods during project-level evaluations. This helps to improve the accuracy and reliability of the countermeasure-level results.
- **Traffic data:** Traffic volume is the primary input to predict crashes using an SPF. It is acceptable to use a single value to represent the traffic volume in the before period and a single value to represent the traffic volume in the after period; however, it is important to use values that reflect changes in traffic from one period to the next because the change in traffic is directly related to the predicted change in crashes. If traffic volumes are missing or inaccurate for either the before or after period, there is an opportunity to add or modify volumes at the site investigation level.
- **SPF and dispersion parameter:** CLEAR Safety provides calibrated SPFs and corresponding dispersion parameters for various facility types. If there is not an SPF for the facility type of interest, then it would be necessary to develop and enter a new SPF in CLEAR Safety or use one of the other before-after methods to perform the evaluation.

6.2.1.2 Before-After with Comparison Group

The before-after with comparison group method compares crash data before and after treatment but also uses data from an untreated group of sites to account for temporal effects and changes in traffic volume. This approach assumes that the crash trends in the treatment and comparison groups are similar.

The before-after with comparison group method is an alternative method for developing CMFs when SPFs are not available to employ the Empirical Bayes method.

The comparison group method is generally less reliable than the Empirical Bayes method because it does not account for regression-to-the-mean. Further, the assumption that the comparison group is unaffected by the treatment is difficult to test and can be an unreasonable assumption in some situations. For example, in an evaluation of red light running cameras, the use of nearby untreated signalized intersections as a comparison group may not be appropriate because the treatment may affect driver behavior at those intersections as well, particularly if drivers are unaware of the location of the cameras.

The comparison group method may be a viable approach to developing CMFs if there is reason to believe there is limited or no potential for regression-to-the-mean. There may be limited regression-to-the-mean in cases where 1) crash frequency is not considered in selecting a site for safety treatment, 2) the safety evaluation is strictly related to a change implemented for operational reasons, or 3) a blanket treatment is applied to all sites of a given type. In practice, except for blanket treatments, it is difficult to confirm that there is no regression-to-the-mean, and only a truly random selection of sites for treatment will ensure there is no selection bias.

The following steps describe how to estimate a CMF and associated standard error using the comparison group method. Refer to Appendix G for a template to conduct a before-after with comparison group evaluation.

1. **Identify a Suitable Comparison Group**: Identify a group of sites without the countermeasure, but similar to the treated sites in terms of crash trends. Comparison sites are typically selected from the same jurisdiction as the treated sites to increase the likelihood that comparison sites will have similar crash trends as the treated sites.
2. **Compute Comparison Group Ratio**: Use the comparison group to calculate a comparison ratio as shown in equation 18, which is the ratio of observed crash frequency in the after period to that in the before period. This helps to adjust for differences between the before and after period, including different durations.

$$Comparison\ Ratio = \frac{Comparison\ Group\ Observed_{after}}{Comparison\ Group\ Observed_{before}} \tag{18}$$

Where:

- Comparison Group $Observed_{after}$ = sum of observed crashes for comparison group in after period
- Comparison Group $Observed_{before}$ = sum of observed crashes for comparison group in before period

3. **Estimate Crashes After Implementation**: For the treatment group, estimate the crashes after implementation as the product of the observed crashes in the treatment group before implementation and the comparison group ratio (step 2), as shown in equation 19. This is the estimated number of crashes at the treated sites in the after period had the countermeasure not been implemented. In addition, estimate the variance of the estimated number of crashes, as shown in equation 20.

$$Treatment\ Group_{estimated,after} = Treatment\ Group_{observed,before} * \frac{Comparison\ Group_{observed,after}}{Comparison\ Group_{observed,before}} \tag{19}$$

Where:

- Treatment $Group_{estimated,\ after}$ = estimated crashes in treatment group after implementation
- Treatment $Group_{observed,\ before}$ = observed crashes in treatment group before implementation

- Comparison Group$_{observed,\ after}$ = observed crashes in comparison group after implementation
- Comparison Group$_{observed,\ before}$ = observed crashes in comparison group before implementation

$$Variance(Treatment\ Group_{estimated,after}) = (Treatment\ Group_{estimated,after})^2 * \left[\frac{1}{Treatment\ Group_{observed,before}} + \frac{1}{Comparison\ Group_{observed,before}} + \frac{1}{Comparison\ Group_{observed,after}}\right] \quad (20)$$

Where:

- Variance(Treatment Group$_{estimated,\ after}$) = variance of estimated crashes after implementation

4. **Compute CMF**: The CMF is approximately equal to the observed crashes in the after period divided by the estimated crashes in the after period. As shown in equation 21, there is a small adjustment based on the estimated crashes in the after period and the associated variance.

$$CMF = \frac{Treatment\ Group_{observed,after} / Treatment\ Group_{estimated,after}}{1+\left(Variance(Treatment\ Group_{estimated,after}) / Treatment\ Group_{estimated,after}{}^2\right)} \quad (21)$$

Where:

- CMF = crash modification factor

5. **Compute Standard Error of CMF**: The standard error of the CMF is computed by equation 22.

$$Standard\ Error(CMF) = \sqrt{\frac{CMF^2 * \left[\left(\frac{1}{Treatment\ Group_{observed,after}}\right)+\left(\frac{Variance(Treatment\ Group_{estimated,after})}{Treatment\ Group_{estimated,after}{}^2}\right)\right]}{\left[1+\left(Variance(Treatment\ Group_{estimated,after}) / Treatment\ Group_{estimated,after}{}^2\right)\right]^2}} \quad (22)$$

Where:

- Standard Error(CMF) = standard error of crash modification factor

6.2.1.3 Before-After with Traffic Volume Correction

The before-after study with traffic volume correction method accounts for changes in traffic volume over time. For example, comparing the crash rates (i.e., crashes per some measure of exposure such as vehicle miles traveled) before and after implementation helps to account for changes in traffic volume. The traffic volume correction may be a linear or nonlinear trend. The use of crash rates implicitly assumes the relationship between crash frequency and traffic volume is linear; however, many studies have shown the relationship between crash frequency and traffic volume is nonlinear. The use of SPFs within the Empirical Bayes framework is more reliable to account for changes in traffic volume because SPFs reflect the nonlinear relationship between crash frequency and traffic volume.

The before-after with traffic volume correction method is generally not as reliable as the Empirical Bayes or comparison group methods for developing quality CMFs.

The before-after with traffic volume correction method is generally not appropriate for developing quality CMFs because it does not account for possible bias due to regression-to-the-mean, and it does not account for temporal effects or trends such as changes in driver behavior and changes in crash reporting. The before-after with traffic volume correction method may be appropriate if there is reason to believe there is limited or no potential for regression-to-the-mean and there are no changes in driver behavior or crash reporting over time. In practice, except for blanket treatments, it is difficult to confirm that there is no regression-to-the-mean, and only a truly random selection of sites for treatment will ensure there is no selection bias. Refer to FHWA's HSIP Evaluation Guide for a template to perform a simple before-after analysis with traffic volume correction.

6.2.1.4 Simple Before-After

The simple before-after method provides a basic comparison of crashes before and after implementation. The simple before-after method is generally not appropriate for developing quality CMFs because it does not account for possible bias due to regression-to-the-mean and does not account for temporal effects or trends such as changes in traffic volume, changes in driver behavior, and changes in crash reporting. The simple before-after method may be appropriate if there is reason to believe there is limited or no potential for regression-to-the-mean and there are no other changes over time that affect safety other than the treatment of interest. In practice, except for blanket treatments, it is difficult to confirm that there is no regression-to-the-mean, and only a truly random selection of sites for treatment will ensure there is no selection bias. Refer to Section 6.2 (Project-Level Evaluation) or FHWA's HSIP Evaluation Guide for a template to perform a simple before-after analysis.

The simple before-after method is generally not appropriate for developing quality CMFs.

6.2.2 Countermeasure-Level Evaluation Results

As countermeasures are proven effective, there is also an opportunity to integrate those measures in planning and design policies and to update the CMFs in CLEAR Safety. CLEAR Safety produces a countermeasure evaluation report that includes the evaluation details (e.g., study period), list of projects included in the before and after periods, before-after results, and any countermeasure evaluation notes entered by the analyst. Figure 14 provides an excerpt of the results from a sample countermeasure evaluation report.

Figure 14. Example of countermeasure evaluation report

Countermeasure-level evaluations can help to inform future decisions, particularly when estimating the expected benefits of similar proposed projects. While countermeasure-level evaluations represent the general countermeasure effect, it is important to understand the nuances of using the results. The following are specific applications of countermeasure-level evaluation results.

Estimate potential safety benefits: CMFs are critical to estimating the potential safety benefits of proposed projects. CLEAR Safety includes CMFs for numerous countermeasures and the Department uses the results from countermeasure-level evaluations to update these CMFs over time. Countermeasure effects may differ by region or facility type. As such, the CMF can change for different scenarios. CLEAR Safety provides separate CMFs by region and facility type as part of the countermeasure-level evaluation process. The analyst has the option to store and update the CMFs by facility type in CLEAR Safety, which will be reflected in subsequent Site Analysis. While CMFs are also computed by region, these CMFs are not stored for future use. If the CMF appears to differ by region, and there is a desire to use a region-based CMF for future analyses, the user can enter these values as “user-defined CMFs” during the Site Analysis process.

Develop BCRs or countermeasure scores: The results of countermeasure-level evaluations can support economic analysis from multiple perspectives.

- **Benefit-cost ratio**: The BCR helps to understand the average return on investment for the countermeasure. The present value cost is based on the average cost to implement and maintain the projects included in the CMF estimate as well as the associated service life. The benefits are based on the estimated CMF value, average expected crashes at the project sites (assuming no treatment), and the average crash costs from CLEAR Safety. Refer to Section 4.3 (Economic Appraisal) for further details on benefit-cost analysis.
- **Countermeasure score**: The countermeasure score, or cost to reduce one crash of a given type and/or severity, is a measure of potential countermeasure effectiveness, independent of where the countermeasure is implemented. Countermeasure scores help to compare how much it costs to reduce a comparable amount of crashes with different countermeasures, not how many crashes each countermeasure can reduce at a comparable cost. This can be very useful in planning-level decisions and early in the countermeasure selection process before conducting a more thorough benefit-cost analysis. When comparing scores among different countermeasures, lower values are desirable. Countermeasure scores are computed using equation 23.

$$Countermeasure\ Score = \frac{Project\ Costs}{(1-CMF)*100} \tag{23}$$

Where:

- Project costs = average annualized value per unit installation (e.g., per mile or per intersection) to compare projects with different service lives and extents
- CMF = crash modification factor for the countermeasure of interest (the CMF can represent total crashes or a specific crash type and/or severity category as long as all countermeasure scores represent the same category).

Adjust project and program delivery: Countermeasure-level evaluations can help to refine project and program delivery by understanding the conditions in which the countermeasure is more or less effective. For example, if certain countermeasures tend to work well in rural areas but are relatively ineffective in urban areas, then this type of information can help to better target investments. Similarly, if certain countermeasures tend to work well in combination with other improvements (e.g., shoulder widening with application of shoulder rumble strips), then this can help to inform design practices. Further, if certain countermeasures are consistently effective (i.e., reduce the expected frequency and severity of crashes), then it may be appropriate to adopt those countermeasures as standard practice. CLEAR Safety provides the evaluation results by region, facility type, and individual site as part of the countermeasure evaluation process. A review of the site-level results can help to identify differences in the countermeasure effect, which can indicate where the treatment works well (or not so well).

Countermeasure evaluations reflecting New York State's experience with a particular treatment provide more precise estimates of future benefits, allowing for better planning and allocation of funds. Using evaluation results contributes to the goal of improving highway safety in the most effective and cost-effective way possible. Though study results are routinely distributed throughout the Department, this alone does not necessarily ensure that they will be used to improve the effectiveness of projects and the efficiency of safety programs. Accordingly, the Department actively promotes the use of evaluation results in the management and further development of the Highway Safety Improvement Program.

Refer to FHWA’s *HSIP Evaluation Guide* for further details on countermeasure-level evaluation.

6.4 Program-Level Evaluation

Program-level evaluation focuses on the overall safety program and subprograms to measure the effectiveness using both crash-based and activity-based performance measures. **The Main Office is generally responsible for performing program-level evaluations and updating CLEAR Safety with annual safety performance targets**. The ultimate goal of program-level evaluations is to improve the efficiency of safety projects, programs, and policies. To be effective, evaluation findings should be presented in an appropriate format and disseminated to program managers.

Program evaluations can enhance the safety management process and inform updates of the New York State SHSP.

The HSIP Annual Report is the primary mechanism for evaluating and reporting on the effectiveness of the overall safety program. The HSIP Annual Report is issued by the NYSDOT Highway Safety Planning Section, in conjunction with the Commercial Transport Division. In addition to presenting evaluation results, it satisfies a Congressional requirement (under 23 CFR Part 924) that requires each State to develop, implement, and evaluate on an annual basis a HSIP that has the objective to significantly reduce fatalities and serious injuries resulting from crashes on all public roads.

The following subsections describe crash-based and activity-based evaluations. In both cases, there is an opportunity to use program evaluation results to enhance the safety management process and to inform updates of the New York State SHSP.

6.4.1 Crash-Based Program-Level

Crash-based program-level evaluations measure effectiveness by changes in the frequency, severity, and rate of crashes at the system level. This can occur at the statewide level, program or subprogram level, or jurisdiction level (region or county). In general, it is appropriate to include all projects associated with a given program for the program-level evaluation. Similar to countermeasure-level evaluations, it is not appropriate to exclude certain sites because the results are not favorable. This can bias the program-level evaluation results and lead to misinformed future investment decisions. It may be appropriate to exclude a site from the analysis if the conditions (e.g., site characteristics or treatment application) are different than the other sites included. If there is a need to exclude a site from the analysis, return to the project level analysis, find the location of interest, and select “Recommend that this project is excluded from higher level evaluations.”

At the statewide level, the Highway Safety Planning Section uses CLEAR Safety to generate inputs for the HSIP Annual Report. This includes annual safety performance targets and related progress, programmed safety funds, program effectiveness, and project effectiveness. Refer to the Department’s HSIP website for the latest safety performance targets and recent HSIP Annual Reports.

CLEAR Safety provides dashboards to assess progress for the following five federally-required safety performance targets under the statewide program evaluation.

1. Number of fatalities
2. Rate of fatalities per 100 million vehicle miles traveled (VMT)
3. Number of serious injuries
4. Rate of serious injuries per 100 million VMT
5. Number of non-motorized fatalities and non-motorized serious injuries

Figure 15 shows an example of the dashboard. Users have the option to show various metrics on the left axis of the dashboard, including annual values (simple tally of count by year), five-year rolling average (each point represents average of prior five years including the year of interest), five-year average trend (linear trend line through the five-year rolling average values), and targets (annual safety targets established by NYSDOT). Users also have the option to show various metrics on the right axis of the dashboard for comparison to the safety metrics. The comparison values include dollars spent, number of projects implemented, number of intersections, and number of miles of roadway.

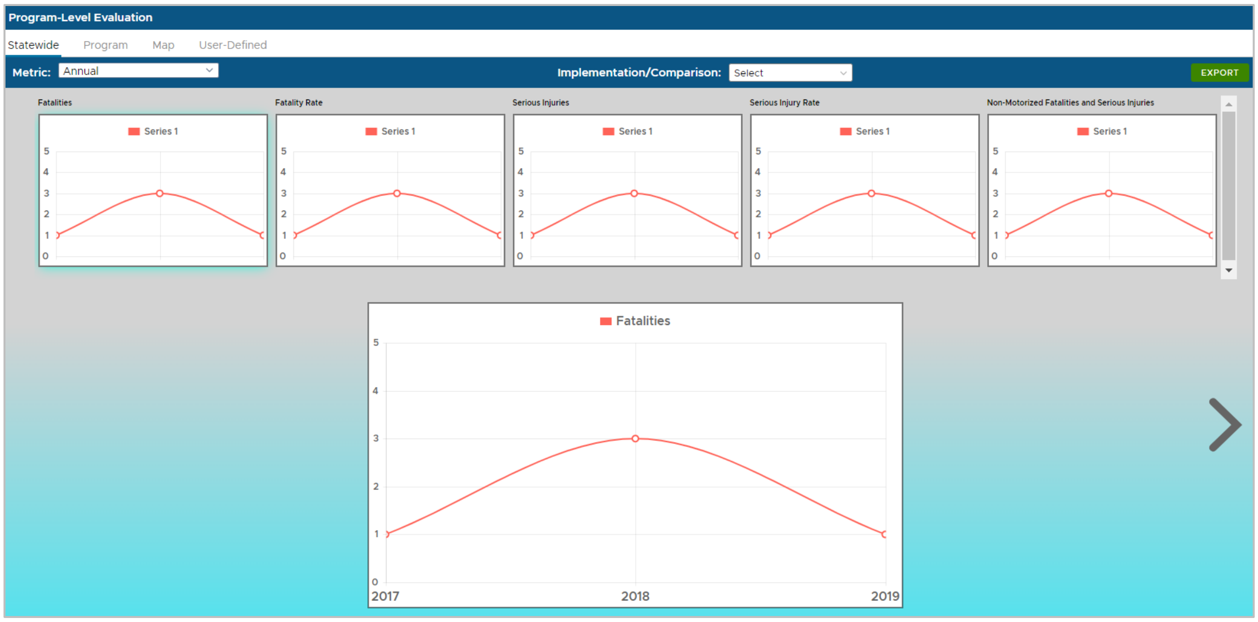


Figure 15. Example statewide safety performance target dashboard

CLEAR Safety provides pre-defined dashboards to support the following program and subprogram evaluations:

- PSAP: Pedestrian Safety Action Plan
- CARDS/SHARDS: Centerline/Shoulder Audible Roadway Delineator
- Roadway Departure
- SKARP: Skid Accident Reduction Program
- SAFETAP: Safety Appurtenance Program
- Intersections
- Empire State Trail

Figure 16 shows an example of the program-level evaluation dashboard. For program-level evaluations, the user can further specify the extent of the program and locations of interest based on road system (i.e., statewide, state, or local), approach (i.e., hotspot, systemic, ad-hoc analysis), boundary type (i.e., statewide, region, county), and facility type (e.g., rural, two-lane, undivided). Similar to the statewide dashboard, users have the option to show various metrics on the left axis of the dashboard, including annual values, five-year rolling average, five-year average trend, and targets. Users also have the option to show various metrics on the right axis of the dashboard for comparison to the safety metrics. The comparison values include dollars spent, number of projects implemented, number of intersections, and number of miles of roadway.

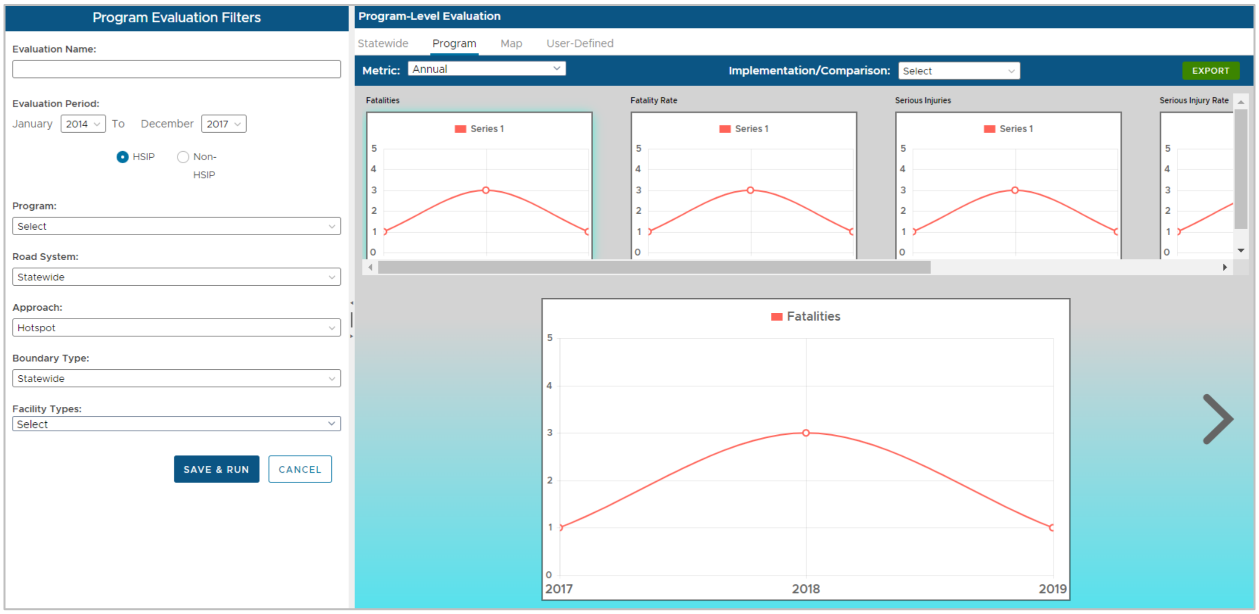


Figure 16. Example program-level evaluation dashboard

Further, there is an opportunity to create User-Defined dashboards to support detailed program-level evaluations. All filters defined on the Program tab are carried forward to the User-Defined evaluation tab. These evaluations are useful for assessing trends in specific crash types and severities over time. Specifically, this type of analysis is useful to compare the timing of a program or subprogram against trends in specific target crash types. For instance, it could be useful to compare the general timing or number of PSAP projects against the number of severe pedestrian crashes by year. Figure 17 shows an example of the user-defined program-level evaluation dashboard.

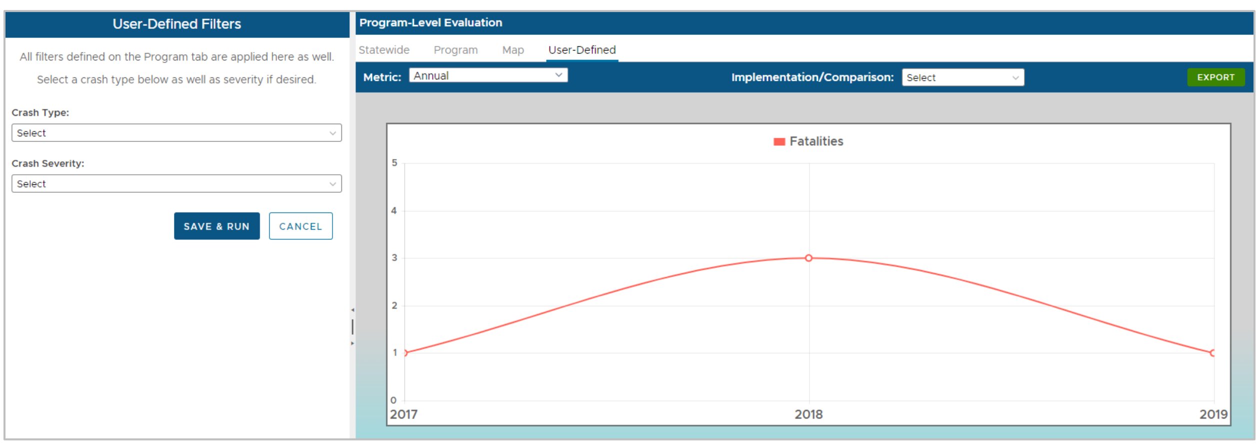


Figure 17. Example of user-defined program-level evaluation dashboard

CLEAR Safety provides options to map the projects associated with a given program evaluation. This can be useful to determine if the projects within a program are grouped in a specific geographic area or dispersed throughout the state. The mapping is strictly for visualization purposes, so the user cannot edit project-level data or remove projects from the evaluation at this stage. If there is a need to modify project information or to exclude a project from program-level evaluations, the user should return to the associated project-level evaluation and make the appropriate changes.

CLEAR Safety also provides an export feature to create a report of the program-level evaluation results. Along with the results, the report includes a list of filters and parameters used to perform the analysis. This is useful if there is a need to replicate the analysis or to understand how the numbers were queried.

Refer to FHWA's *HSIP Evaluation Guide* for further details on crash-based program-level evaluation.

6.4.2 Activity-Based Program-Level

While there is a tendency to focus on the safety effectiveness of projects and programs during evaluation efforts, there is also an opportunity to evaluate the underlying policies, processes, and procedures. Specifically, activity-based program evaluations can help to assess the HSIP process from start to finish, identifying opportunities to improve planning, implementation, evaluation, and documentation processes and decisions.

Activity-based evaluations typically focus on non-crash-based performance measures. For instance, activity-based evaluations can assess differences between planned and actual resource expenditures and the productivity of implementing highway safety projects and programs. The following are specific opportunities to use CLEAR Safety for activity-based evaluations:

Investigations: There is an opportunity to review the number and quality of investigations completed as part of the AWP, SAFETAP, and other requests (e.g., those generated by the public, political officials, or the design unit). Specific to the AWP, each region is required to perform a certain number of investigations. The results of safety investigations are reported to the Main Office quarterly, summarizing the investigation (origin, findings, and recommendations). CLEAR Safety automates this process, replacing the need for Form TE-156a.

The Main Office uses this information to evaluate Regional performance both in terms of numbers and quality of completed investigations. More importantly, these evaluations can help to identify challenges and share noteworthy practices among regions. If a region is having difficulty performing the required number of investigations, this type of evaluation can identify and address the underlying reasons. Further, there is an opportunity to track the outcome of the investigations (i.e., recommendation or no recommendation) and compare the number of investigations to the number of recommendations by type (e.g., maintenance, capital improvement, initiative, or other recommendation). Figure 18 provides an example of an activity-based dashboard for investigations, which is available under the Overview section of the Site Analysis module within CLEAR Safety.

XXX

Figure 18. Example of activity-based dashboard for investigations

Implementations: For assigned recommendations, there is an opportunity to track and assess the number of implemented recommendations. It is useful to track and assess these by type (e.g., maintenance, capital improvement, initiative, or other recommendation) or program (e.g., PSAP, CARDS/SHARDS, SKARP, SAFETAP). This can help to identify challenges in the implementation process. Figure 19 provides an example of an activity-based dashboard for projects and initiatives, which is available under the Overview section of the Implementation module within CLEAR Safety.

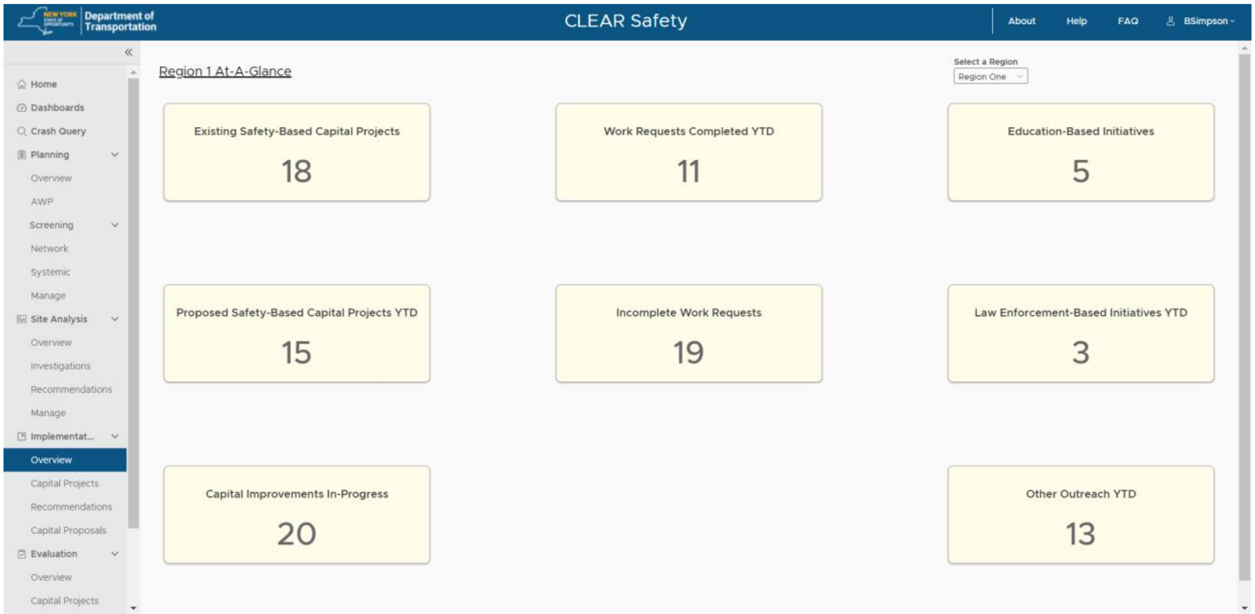


Figure 19. Example of activity-based dashboard for projects and initiatives

Evaluations: Each Region is required to perform project-level evaluations for completed HSIP projects. The associated activity-based evaluation would assess the number of outstanding project evaluations and potentially compare the number of completed evaluations by year. If regions are having difficulty performing project-level evaluations, the activity-based evaluation can go further to identify and address the underlying reasons. Figure 20 provides an example of an activity-based dashboard for evaluations, which is available under the Overview section of the Evaluation module within CLEAR Safety.

XXX

Figure 20. Example of activity-based dashboard for evaluations

6.5 Reporting and Communicating Evaluation Results

This section describes the role of evaluations in improving the effectiveness and efficiency of the Department's safety efforts and the procedures established to ensure their continued influence. While the Regions are required to perform evaluations for all completed HSIP projects and CLEAR Safety provides tools to support countermeasure and program evaluations, this alone does not ensure the results will be used to improve the effectiveness and efficiency of safety programs. Accordingly, the Office of Traffic Safety & Mobility actively promotes the use of evaluation findings in the management and further development of the HSIP through quarterly progress reports and by periodic reviews and updates to procedures and policies.

Figure 21 shows an example quarterly progress report from the Office of Traffic Safety & Mobility. The report presents the vision and goals of the safety program as well as the seven-year trend in fatalities and fatality rate. The report also presents the progress in obligating HSIP funds and letting projects by region and fiscal year.

SAFETY PROGRAM MANAGEMENT BUREAU

Quarterly Report for period ending XX/XX/XXXX

NEW YORK STATE OF OPPORTUNITY. Department of Transportation

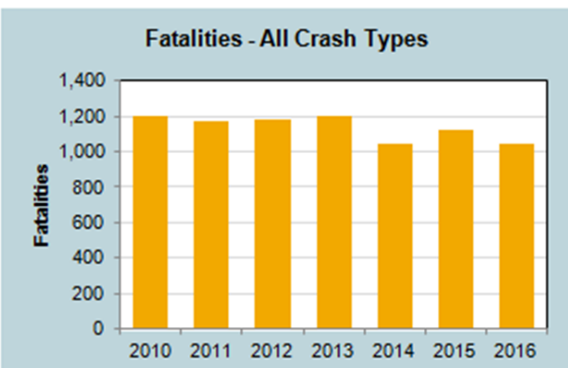
Report Date: XXXX

Vision

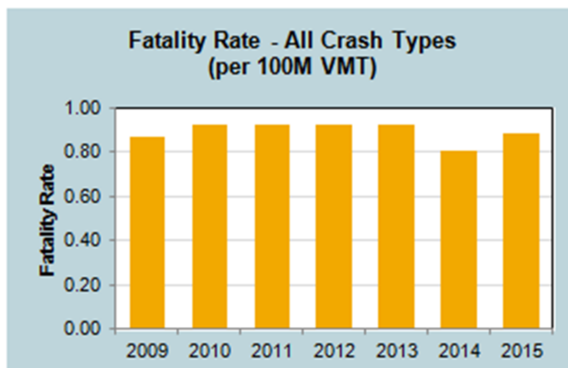
New York's safety community will continue to work to ensure that its customers - those who live, work and travel in New York State - have a safe, efficient, balanced and environmentally sound transportation system, and that safety is appropriately considered in all education, enforcement, engineering and emergency medical services activities in New York State in order to reduce fatal and injury crashes.

Safety Goals

- Decrease total fatalities XX percent from the XXXX-XXXX calendar base year average of XX to XX by XXXX. Decrease fatalities/100 million VMT XX percent from XX in XXXX to XX by XXXX.
- Complete required number of Highway Safety Investigations (XX% of identified PILS each year).
- Construct Centerline Audible Roadway Delineators (CARDS) on XX% of the eligible miles by the end of XXXX.
- Install Pedestrian Countdown Timers at XX% of the eligible intersections by the end of XXXX.
- Obligate XX% of the Annual HSIP funds.



Source: 2009-2015 FARS; 2016 – Preliminary ITSMR



Source: 2009-2015 FARS

Total HSIP Obligations by Federal Fiscal Year (FFY)								
Region	FFY XX		FFY XX		FFY XX		FFY XX	
	Obligations	# of projects let	Obligations	# of projects let	Obligations	# of projects let	Obligations	# of projects let to date
1	$X.XX	X	$X.XX	X	$X.XX	X	$X.XX	X
2	$X.XX	X	$X.XX	X	$X.XX	X	$X.XX	X
3	$X.XX	X	$X.XX	X	$X.XX	X	$X.XX	X
4	$X.XX	X	$X.XX	X	$X.XX	X	$X.XX	X
5	$X.XX	X	$X.XX	X	$X.XX	X	$X.XX	X
6	$X.XX	X	$X.XX	X	$X.XX	X	$X.XX	X
7	$X.XX	X	$X.XX	X	$X.XX	X	$X.XX	X
8	$X.XX	X	$X.XX	X	$X.XX	X	$X.XX	X
9	$X.XX	X	$X.XX	X	$X.XX	X	$X.XX	X
10	$X.XX	X	$X.XX	X	$X.XX	X	$X.XX	X
11	$X.XX	X	$X.XX	X	$X.XX	X	$X.XX	X
MO	$X.XX	X	$X.XX	X	$X.XX	X	$X.XX	X
Total	**$X.XX**	**X**	**$X.XX**	**X**	**$X.XX**	**X**	**$X.XX**	**X**

Source: PSS: Construction Contract Letting Report by Fund Use

Safety Program Management Bureau Quarterly Report Page 1

Figure 21. Example quarterly report

In addition to annual HSIP and statewide progress reports, the Main Office develops regional reports to track overall progress toward the regional AWP and other organizational goals such as:

- Number of highway safety investigations completed.
- Percent of HSIP funds obligated.
- Effectiveness of focus safety programs (e.g., installation rates of centerline rumble strips and pedestrian countdown timers).

The intent of the regional reports is to encourage regions to improve performance management through open communication and positive feedback. If a region is lagging, then the Main Office will work with the region to identify and resolve the challenges. Through the combination of CLEAR Safety dashboards, statewide and regional progress reports, and open communication, the Main Office and regional offices have a better understanding of how activities and projects contribute to the statewide safety goals and outcomes. By actively evaluating and monitoring the safety program, the Main Office is able to adjust projects, programs, and policies to improve the effectiveness and efficiency of safety expenditures.

On occasion, the Main Office prepares additional reports to disseminate the results of special evaluation studies. These special reports often focus on specific crash types (e.g., pedestrian, intersection, or roadway departure) or the effectiveness of major program initiatives (e.g., CARDS/SHARDS, PSAP, or SKARP programs). Main Office documents the results either informally through memos or formally through safety action plans (e.g., PSAP) and provides the results to the Regional Offices for review and implementation.

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7. GLOSSARY

Countermeasure (aka treatment, improvement): A strategy intended to reduce the crash frequency or severity, or both, at a site or multiple sites.

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 severity: The level of most serious injury or property damage due to a crash, commonly divided into categories based on the KABCO scale.

Expected crashes: The weighted average of observed crash frequency and predicted crash frequency.

Focus crash type: A prevalent severe crash type for a given jurisdiction.

Focus facility type: The locations where a target crash type is most prevalent (e.g., rural, two-lane, undivided segments or urban, four-leg, signalized intersections).

Hotspot approach: A general approach to developing projects during the planning stage of the safety management process. This approach focuses on selecting and treating sites based on site-specific crashes. This approach is complementary to the systemic approach.

Observed crashes: The number of historical crashes occurring during a specified time period.

Predicted crashes: The estimated safety performance based on other segments or intersections of a common facility type (i.e., similar area type, geometric characteristics, and traffic control type).

Regression-to-the-mean: The tendency for the occurrence of crashes at a particular site to fluctuate up or down, over the long term, and to converge to a long-term average.

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).

Surrogate: A non-crash-based measure of safety that is an observable event, behavior, performance measure, or index that is related to crash occurrence or crash severity.

Risk factor: A characteristic common among a group of focus facility types that is associated with an increased risk of a focus crash type. Risk factors may include site-specific crash history, roadway and roadside attributes, operational characteristics, and socioeconomic and demographic factors.

Systemic approach: A general approach to developing projects during the planning stage of the safety management process. This approach focuses on selecting and treating sites based on site-specific risk factors (i.e., geometric and operational attributes known to increase crash risk). This approach is complementary to the hotspot approach.

8. APPENDIX A: FACILITY TYPES

The following is a list of all facility types for which SPFs and average crash rates are available in CLEAR Safety. The facility types are categorized by segments, ramps, intersections, and ramp terminals.

Segment Facility Types

1. Rural 2-lane, undivided.
2. Rural 3-lane, undivided.
3. Rural 4-lane, undivided.
4. Rural 6-lane, undivided.
5. Urban 2-lane, undivided.
6. Urban undivided 3- and 4-lane, two-way.
7. Urban undivided 5 or more lanes, two-way.
8. Rural 1-lane, 1-way.
9. Rural 2-lane, 1-way.
10. Urban 1-lane, 1-way.
11. Urban 2-lane, 1-way.
12. Rural divided, 2-lanes.
13. Rural divided, 3 or more lanes.
14. Urban divided, 2-lanes.
15. Urban divided, 3 or more lanes.
16. Urban divided, 4 lanes.
17. Urban divided, 5 lanes.
18. Urban divided 6 lanes.
19. Rural 4 lane freeways.
20. Rural 6 or more lane freeways.
21. Urban 4 lane freeways.
22. Urban 6 lane freeways.
23. Urban 8 or more lane freeways.

Ramp Facility Types

24. Rural parclo entrance ramp.
25. Rural free-flow entrance ramp.
26. Urban parclo entrance ramp.
27. Urban free-flow entrance ramp.
28. Rural parclo exit ramp.
29. Rural free-flow exit ramp.
30. Urban parclo exit ramp.
31. Urban free-flow exit ramp.
32. Outer connection ramp.
33. Collector-distributor road.
34. Direct ramp.
35. Semi-direct ramp.
36. Rural diamond/slip entrance ramp.
37. Rural buttonhook entrance ramp.
38. Urban diamond/slip entrance ramp.

39. Urban buttonhook entrance ramp.
40. Rural diamond/slip exit ramp.
41. Rural buttonhook exit ramp.
42. Urban diamond/slip exit ramp.
43. Urban buttonhook exit ramp.

Intersection Facility Types

44. Two-way STOP 3-leg.
45. Two-way STOP 4-leg.
46. Two-way STOP 5+leg.
47. All-way STOP 3-leg.
48. All-way STOP 4-leg.
49. All-way STOP 5 or more leg.
50. Yield 3-leg.
51. Yield 4-leg.
52. Yield 5 or more leg.
53. Signalized Rural 3-leg.
54. Signalized Rural 4-leg.
55. Signalized Urban 3-leg.
56. Signalized Urban 4-leg.
57. Signalized Urban 5 or more leg.
58. Roundabout.
59. Uncontrolled 3-leg (2-way at 2-way).
60. Uncontrolled 4-leg (2-way at 2-way).
61. Uncontrolled 3-leg (1-way at 2-way).
62. Uncontrolled 4-leg (1-way at 2-way).
63. Uncontrolled 3-leg (2-way at 1-way).
64. Uncontrolled 4-leg (2-way at 1-way).
65. Uncontrolled 3-leg (1-way at 1-way).
66. Uncontrolled 4-leg (1-way at 1-way).

Ramp Terminal Facility Types

67. Signalized ramp terminals.
68. Two-way STOP ramp terminals.
69. Uncontrolled ramp terminals.
70. Yield ramp terminals.

9. APPENDIX B: SAFETY PERFORMANCE FUNCTIONS (SPFS)

The following sections present the details for each SPF and average crash rate. Further, each section presents the range (minimum and maximum) of applicable data for applying the SPFs and average crash rates. The SPFs and average crash rates are not intended to be applied to sites with characteristics outside the range of minimum and maximum values. While an analyst could apply these SPFs and average crash rates to estimate safety performance manually, it is highly recommended to use CLEAR Safety to make computations and analyze safety performance.

The following is the general functional form for SPFs for roadway segments:

$$N = Length \times AADT^{\beta} \times exp^{\alpha}$$

Where:

- N = predicted crash frequency per site per year.
- Length = Segment length in miles.
- AADT = Annual average daily traffic.
- α and β = coefficients estimated through regression analysis.

This functional form is called a power function and is traditionally estimated using a count regression model. The negative binomial model is the general standard for SPF estimation as crash data tend to have over-dispersed count outcome variables. Also, standard practice is to constrain the segment length variable to have a coefficient of 1.0, which is why no parameter is shown for segment length. In this way, an identical segment that is twice in length will predict exactly twice as many crashes as the shorter segment.

For roadway segments, other functional forms may provide an improvement over the power function currently used. These include the following:

- Exponential Function: N = $L \times e(\alpha+\beta\times AADT)$
- Hoerl Function: N = $L \times AADT^{\beta}{}_1 \times e(\alpha+\beta_2\times AADT)$
- Polynomial Function: N = $L \times e(\alpha+\beta_1\times AADT+\beta_2\times AADT^2)$

The following is the general functional form for intersections:

$$N = AADT_{maj}^{\beta_1} \times AADT_{min}^{\beta_2} \times e^{\alpha}$$

Where:

- N = predicted crash frequency per site per year.
- $AADT_{maj}$ = Annual average daily traffic for the major road.
- $AADT_{min}$ = Annual average daily traffic for the minor road.
- α and β = coefficients estimated through regression analysis.

A.1 Rural two-lane undivided segments (1)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant + \beta_2 \times AADT)}$$

Where:

- N = predicted crash frequency per site per year.
- Length = Segment length in miles.
- AADT = Annual average daily traffic.

The project team estimated the SPFs considering a variable dispersion parameter that is a function of the segment length using the logarithm of segment length in the log-dispersion model, resulting in the functional form shown in the following equation:

$$Dispersion = Length^{\beta_3} \times exp^{\gamma}$$

The value of the constant is the exponent of the coefficient from the model of the logarithm of dispersion.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.698	0.050	-6.947	0.061	--	--
Length	1.000	--	1.000	--	< 0.01	2.00
β_1 (AADT)	0.855	0.008	0.749	0.008	1	22,238
β_2 (AADT)	-0.000066	0.000005	--	--	1	22,238
Dispersion Parameter						
γ	-1.317	0.021	-1.234	-0.345	--	--
Length	-0.466	0.045	-0.345	0.154	<0.01	2.00

The average crash rate is 0.238 total crashes/mile and 0.033 fatal and injury crashes per mile for segments with no AADT value.

A.2 Rural three-lane undivided segments (2)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.106	0.555	-7.488	1.117	--	--
Length	1.000	--	1.000	--	0.10	1.85
β_1 (AADT)	0.647	0.068	0.841	0.135	144	13,011
Dispersion	0.275	0.048	0.750	0.201	--	--

The average crash rate is 0.255 total crashes/mile and 0.000 fatal and injury crashes per mile for segments with no AADT value.

A.3 Rural four lane undivided segments (3)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.799	0.713	-9.297	1.155	--	--
Length	1.000	--	1.000	--	<0.01	1.834
β_1 (AADT)	0.730	0.086	1.071	0.135	100	17,340
Dispersion	0.277	0.066	0.174	0.090	--	--

The average crash rate is 8.897 total crashes/mile and 0.000 fatal and injury crashes per mile for segments with no AADT value.

A.4 Rural six lane undivided segments (4)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.799	0.713	-9.297	1.155	--	--
Length	1.000	--	1.000	--	0.07	0.17
β_1 (AADT)	0.730	0.086	1.071	0.135	2,103	2,332
Dispersion	0.277	0.066	0.174	0.090	--	--

The average crash rate is 8.897 total crashes/mile and 0.000 fatal and injury crashes per mile for segments with no AADT value.

A.5 Urban two-lane undivided segments (5)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.854	0.054	-8.218	0.937	--	--
Length	1.000	--	1.000	--	< 0.01	2.00
β_1 (AADT)	0.742	0.007	1.071	0.135	0	31,912
Dispersion Parameter						
γ	-0.517	0.017	-0.414	0.037	--	--
Length	-0.782	0.019	-0.721	0.031	< 0.01	2.00

The average crash rate is 0.755 total crashes/mile and 0.110 fatal and injury crashes per mile for segments with no AADT value.

A.6 Urban undivided three and four lane, two-way segments (6)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Minimum and Maximum values were averaged together to account for both three and four lanes.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.074	0.546	-7.941	0.856	--	--
Length	1.000	--	1.000	--	< 0.01	1.94
β_1 (AADT)	0.847	0.068	0.974	0.104	3 leg: 35 4 leg: 178	3 leg: 35,014 4 leg: 35,663
Dispersion Parameter						
γ	-0.138	0.032	-0.201	0.055	--	--
Length	-0.243	0.058	-0.434	0.081	< 0.01	1.94

The average crash rate is 4.674 total crashes/mile and 1.214 fatal and injury crashes per mile for segments with no AADT value.

A.7 Urban undivided five or more lanes, two-way segments (7)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.822	0.633	-7.672	0.958	--	--
Length	1.000	--	1.000	--	0.003	1.99
β_1 (AADT)	0.847	0.068	0.974	0.104	817	39,613
Dispersion Parameter						
γ	-0.138	0.032	-0.200	0.055	--	--
Length	-0.243	0.058	-0.433	0.081	0.003	1.99

The average crash rate is 13.247 total crashes/mile and 3.065 fatal and injury crashes per mile for segments with no AADT value.

A.8 Rural one-lane, one-way (8)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.216	1.614	-6.297	0.612	--	--
Length	1.000	--	1.000	--	0.02	1.86
β_1 (AADT)	0.498	0.225	0.682	0.081	34	3,163
Dispersion	1.242	0.088	0.919	0.187	--	--

The average crash rate is 0.386 total crashes/mile and 0.016 fatal and injury crashes per mile for segments with no AADT value.

A.9 Rural two-lane, one-way (9)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.027	1.724	-6.012	0.781	--	--
Length	1.000	--	1.000	--	0.006	1.76
β_1 (AADT)	0.498	0.225	0.682	0.081	17	638
Dispersion	1.242	0.088	0.919	0.187	--	--

The average crash rate is 0.731 total crashes/mile and 0.038 fatal and injury crashes per mile for segments with no AADT value.

A.10 Urban one-lane, one-way (10)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-1.888	0.316	-6.297	0.612	--	--
Length	1.000	--	1.000	--	< 0.01	1.98
β_1 (AADT)	0.425	0.044	0.682	0.081	10	20,970
Dispersion	1.242	0.088	0.919	0.187	--	--

The average crash rate is 1.618 total crashes/mile and 0.448 fatal and injury crashes per mile for segments with no AADT value.

A.11 Urban two-lane, one-way (11)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-1.700	0.426	-6.012	0.781	--	--
Length	1.000	--	1.000	--	<0.01	1.94
β_1 (AADT)	0.425	0.044	0.682	0.081	20	31,912
Dispersion	1.242	0.088	0.919	0.187	--	--

The average crash rate is 2.816 total crashes/mile and 0.821 fatal and injury crashes per mile for segments with no AADT value.

A.12 Rural two-lane divided segments (12)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-3.366	0.722	-6.025	1.602	--	--
Length	1.000	--	1.000	--	< 0.01	1.96
β_1 (AADT)	0.531	0.094	0.622	0.207	100	22,328
Dispersion Parameter						
γ	-0.771	0.156	-1.230	0.354	--	--
Length	-2.093	0.167	-1.588	0.409	< 0.01	1.96

The average crash rate is 0.554 total crashes/mile and 0.049 fatal and injury crashes per mile for segments with no AADT value.

A.13 Rural three or more lanes divided segments (13)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.783	0.368	-8.497	0.726	--	--
Length	1.000	--	1.000	--	0.001	1.99
β_1 (AADT)	0.698	0.044	0.905	0.084	212	42,977
Dispersion Parameter						
γ	-0.392	0.161	-0.425	0.299	--	--
Length	-1.470	0.142	-0.822	0.255	0.001	1.99

The average crash rate is 0.408 total crashes/mile and 0.000 fatal and injury crashes per mile for segments with no AADT value.

A.14 Urban two-lane divided segments (14)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.585	0.549	-9.646	0.824	--	--
Length	1.000	--	1.000	--	< 0.01	1.965
β_1 (AADT)	0.001	0.071	-0.172	0.114	11	26,670
Dispersion	1.001	0.071	0.842	0.096	--	--

The average crash rate is 2.890 total crashes/mile and 0.812 fatal and injury crashes per mile for segments with no AADT value.

A.15 Urban three or more lanes divided segments (15)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-7.877	1.847	-7.658	2.484	--	--
Length	1.000	--	1.000	--	< 0.01	1.988
β_1 (AADT)	0.140	0.182	0.416	0.272	298	132,117
Dispersion	1.151	0.209	1.515	0.413	--	--

The average crash rate is 13.929 total crashes/mile and 7.534 fatal and injury crashes per mile for segments with no AADT value.

A.16 Urban four-lane divided segments – Undivided Dataset (16)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-8.774	0.872	-13.189	1.290	--	--
Length	1.000	--	1.000	--	< 0.01	1.988
β_1 (AADT)	1.229	0.104	1.545	0.151	298	58,774
Dispersion Parameter						
γ	-0.220	0.046	-0.175	0.071	--	--
Length	-0.198	0.067	-0.055	0.083	< 0.01	1.988

The average crash rate is 12.550 total crashes/mile and 3.257 fatal and injury crashes per mile for segments with no AADT value.

A.17 Urban four-lane divided segments – Divided Dataset (17)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-12.229	1.188	-17.609	2.264	--	--
Length	1.000	--	1.000	--	0.01	1.99
β_1 (AADT)	1.405	0.120	1.751	0.228	10,006	64,746
Dispersion						
γ	-0.863	0.124	-1.080	0.238		
Length	-2.223	0.202	-1.770	0.377	0.01	1.99

The average crash rate is 12.550 total crashes/mile and 3.257 fatal and injury crashes per mile for segments with no AADT value.

A.18 Urban five-lane divided segments (18)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-2.474	2.794	-2.605	2.847	--	--
Length	1.000	--	1.000	--	< 0.01	1.128
β_1 (AADT)	0.528	0.297	0.390	0.302	3012	35,663
Dispersion	1.320	0.232	1.013	0.268	--	--

The average crash rate is 13.311 total crashes/mile and 4.561 fatal and injury crashes per mile for segments with no AADT value.

A.19 Urban six-lane divided segments – Undivided Dataset (19)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-7.797	1.750	-9.822	2.121	--	--
Length	1.000	--	1.000	--	< 0.01	1.98
β_1 (AADT)	1.092	0.192	1.152	0.230	978	132,117
Dispersion Parameter						
γ	-0.394	0.120	-0.644	0.185	--	--
Length	-1.245	0.185	-1.585	0.253	< 0.01	1.98

The average crash rate is 14.332 total crashes/mile and 3.639 fatal and injury crashes per mile for segments with no AADT value.

A.20 Urban six-lane divided segments – Divided Dataset (20)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table. Please note that the dispersion parameter is constant for fatal and injury crashes and varies with segment length for total crash frequency.

<table>
<tr><th rowspan="2">Variable</th><th colspan="2">Total Crashes</th><th colspan="2">Fatal and Injury Crashes</th><th rowspan="2">Minimum Value</th><th rowspan="2">Maximum Value</th></tr>
<tr><th>Coefficient</th><th>Standard Error</th><th>Coefficient</th><th>Standard Error</th></tr>
<tr><td>Constant</td><td>-7.388</td><td>2.145</td><td>-12.596</td><td>3.063</td><td>--</td><td>--</td></tr>
<tr><td>Length</td><td>1.000</td><td>--</td><td>1.000</td><td>--</td><td>0.007</td><td>1.762</td></tr>
<tr><td>β_1 (AADT)</td><td>0.980</td><td>0.199</td><td>1.323</td><td>0.284</td><td>16,660</td><td>78,089</td></tr>
<tr><td colspan="7">Dispersion Parameter</td></tr>
<tr><td>γ</td><td>-0.364</td><td>0.141</td><td rowspan="2">0.760</td><td rowspan="2">0.161</td><td>--</td><td>--</td></tr>
<tr><td>Length</td><td>-1.012</td><td>0.278</td><td>0.007</td><td>1.762</td></tr>
</table>

The average crash rate is 14.332 total crashes/mile and 3.639 fatal and injury crashes per mile for segments with no AADT value.

A.21 Rural four-lane freeways (21)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table. Please note that the dispersion parameter is constant for total crashes and varies with segment length for fatal and injury crash frequency.

<table>
<tr><th rowspan="2">Variable</th><th colspan="2">Total Crashes</th><th colspan="2">Fatal and Injury Crashes</th><th rowspan="2">Minimum Value</th><th rowspan="2">Maximum Value</th></tr>
<tr><th>Coefficient</th><th>Standard Error</th><th>Coefficient</th><th>Standard Error</th></tr>
<tr><td>Constant</td><td>-7.100</td><td>0.708</td><td>-12.711</td><td>1.518</td><td>--</td><td>--</td></tr>
<tr><td>Length</td><td>1.000</td><td>--</td><td>1.000</td><td>--</td><td>0.006</td><td>1.995</td></tr>
<tr><td>β_1 (AADT)</td><td>0.937</td><td>0.088</td><td>1.352</td><td>0.187</td><td>2,143</td><td>27,794</td></tr>
<tr><td colspan="7">Dispersion Parameter</td></tr>
<tr><td>γ</td><td rowspan="2">0.118</td><td rowspan="2">0.009</td><td>-1.161</td><td>0.374</td><td>--</td><td>--</td></tr>
<tr><td>Length</td><td>-1.547</td><td>0.197</td><td>0.006</td><td>1.995</td></tr>
</table>

The average crash rate is 2.916 total crashes/mile and 0.253 fatal and injury crashes per mile for segments with no AADT value.

A.22 Rural Freeway all-lanes (22)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-3.996	0.653	-6.982	1.319	--	--
Length	1.000	--	1.000	--	< 0.01	1.98
β_1 (AADT)	0.584	0.076	0.701	0.150	285	20,686
Dispersion Parameter						
γ	-0.783	0.234	-1.166	0.417	--	--
Length	-1.229	0.191	-0.696	0.386	< 0.01	1.98

The average crash rate is 11.957 total crashes/mile and 4.348 fatal and injury crashes per mile for segments with no AADT value

A.23 Rural six or more lane freeways (23)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-3.993	0.671	-7.312	1.201	--	--
Length	1.000	--	1.000	--	0.01	1.795
β_1 (AADT)	0.566	0.070	0.714	0.122	2,739	42,977
Dispersion	0.093	0.033	0.070	0.081	--	--

The average crash rate is 3.183 total crashes/mile and 0.079 fatal and injury crashes per mile for segments with no AADT value.

A.24 Urban four-lane freeway – Undivided Dataset (24)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.300	0.578	-6.846	0.866	--	--
Length	1.000	--	1.000	--	< 0.01	1.93
β_1 (AADT)	0.646	0.061	0.742	0.091	551	56,920
Dispersion Parameter						
γ	-0.499	0.091	-0.384	0.144	--	--
Length	-0.952	0.106	-0.434	0.141	< 0.01	1.93

The average crash rate is 14.222 total crashes/mile and 5.409 fatal and injury crashes per mile for segments with no AADT value.

A.25 Urban four-lane freeway – Divided Dataset (25)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-7.723	0.327	-12.121	0.583	--	--
Length	1.000	--	1.000	--	0.002	1.99
β_1 (AADT)	0.962	0.034	1.222	0.059	1,774	65,062
Dispersion Parameter						
γ	-0.533	0.060	-0.546	0.100	--	--
Length	-1.369	0.060	-0.782	0.088	0.002	1.99

The average crash rate is 10.388 total crashes/mile and 3.543 fatal and injury crashes per mile for segments with no AADT value.

A.26 Urban six-lane freeway (26)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-10.267	0.552	-15.702	0.801	--	--
Length	1.000	--	1.000	--	<0.01	1.995
β_1 (AADT)	1.235	0.052	1.595	0.076	3,768	78,089
Dispersion Parameter						
γ	-0.457	0.062	-0.333	0.100	--	--
Length	-1.198	0.069	-0.927	0.083	< 0.01	1.995

The average crash rate is 72.243 total crashes/mile and 23.895 fatal and injury crashes per mile for segments with no AADT value.

A.27 Urban five or more lane freeway (27)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table. Please note that the dispersion parameter is constant for fatal and injury crashes and varies with segment length for total crash frequency.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-8.714	1.021	-11.805	1.390	--	--
Length	1.000	--	1.000	--	0.001	1.99
β_1 (AADT)	1.092	0.100	1.254	0.135	2,424	65,214
Dispersion Parameter						
γ	-0.367	0.157	0.321	0.073	--	--
Length	-1.198	0.218			0.001	1.99

The average crash rate is 23.988 total crashes/mile and 7.813 fatal and injury crashes per mile for segments with no AADT value.

A.28 Urban eight or more lanes freeway (28)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-7.358	2.269	-9.927	2.584	--	--
Length	1.000	--	1.000	--	0.001	1.995
β_1 (AADT)	0.998	0.213	1.081	0.241	9,122	78,089
Dispersion	0.529	0.084	0.360	0.090	--	--

The average crash rate is 24.019 total crashes/mile and 7.734 fatal and injury crashes per mile for segments with no AADT value.

A.29 Rural Parclo Entrance Ramp (29)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.088	2.002	-5.917	3.327	--	--
Length	1.000	--	1.000	--	0.034	6.06
β_1 (AADT)	0.424	0.225	0.388	0.364	47	3,848
Dispersion	0.286	0.099	0.968	0.172	--	--

A.30 Rural Free-Flow Entrance Ramp (30)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-1.205	0.928	-2.633	1.506	--	--
Length	1.000	--	1.000	--	0.034	6.06
β_1 (AADT)	0.120	0.087	0.077	0.135	47	3,848
Dispersion	0.286	0.099	0.968	0.172	--	--

A.31 Urban Parclo Entrance Ramp (31)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-3.378	1.770	-5.055	2.898	--	--
Length	1.000	--	1.000	--	0.03	6.06
β_1 (AADT)	0.424	0.225	0.388	0.364	22	33,375
Dispersion	0.286	0.099	0.968	0.172	--	--

A.32 Urban Free-Flow Entrance Ramp (32)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-0.496	0.696	-1.771	1.076	--	--
Length	1.000	--	1.000	--	0.03	6.06
β_1 (AADT)	0.120	0.087	0.077	0.135	22	33,375
Dispersion	0.286	0.099	0.968	0.172	--	--

A.33 Rural Parclo Exit Ramp (33)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.471	0.558	-6.530	1.355	--	--
Length	1.000	--	1.000	--	0.119	0.99
β_1 (AADT)	0.635	0.070	0.551	0.120	23	4,344
Dispersion	0.063	0.106	0.302	0.176	--	--

A.34 Rural Free-Flow Exit Ramp (34)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.471	0.558	-6.530	1.355	--	--
Length	1.000	--	1.000	--	0.119	0.99
β_1 (AADT)	0.635	0.070	0.551	0.120	23	4,344
Dispersion	0.063	0.106	0.302	0.176	--	--

A.35 Urban Parclo Exit Ramp (35)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.471	0.558	-5.711	0.903	--	--
Length	1.000	--	1.000	--	0.054	2.73
β_1 (AADT)	0.635	0.070	0.551	0.120	23	16,636
Dispersion	0.063	0.106	0.302	0.176	--	--

A.36 Urban Free-Flow Exit Ramp (36)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.471	0.558	-5.711	0.903	--	--
Length	1.000	--	1.000	--	0.053	2.73
β_1 (AADT)	0.635	0.070	0.551	0.120	23	16,636
Dispersion	0.063	0.106	0.302	0.176	--	--

A.37 Outer Connection Ramp (37)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-7.268	0.823	-9.337	1.567	--	--
Length	1.000	--	1.000	--	0.02	37.26
β_1 (AADT)	0.914	0.111	0.978	0.210	21	50,994
Dispersion	-0.058	0.126	0.405	0.224	--	--

A.38 Collector-Distributor Road (38)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-3.596	1.009	-6.285	1.735	--	--
Length	1.000	--	1.000	--	0.019	38.38
β_1 (AADT)	0.430	0.119	0.577	0.201	15	92,514
Dispersion	0.815	0.173	1.091	0.268	--	--

A.39 Direct Ramp (39)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-2.716	0.527	-6.232	0.922	--	--
Length	1.000	--	1.000	--	0.02	2.359
β_1 (AADT)	0.397	0.078	0.613	0.104	198	62,891
Dispersion	-0.053	0.107	0.325	0.162	--	--

A.40 Semi-Direct Ramp (40)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-2.716	0.527	-6.232	0.922	--	--
Length	1.000	--	1.000	--	0.06	26.675
β_1 (AADT)	0.430	0.061	0.613	0.104	71	54,817
Dispersion	-0.053	0.107	0.325	0.162	--	--

A.41 Rural Diamond/Slip Entrance Ramp (41)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.565	0.829	-8.292	1.829	--	--
Length	1.000	--	1.000	--	< 0.01	37.94
β_1 (AADT)	0.579	0.085	0.623	0.192	6	10,544
Dispersion	0.288	0.096	0.997	0.185	--	--

A.42 Rural Buttonhook Entrance Ramp (42)

The functional form of the SPF is

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.565	0.829	-8.292	1.829	--	--
Length	1.000	--	1.000	--	0.218	0.418
β_1 (AADT)	0.579	0.085	0.623	0.192	77	3,865
Dispersion	-0.288	0.096	0.997	0.185	--	--

A.43 Urban Diamond/Slip Entrance Ramp (43)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.276	0.651	-7.035	1.431	--	--
Length	1.000	--	1.000	--	0.023	0.366
β_1 (AADT)	0.579	0.085	0.623	0.192	158	18,931
Dispersion	0.288	0.096	0.997	0.185	--	--

A.44 Urban Buttonhook Entrance Ramp (44)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.276	0.651	-7.035	1.431	--	--
Length	1.000	--	1.000	--	0.03	31.665
β_1 (AADT)	0.579	0.085	0.623	0.192	77	20,105
Dispersion	0.288	0.096	0.997	0.185	--	--

A.45 Rural Diamond/Slip Exit Ramp (45)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-7.198	0.425	-11.704	0.970	--	--
Length	1.000	--	1.000	--	0.03	4.78
β_1 (AADT)	0.869	0.055	1.211	0.123	6	10,163
Dispersion	-0.313	0.094	-0.181	0.224	--	--

A.46 Rural Buttonhook Exit Ramp (46)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.481	1.726	-6.114	3.251	--	--
Length	1.000	--	1.000	--	0.136	2.02
β_1 (AADT)	0.519	0.221	0.510	0.409	99	20,105
Dispersion	-0.313	0.094	-0.181	0.224	--	--

A.47 Urban Diamond/Slip Exit Ramp (47)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-7.198	0.425	-11.704	0.970	--	--
Length	1.000	--	1.000	--	0.038	0.248
β_1 (AADT)	0.869	0.055	1.211	0.123	138	10,618
Dispersion	-0.313	0.094	-0.181	0.224	--	--

A.48 Urban Buttonhook Exit Ramp (48)

The functional form of the SPF is:

$$N = Length \times AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.481	1.726	-6.114	3.251	--	--
Length	1.000	--	1.000	--	0.07	5.374
β_1 (AADT)	0.519	0.221	0.510	0.409	95	20,105
Dispersion	-0.313	0.094	-0.181	0.224	--	--

A.49 Two-Way STOP 3-leg – Major and Minor AADT (49)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-8.172	0.105	-11.460	0.195	--	--
β_1 (AADT Major)	0.576	0.012	0.776	0.021	1	54,378
β_2 (AADT Minor)	0.392	0.010	0.419	0.016	1	28,074
Dispersion	-0.415	0.032	-0.212	0.060	--	--

A.50 Rural Two-Way STOP 3-leg – Major AADT (50)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-7.044	0.074	-10.504	0.142	--	--
β_1 (AADT)	0.685	0.006	0.913	0.012	1	18,851
Dispersion	0.008	0.014	0.173	0.027	--	--

A.51 Urban Two-Way STOP 3-leg – Major AADT (51)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-6.782	0.055	-10.150	0.105	--	--
β_1 (AADT)	0.685	0.006	0.913	0.012	1	54,976
Dispersion	0.008	0.014	0.173	0.027	--	--

A.52 Rural Two-Way STOP 4-leg – Major and Minor AADT (52)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-7.122	0.138	-8.749	0.303	--	--
β_1 (AADT Major)	0.484	0.015	0.506	0.024	5	12,618
β_2 (AADT Minor)	0.429	0.014	0.473	0.021	4	18,313
Dispersion	-0.527	0.038	-0.163	0.053	--	--

A.53 Urban Two-Way STOP 4-leg – Major and Minor AADT (53)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-7.122	0.138	-8.637	0.245	--	--
β_1 (AADT Major)	0.484	0.015	0.506	0.024	62	53,321
β_2 (AADT Minor)	0.429	0.014	0.473	0.021	2	38,694
Dispersion	-0.527	0.038	-0.163	0.053	--	--

A.54 Rural Two-Way STOP 4-leg – Major AADT (54)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.892	0.103	-6.317	0.153	--	--
β_1 (AADT)	0.489	0.008	0.512	0.012	1	13,888
Dispersion	-0.151	0.029	0.176	0.028	--	--

A.55 Urban Two-Way STOP 4-leg – Major AADT (55)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.354	0.069	-5.512	0.100	--	--
β_1 (AADT)	0.489	0.008	0.512	0.012	1	54,976
Dispersion	-0.151	0.029	0.176	0.028	--	--

A.56 Two-Way STOP 5+ leg – Major and Minor AADT (56)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-6.880	0.435	-9.590	0.686	--	--
β_1 (AADT Major)	0.537	0.054	0.692	0.081	59	43,119
β_2 (AADT Minor)	0.314	0.046	0.334	0.063	15	41,473
Dispersion	-0.518	0.137	-0.528	0.212	--	--

A.57 Rural Two-Way STOP 5+ leg – Major AADT (57)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.757	0.542	-7.149	0.780	--	--
β_1 (AADT)	0.581	0.043	0.569	0.058	10	9,838
Dispersion	-0.005	0.085	0.051	0.133	--	--

A.58 Urban Two-Way STOP 5+ leg – Major AADT (58)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.173	0.383	-6.216	0.530	--	--
β_1 (AADT)	0.581	0.043	0.569	0.058	10	52,518
Dispersion	-0.005	0.085	0.051	0.133	--	--

A.59 All-Way STOP 3-leg – Major and Minor AADT (59)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-9.695	0.782	-12.466	1.576	--	--
β_1 (AADT Major)	0.698	0.097	0.936	0.187	40	12,995
β_2 (AADT Minor)	0.423	0.071	0.327	0.128	28	18,407
Dispersion	-0.403	0.165	0.456	0.272	--	--

A.60 All-Way STOP 3-leg – Major AADT (60)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.914	0.276	-10.404	0.669	--	--
β_1 (AADT)	0.591	0.035	0.944	0.082	5	41,757
Dispersion	0.041	0.087	0.528	0.190	--	--

A.61 All-Way STOP 4-leg – Major and Minor AADT (61)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-7.796	0.375	-11.121	0.632	--	--
β_1 (AADT Major)	0.669	0.049	0.937	0.080	103	26,019
β_2 (AADT Minor)	0.300	0.038	0.277	0.059	1	11,678
Dispersion	-0.573	0.077	-0.358	0.132	--	--

A.62 Rural All-Way STOP 4-leg – Major AADT (62)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-6.109	0.301	-9.881	0.623	--	--
β_1 (AADT)	0.664	0.022	0.901	0.038	58	11,961
Dispersion	-0.489	0.054	0.039	0.306	--	--

A.63 Urban All-Way STOP 4-leg – Major AADT (63)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.722	0.170	-8.766	0.306	--	--
β_1 (AADT)	0.664	0.022	0.901	0.038	2	35,169
Dispersion	-0.489	0.054	0.039	0.306	--	--

A.64 All-Way STOP 5+ leg – Major and Minor AADT (64)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-9.612	1.719	-12.261	2.802	--	--
β_1 (AADT Major)	0.613	0.183	0.679	0.270	30	14,007
β_2 (AADT Minor)	0.570	0.153	0.670	0.237	72	12,904
Dispersion	-0.509	0.301	-0.530	0.539	--	--

A.65 All-Way STOP 5+ leg – Major AADT (65)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.390	0.946	-5.786	1.553	--	--
β_1 (AADT)	0.478	0.117	0.502	0.190	39	17,120
Dispersion	-0.681	0.355	-0.156	0.686	--	--

A.66 Yield 3-leg and 4-leg – Major and Minor AADT (66)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-7.519	0.600	-9.663	1.086	--	--
β_1 (AADT Major)	0.481	0.080	0.536	0.136	3 leg: 7 4 leg: 98	3 leg: 33,145 4 leg: 35,169
β_2 (AADT Minor)	0.414	0.066	0.430	0.104	3 leg: 1 4 leg: 31	3 leg: 14,823 4 leg: 9,820
Dispersion	-0.120	0.200	-0.474	0.589	--	--

A.67 Yield 3-leg – Major AADT (67)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-6.618	0.357	-10.220	0.820	--	--
β_1 (AADT)	0.635	0.047	0.890	0.102	2	26,859
Dispersion	0.184	0.156	0.486	0.367	--	--

A.68 Yield 4-leg – Major AADT (68)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.922	0.892	-9.170	1.927	--	--
β_1 (AADT)	0.624	0.114	0.872	0.233	11	54976
Dispersion	0.395	0.366	0.992	0.512	--	--

A.69 Yield 5+ leg – Major and Minor AADT (69)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-8.373	1.411	-15.891	3.222	--	--
β_1 (AADT Major)	0.679	0.206	1.270	0.467	168	22838
β_2 (AADT Minor)	0.365	0.142	0.478	0.348	20	17040
Dispersion	-4.223	5.702	-17.585	293.888	--	--

A.70 Yield 5+ leg – Major AADT (70)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.031	1.062	-6.758	1.682	--	--
β_1 (AADT)	0.474	0.146	0.682	0.214	84	21,887
Dispersion	-0.068	0.495	-0.031	0.803	--	--

A.71 Signalized Rural 3-leg – Major and Minor AADT (71)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-6.502	1.762	-10.598	2.659	--	--
β_1 (AADT Major)	0.181	0.112	0.612	0.170	0	138,029
β_2 (AADT Minor)	0.653	0.158	0.523	0.226	0	61,129
Dispersion	-1.988	0.886	-18.683	0.0004	--	--

A.72 Signalized Rural 3-leg – Major AADT (72)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-3.978	2.946	-5.545	3.430	--	--
β_1 (AADT)	0.450	0.344	0.459	0.396	0	138,029
Dispersion	-0.287	0.485	-15.961	2409.211	--	--

A.73 Signalized Rural 4-leg – Major and Minor AADT (73)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-8.537	0.984	-7.041	1.575	--	--
β_1 (AADT Major)	0.509	0.082	0.284	0.130	0	138,029
β_2 (AADT Minor)	0.581	0.074	0.451	0.118	0	61,129
Dispersion	-1.930	0.281	-1.969	0.709	--	--

A.74 Signalized Rural 4-leg – Major AADT (74)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.098	0.395	-7.382	0.686	--	--
β_1 (AADT)	0.538	0.013	0.571	0.016	0	138,029
Dispersion	-0.806	0.023	-0.868	0.031	--	--

A.75 Signalized Urban 3-leg – Major and Minor AADT (75)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-8.658	0.345	-9.490	0.412	--	--
β_1 (AADT Major)	0.701	0.033	0.700	0.039	0	138,029
β_2 (AADT Minor)	0.356	0.023	0.323	0.027	0	61,129
Dispersion	-0.654	0.044	-0.735	0.062	--	--

A.76 Signalized Urban 3-leg – Major AADT (76)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.941	0.284	-6.563	0.355	--	--
β_1 (AADT)	0.696	0.030	0.654	0.037	0	138,029
Dispersion	-0.394	0.035	-0.324	0.048	--	--

A.77 Signalized Urban 4-leg – Major and Minor AADT (77)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-7.601	0.129	-8.804	0.145	--	--
β_1 (AADT Major)	0.539	0.013	0.569	0.015	0	138,029
β_2 (AADT Minor)	0.451	0.011	0.455	0.012	0	61,129
Dispersion	-0.942	0.021	-1.079	0.028	--	--

A.78 Signalized Urban 4-leg – Major AADT (78)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.253	.124	-5.329	0.148	--	--
β_1 (AADT)	0.538	0.013	0.571	0.016	0	138,029
Dispersion	-0.806	0.023	-0.868	0.031	--	--

A.79 Signalized Rural Urban 5+ leg – Major and Minor AADT (79)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-8.108	0.441	-8.612	0.523	--	--
β_1 (AADT Major)	0.597	0.043	0.545	0.050	0	138,029
β_2 (AADT Minor)	0.449	0.034	0.460	0.039	0	61,129
Dispersion	-0.819	0.061	-0.737	0.072	--	--

A.80 Signalized Rural Urban 5+ leg – Major AADT (80)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-3.070	0.561	-4.627	0.646	--	--
β_1 (AADT)	0.450	0.059	0.516	0.067	0	138,029
Dispersion	-0.407	0.082	-0.425	0.102	--	--

A.81 Rural Roundabout – Major and Minor AADT (81)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-14.130	2.824	-20.437	3.081	--	--
β_1 (AADT Major)	1.153	0.225	1.332	0.309	2,458	11,519
β_2 (AADT Minor)	0.708	0.200	0.882	0.290	785	9,915
Dispersion	-0.553	0.253	-0.740	0.443	--	--

A.82 Urban Roundabout – Major and Minor AADT (82)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-15.359	2.267	-20.437	3.081	--	--
β_1 (AADT Major)	1.153	0.225	1.332	0.309	1,267	32,263
β_2 (AADT Minor)	0.708	0.200	0.882	0.290	828	19,332
Dispersion	-0.553	0.253	-0.740	0.443	--	--

A.83 Roundabout – Major AADT (83)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-9.770	2.077	-6.059	0.347	--	--
β_1 (AADT)	1.144	0.221	0.583	0.347	8	22,737
Dispersion	-2.527	0.874	-0.902	1.012	--	--

A.84 Uncontrolled 3-leg TT – Major and Minor AADT (84)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-6.959	1.768	-8.299	2.370	--	--
β_1 (AADT Major)	0.516	0.165	0.657	0.220	261	138,029
β_2 (AADT Minor)	0.295	0.170	0.193	0.236	173	8,706
Dispersion	0.140	0.236	0.524	0.324	--	--

A.85 Uncontrolled 3-leg TT – Major AADT (85)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.391	0.544	-8.597	0.822	--	--
β_1 (AADT)	0.564	0.064	0.840	0.094	75	54,452
Dispersion	0.075	0.126	0.234	0.168	--	--

A.86 Uncontrolled 4-leg TT – Major and Minor AADT (86)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.158	3.327	-2.378	6.477	--	--
β_1 (AADT Major)	0.343	0.259	-0.129	0.307	531	30,852
β_2 (AADT Minor)	0.139	0.371	0.300	0.998	278	3,503
Dispersion	-19.566	66.719	-19.081	0.00006	--	--

A.87 Uncontrolled 4-leg TT – Major AADT (87)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-2.106	1.795	-6.549	3.329	--	--
β_1 (AADT)	0.213	0.228	0.597	0.414	531	12,672
Dispersion	-0.669	0.552	0.409	0.875	--	--

A.88 Rural Uncontrolled 3-leg OT – Major and Minor AADT (88)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-8.646	2.135	-11.938	1.621	--	--
β_1 (AADT Major)	0.562	0.118	0.853	0.176	184	7,203
β_2 (AADT Minor)	0.213	0.080	0.429	0.176	34	342
Dispersion	-0.138	0.140	0.093	0.191	--	--

A.89 Urban Uncontrolled 3-leg OT – Major and Minor AADT (89)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-6.743	1.016	-11.938	1.621	--	--
β_1 (AADT Major)	0.562	0.118	0.853	0.176	49	52,057
β_2 (AADT Minor)	0.213	0.080	0.429	0.176	14	26,049
Dispersion	-0.138	0.140	0.093	0.191	--	--

A.90 Rural Uncontrolled 3-leg OT – Major AADT (90)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-6.699	0.732	-10.559	1.260	--	--
β_1 (AADT)	0.593	0.043	0.865	0.067	238	11,618
Dispersion	0.002	0.061	0.326	0.085	--	--

A.91 Urban Uncontrolled 3-leg OT – Major AADT (91)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.718	0.385	-9.187	0.611	--	--
β_1 (AADT)	0.593	0.043	0.865	0.067	11	54,976
Dispersion	0.002	0.061	0.326	0.085	--	--

A.92 Uncontrolled 4-leg OT – Major and Minor AADT (92)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-6.309	2.173	-14.493	3.3866	--	--
β_1 (AADT Major)	0.584	0.213	1.213	0.375	1,460	28,174
β_2 (AADT Minor)	0.152	0.135	0.302	0.169	148	15,677
Dispersion	-1.214	0.491	-1.343	1.290	--	--

A.93 Uncontrolled 4-leg OT – Major AADT (93)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.187	1.006	-8.200	1.443	--	--
β_1 (AADT)	0.435	0.110	0.787	0.156	27	33,210
Dispersion	-0.417	0.176	-0.196	0.212	--	--

A.94 Uncontrolled 3-leg and 4-leg TO – Major and Minor AADT (94)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table. Three and Four leg intersections were combines due to sample size. In this sample, there were only four 4-leg intersections.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-6.879	1.810	-9.125	2.202	--	--
β_1 (AADT Major)	0.448	0.178	0.582	0.194	3-leg: 591 4-leg: 1,310	3-leg: 50,584 4-leg: 13,688
β_2 (AADT Minor)	0.400	0.131	0.444	0.150	3-leg: 38 4-leg: 1,885	3-leg: 17,298 4-leg: 6,631
Dispersion	0.065	0.337	-0.032	0.409	--	--

A.95 Uncontrolled 3-leg TO – Major AADT (95)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-3.954	0.623	-6.634	1.122	--	--
β_1 (AADT)	0.371	0.083	0.539	0.144	4	50,584
Dispersion	0.553	0.188	0.994	0.335	--	--

A.96 Uncontrolled 3-leg OO – Major and Minor AADT (96)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-8.520	0.302	-10.926	0.514	--	--
β_1 (AADT Major)	0.600	0.037	0.709	0.062	4	57,028
β_2 (AADT Minor)	0.403	0.034	0.413	0.049	1	30,070
Dispersion	0.060	0.098	-0.121	0.200	--	--

A.97 Rural Uncontrolled 3-leg OO – Major AADT (97)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-7.762	0.174	-11.510	0.231	--	--
β_1 (AADT)	0.744	0.014	1.040	0.026	1	12,676
Dispersion	0.168	0.037	0.284	0.073	--	--

A.98 Uncontrolled 4-leg OO – Major and Minor AADT (98)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-8.822	0.664	-10.760	1.057	--	--
β_1 (AADT Major)	0.587	0.088	0.773	0.136	25	34,337
β_2 (AADT Minor)	0.527	0.078	0.732	0.126	7	14,427
Dispersion	-0.309	0.214	-0.167	0.338	--	--

A.99 Rural Uncontrolled 4-leg OO – Major AADT (99)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-6.266	0.519	-9.484	0.576	--	--
β_1 (AADT)	0.606	0.039	0.876	0.065	5	9647
Dispersion	0.077	0.106	0.122	0.192	--	--

A.100 Urban Uncontrolled 4-leg OO – Major AADT (100)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.757	0.339	-9.484	0.576	--	--
β_1 (AADT)	0.606	0.039	0.876	0.065	9	44,706
Dispersion	0.077	0.106	0.122	0.192	--	--

A.101 Signalized Ramp Terminals – Major and Minor AADT (101)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-8.062	0.602	-8.210	0.737	--	--
β_1 (AADT Major)	0.664	0.043	0.667	0.053	0	85,318
β_2 (AADT Minor)	0.396	0.045	0.285	0.055	0	138,029
Dispersion	-0.229	0.057	0.072	0.066	--	--

A.102 Signalized Ramp Terminals – Major AADT (102)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-5.222	1.457	-6.847	1.860	--	--
β_1 (AADT)	0.721	0.153	0.793	0.195	0	85,318
Dispersion	-0.099	0.141	0.128	0.158	--	--

A.103 Two-way STOP Ramp Terminals – Major and Minor AADT (103)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-8.376	0.481	-9.877	0.746	--	--
β_1 (AADT Major)	0.585	0.057	0.750	0.081	13	51,190
β_2 (AADT Minor)	0.421	0.054	0.291	0.078	33	51,190
Dispersion	0.074	0.092	0.446	0.136	--	--

A.104 Two-way STOP Ramp Terminals – Major AADT (104)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-6.860	1.151	-7.187	1.571	--	--
β_1 (AADT)	0.747	0.133	0.635	0.179	6	29,944
Dispersion	0.031	0.252	0.134	0.424	--	--

A.105 Uncontrolled Ramp Terminals – Major and Minor AADT (105)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-9.680	1.460	-11.788	1.895	--	--
β_1 (AADT Major)	0.596	0.143	0.635	0.178	35	116,297
β_2 (AADT Minor)	0.497	0.112	0.535	0.155	137	67,099
Dispersion	0.640	0.142	0.740	0.227	--	--

A.106 Uncontrolled Ramp Terminals – Major AADT (106)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.877	1.661	-4.199	2.736	--	--
β_1 (AADT)	0.468	0.200	0.265	0.340	65	50,951
Dispersion	0.194	0.466	1.578	0.679	--	--

A.107 Yield Ramp Terminals – Major and Minor AADT (107)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times AADT^{\beta_2} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-8.459	1.314	-9.113	1.834	--	--
β_1 (AADT Major)	0.365	0.151	0.327	0.209	53	15,676
β_2 (AADT Minor)	0.592	0.173	0.559	0.239	202	44,536
Dispersion	0.188	0.246	0.424	0.370	--	--

A.108 Yield Ramp Terminals – Major AADT (108)

The functional form of the SPF is:

$$N = AADT^{\beta_1} \times exp^{(Constant)}$$

The dispersion parameter for this segment type has a constant value as shown in the following table.

Variable	Total Crashes		Fatal and Injury Crashes		Minimum Value	Maximum Value
	Coefficient	Standard Error	Coefficient	Standard Error		
Constant	-4.976	4.275	-8.629	4.354	--	--
β_1 (AADT)	0.548	0.501	0.876	0.496	717	12,804
Dispersion	0.495	0.621	-0.076	0.976	--	--

10. APPENDIX C: COUNTERMEASURES AND ASSOCIATED CMFS, SERVICE LIFE, AND COST

- List all countermeasures by facility type along with the CMFs, service life, and cost

11. APPENDIX D: NYSDOT PROJECT DEVELOPMENT PROCESS

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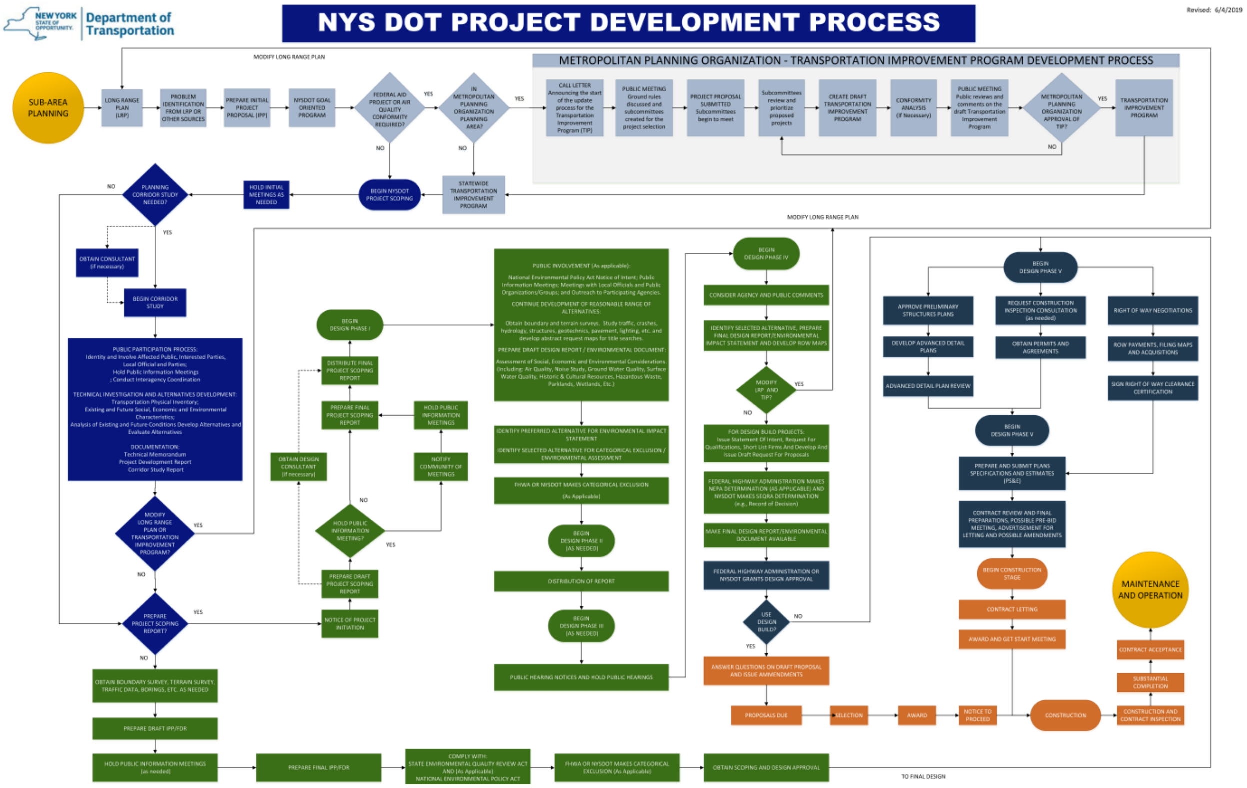

12. APPENDIX E: SAMPLE SIZE SPREADSHEET TEMPLATE

Appendix E provides a sample size template to estimate the required sample size to detect an expected change in safety performance at a given level of significance. Using the following spreadsheet template, the green cells represent user inputs. The yellow cells represent the outputs, computed automatically based on the user inputs. Assuming the number of years before and after implementation is one, the sample size represents the total crashes required in a given period (before or after). Input the desired level of significance, the variance of the odds ratio, and the expected reduction. For the variance of the odds ratio, examine the sensitivity assuming values from 0.001 to 0.01.[2]

With these variables input, enter a value for the number of "before" crashes per year in the treatment group. Adjust the value until the upper bound of the confidence interval is 1.0. If the upper bound is greater than 1.0 (not statistically significant), then increase the sample size. If the upper bound is less than 1.0 (statistically significant), then decrease the sample size until the upper bound is 0.9999. When the upper bound dips below 1.0, the associated sample size is the sample required to obtain significant results for the given level of effectiveness and significance. It is useful to start by changing the sample size by units of 100, then 10, and then 1 until the analyst identifies the threshold.

Excel Row	Variable Inputs (Column A)	Excel Formula (Column B)	Example
1	Number of "before" crashes per year in treatment group	User Input	193
2	Number of "before" years	1	1
3	Number of "after" years	1	1
4	Number of "before" crashes per year in comparison group	=B1	193
5	Variance of odds ratio	User Input	0.001
6	Desired level of significance (α)	User Input	0.1
7	Cumulative probability	=ABS(NORMSINV(B6/2))	1.64
8	Expected % reduction [100*(1-CMF)]	User Input	20
9	Number of "before" crashes in treatment group	=B1*B2	193
10	Estimated number of "after" crashes in treatment group	=B1*B3*(1-B8/100)	154.4
11	Number of "before" crashes in comparison group	=B4*B2	193
12	Estimated number of "after" crashes in comparison group	=B4*B3	193
13	Estimated number of "after" crashes in treatment group without change	=B9*B12/B11	193
14	Estimate of the variance of crashes "after" without change	=B9*(B12/B11)^2*(1+B9*B5+ B9/B11+B9/B12)	616.249
15	Estimated index of effectiveness [CMF]	=B10/B13	0.8
16	Standard deviation of the estimated index of effectiveness [SE(CMF)]	=(B15^2(1/B10+B14/B13^2))^ 0.5	0.121

[2] Hauer, E. (1997), Observational Before-After Studies in Road Safety, Pergamon, Elsevier Science Ltd.

Excel Row	Variable Inputs (Column A)	Excel Formula (Column B)	Exampl e
17	Lower bound of confidence interval	=B15-B7*B16	0.6003
18	Upper bound of confidence interval	= B15+B7*B16	0.9997

13. APPENDIX F: EMPIRICAL BAYES BEFORE-AFTER TEMPLATE

The following table presents sample data for an example countermeasure evaluation followed by a spreadsheet template and completed example for estimating countermeasure effectiveness using the Empirical Bayes before-after method. The example presents data for a scenario where an agency installed a treatment at a two-way stop-controlled intersection along a rural, two-lane highway. To estimate the safety effectiveness and standard error for this countermeasure using the Empirical Bayes before-after method, use the spreadsheet template below. The green cells represent user inputs. The yellow cells represent the outputs, computed automatically based on the user inputs. This assumes the analyst has developed or calibrated an SPF and dispersion parameter. It also assumes the annual crashes are "predicted" using an SPF and appropriate calibration factors. For this example, the equation below represents the uncalibrated SPF and the table presents the calibration and dispersion parameters.

$$SPF = \exp\left[-8.56 + 0.60 * \ln\left(AADT_{major\ road}\right) + 0.61 * \ln\left(AADT_{minor\ road}\right)\right]$$

Sample Data

Treatment Site Data	Before	After
Total observed crashes	18	10
Duration (years)	3	2
Traffic volume major road (vehicles/day)	7,000	7,700
Traffic volume minor road (vehicles/day)	500	600
Calibration Factors for SPF	0.69	1.08
Dispersion parameter of SPF (k)	0.24	0.24

Spreadsheet Template

Excel Row	Variable Inputs (Column A)	Excel Formula (Column B)	Example
1	Number of Observed Crashes "Before" in Treatment Group	User Input	18
2	Number of Observed Crashes "After" in Treatment Group	User Input	10
3	Number of Predicted Crashes "Before" in Treatment Group	User Input: Sum of predicted annual crashes for each year in before period	3.56
4	Number of Predicted Crashes "After" in Treatment Group	User Input: Sum of predicted annual crashes for each year in after period	4.40
5	Dispersion parameter of SPF (k)	User Input	0.24
6	SPF Weight	=1/(1+B5*B3)	0.54
7	Expected Number of Crashes "Before" in Treatment Group	=B6*B3+(1-B6)*B1	10.22
8	Expected Number of Crashes "After" in Treatment Group Without Change	=B7*(B4/B3)	12.62
9	Variance of Observed Crashes "After" in Treatment Group	=B2	10
10	Variance of Expected Number of Crashes "After" in Treatment Group Without Change	=(B8^2)*((B4/B3)*(1-B6))	90.63
11	Estimate of Effectiveness (CMF)	=(B2/B8)/(1+(B10/(B8^2)))	0.51
12	Variance of CMF	=(B11^2)*((B9/(B2^2))+(B10/(B8^2)))/ (1+(B10/(B8^2))^2)	0.13
13	Standard Error of CMF	=SQRT(B12)	0.36

14. APPENDIX G: BEFORE-AFTER WITH COMPARISON GROUP TEMPLATE

The following table presents sample data for an example countermeasure evaluation followed by a spreadsheet template and completed example for estimating countermeasure effectiveness using the before-after with comparison group method. The example presents data for a scenario where an agency installed a treatment at 25 signalized intersections and identified a representative comparison group, including 25 similar signalized intersections without the treatment. To estimate the safety effectiveness and standard error for this countermeasure using the before-after with comparison group method, use the spreadsheet template below. The green cells represent user inputs. The yellow cells represent the outputs, computed automatically based on the user inputs. This assumes the before and after periods are the same for the treatment group and comparison group.

Sample Data

Input Data	Before	After
Total observed crashes for treatment group	100	75
Total observed crashes for comparison group	84	80
Duration (years)	3	3

Spreadsheet Template

Excel Row	Variable Inputs (Column A)	Excel Formula (Column B)	Example
1	Number of Observed Crashes "Before" in Treatment Group	User Input	100
2	Number of Observed Crashes "After" in Treatment Group	User Input	75
3	Number of Observed Crashes "Before" in Comparison Group	User Input	84
4	Number of Observed Crashes "After" in Comparison Group	User Input	80
5	Estimated Number of Crashes "After" in Treatment Group Without Change	=B1*(B4/B3)	95.2
6	Variance of Observed Crashes "After" in Treatment Group	=B2	75
7	Variance of Estimated Number of Crashes "After" in Treatment Group Without Change	=(B5^2)*((1/B1)+(1/B3)+(1/B4))	312.1
8	Estimate of Effectiveness (CMF)	=(B2/B5)/(1+(B7/(B5^2)))	0.76
9	Variance of CMF	=(B8^2)*((B6/(B2^2))+(B7/(B5^2)))/(1+(B7/(B5^2))^2)	0.03
10	Standard Error of CMF	=SQRT(B9)	0.17