Priorities in Roadway Safety Data Guide

Prioritization Considerations

Analysis Type and Usage

Data-related Costs

Existing Data and Management

Regional and Jurisdictional Data

Data Variability Over Time

Data Sharing

FHWA Safety Program

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NOTICE

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16. Abstract

This *Priorities in Roadway Safety Data Guide* is the capstone of more than five years of related projects aimed at helping State, Tribal, and local agencies develop more complete data to support advanced safety analysis and decision-making. The Guide follows, and promotes, the data-driven approach to safety decision making. It introduces users to the data needs to support Federal programs like the Highway Safety Improvement Program and addresses the importance of data quality to support performance measurement, Strategic Highway Safety Plans, and other important planning efforts. The Guide provides information on data elements and requirements, a detailed overview of analysis methods and their data requirements, guidance on prioritizing data elements, and methods for planning, coordinating, and managing major data collection efforts.

The Guide promotes an all-public-roads approach to safety that addresses the need for local data and emphasizes the importance of partnerships among agencies to achieve the desired data goals. The Guide also provides safety engineers and analysts with information about data needs in planning, programming, and developing projects under all highway programs.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

AADT	Annual average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
B/C	Benefit-cost
CDIP	Crash Data Improvement Program
CMF	Crash modification factor
DDSA	Data-Driven Safety Analysis
DOT	Department of Transportation
EB	Empirical Bayes
EDC	Every Day Counts
EMS	Emergency medical services
FAST Act	Fixing America's Surface Transportation Act
FHWA	Federal Highway Administration
GIS	Geographic information system
HPMS	Highway Performance Monitoring System
HSIP	Highway Safety Improvement Program
HSM	Highway Safety Manual
IHSDM	Interactive Highway Safety Design Model
ITS	Intelligent transportation system
LTAP	Local Technical Assistance Program
LRS	Linear referencing system
MAP-21	Moving Ahead for Progress in the 21st Century
MIRE	Model Inventory of Roadway Elements
MIRE FDE	Model Inventory of Roadway Elements Fundamental Data Elements
MIS	Management information system
MPO	Metropolitan Planning Organization
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
QC	Quality control
RDIP	Roadway Data Improvement Program
RPC	Regional Planning Commission
SHSP	Strategic Highway Safety Plan
SPF	Safety performance function
SSPST	Systemic Safety Project Selection Tool
TRCC	Traffic Records Coordinating Committee
TRA	Traffic Records Assessment
TTAP	Tribal Technical Assistance Program
VMT	Vehicle miles traveled

EXECUTIVE SUMMARY

There is a growing awareness of the importance of data-driven safety analysis. By integrating roadway, traffic, and crash data, State and local highway agencies can implement and improve data-driven, performance-based safety analyses in planning, programming, and design processes. Data-driven safety analysis (DDSA) is the application of the latest software tools and methods for analyzing crash and roadway data. Data-driven analyses promote objective, informed decision making by quantifying the expected safety impact of each decision in the project development process. Performance-based analysis and practical design aims to compare conditions to a baseline threshold with the aim of determining optimal design criteria, considering safety and cost, while not over-engineering roadways. Advanced analysis methods enhance decision-making capabilities; improve productivity; allow agencies to plan, program, and develop projects that strategically address their missions and goals; lead to more effective and efficient stewardship of funds and programs; and help move toward zero fatalities and serious injuries on the Nation's roadways.

Data availability and quality are key aspects of a successful data-driven safety program; however, it can be daunting to figure out where to begin with data improvement. This Guide can help by providing agencies with a means to prioritize their safety data needs. The Guide builds upon the previous efforts of the Federal Highway Administration (FHWA) in safety analysis, data quality, and data integration.

This Guide helps agencies understand their options and provides important considerations for prioritizing their safety data needs, building upon FHWA's previous efforts in safety analysis, data quality, and data integration. Agencies can use this Guide alongside other FHWA reports and Guides to prioritize safety data collection and maintenance to allocate resources efficiently and support the most important safety analyses to the agency.

The Guide promotes an all-public-roads approach to safety that addresses the need for local data and emphasizes the importance of partner agencies in contributing to overall data improvement. The Guide also provides safety engineers and analysts with information about data needs in planning, programming, and developing projects under all highway programs. Broad participation in the prioritization effort will help agencies find more opportunities to improve safety.

CHAPTER 1—INTRODUCTION

BACKGROUND

There is a growing awareness of the importance of data-driven safety analysis (DDSA). By integrating roadway, traffic, and crash data, State and local highway agencies can implement and improve performance-based safety analyses in planning, programming, and design processes by using advanced analysis methods. Advanced analysis methods provide the following benefits to agencies:

- Enhance decision-making capabilities.
- Improve productivity.
- Allow agencies to meet their performance goals for reductions of fatal and serious injury crashes.
- Lead to more effective and efficient stewardship of funds and programs.
- Help move toward zero fatalities and serious injuries on the Nation's roadways.

Figure 1 shows the logical links between better data, better decisions, more effective resource allocation, and ultimate reductions in fatalities and serious injuries.

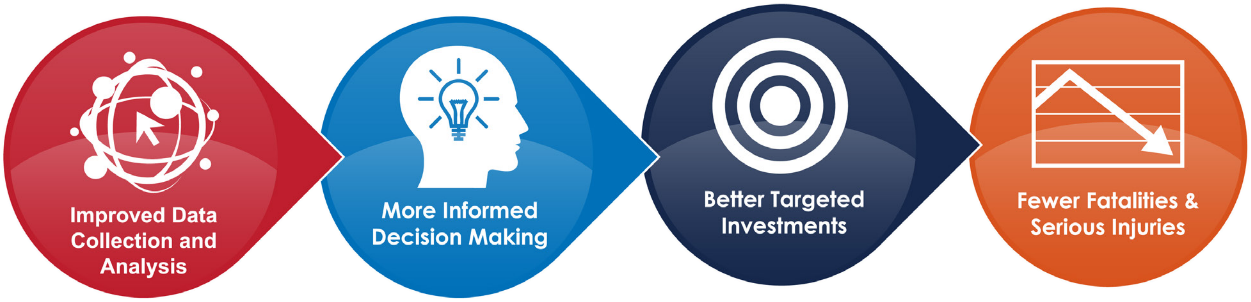


Figure 1. Graphic. Data-driven safety analysis linking better data to safety improvements.

This Guide is intended to help agencies prioritize data needs for safety planning and program management as well as in the broader consideration of safety in all highway programs and projects. The consideration of safety in all highway projects is essential to reach the goals of achieving a significant reduction in fatalities and serious injuries.

Legislation and Safety Programs

Recent highway authorization bills have reinforced the importance of safety data and advanced safety analysis techniques as part of safety programs and public accountability for safety. The Moving Ahead for Progress in the 21st Century Act (MAP-21) required that each State have a safety data system in place to perform analyses for the Highway Safety Improvement Program (HSIP) supporting the strategic and performance-based goals in their Strategic Highway Safety Plan (SHSP) on all public roads. The legislation defines safety data as crash, roadway, and traffic data on a public road.

An SHSP is a comprehensive plan for reducing fatalities and serious injuries on all public roads. States coordinate with Federal, Tribal, and local highway agencies, and other public and private partners, to develop and manage the SHSP. SHSPs guide investments in safety emphasis areas—representing significant contributors to fatal and serious injury crashes—through goals and strategies set for each area. Most SHSPs integrate strategies from engineering, education, enforcement, and emergency medical services (i.e., the 4E approach). Crash, roadway, and traffic safety data are necessary during SHSP planning and development through implementation and performance measurement. As a data-driven planning effort, the SHSP quantifies safety problems within each emphasis area and estimates the safety impacts of expected improvement strategies in the plan. Many States include data system and analysis capability improvement among their SHSP emphasis areas or strategies, which formalizes the need for improvement and allows them to spend HSIP funds on data improvement. The SHSP plays an important role in tracking a State's performance and progress towards achieving their goals.

The HSIP is a core Federal-aid, State-administered highway program with the purpose to achieve a significant reduction in fatalities and serious injuries. A State's HSIP is the primary means for carrying out the engineering and infrastructure safety improvement strategies included in the SHSP. Agencies use safety management approaches to identify locations with potential for safety improvement and implement countermeasures to address the safety issues at those locations. Safety engineers, planners, and analysts use data at all steps in safety management process. Higher quality data are essential to make more reliable investments.

MAP-21 also required the Secretary of Transportation to establish the minimum data elements, from the Model Inventory of Roadway Elements (MIRE), that analysts need to conduct system-wide network screening and improve investment decision making.(1) This led to the development of the MIRE Fundamental Data Elements (MIRE FDE), a group of roadway data elements that support enhanced network-level safety analysis. The Fixing America's Surface Transportation (FAST) Act continues the emphasis on safety data and the requirement to collect and maintain the MIRE FDE. States need to incorporate specific quantifiable and measurable anticipated improvements for collecting MIRE FDE into their State Traffic Records

Strategic Plan by July 1, 2017, and have access to the MIRE FDE on all public roads by September 30, 2026.

Safety research over the past two decades has considerably advanced the scientific basis for safety analysis methods applicable to most types of road facilities. However, while agencies have an increased awareness of the importance of safety, and agencies continue to aspire to improve their analysis capabilities with varying degrees of success, the state of the practice in safety analysis and evaluation lags behind the state of the science. This disparity is largely due to limitations in data quality and availability. Agencies can use this Guide to proceed with the next evolutionary steps toward institutionalization of modern, improved safety management practices.

OVERVIEW OF GUIDE

The Guide is organized into six chapters followed by appendices containing related material. The following chapters present a reference for data elements to prioritize, an overview of analysis-related data uses, a walkthrough of prioritization considerations, and steps to take after prioritizing data.

The Guide first concentrates on the data that States need to support Federal safety programs. The HSIP and SHSP are familiar to State and local safety staff. States are already making changes in response to legislative requirements, and FHWA policy, for data-driven decision making in these programs. The Guide does not stop with required implementations based on policy and law. The scope includes encouraging broad consideration of safety in planning, programming, and developing projects under all highway programs.

Additionally, the Guide promotes an all-public-roads approach to safety and thus addresses the need for local data and the involvement of Metropolitan Planning Organizations (MPOs), Regional Planning Commissions (RPCs), Local Technical Assistance Programs (LTAPs), Tribal Technical Assistance Programs (TTAPs), and the local and tribal agencies that can contribute to overall data improvement.

Scope

Chapter 2 summarizes MIRE as a reference of roadway data elements and attributes that an agency could prioritize. The chapter discusses MIRE FDE, a subset of critically required data elements, and MIRE Management Information System (MIS), a system to organize and maintain data.

Chapter 3 discusses analysis applications and technical data considerations. The chapter has two sections: network-level analyses, which require a minimum level of data for all sites, and project-level analyses, which require detailed data for a few sites of interest. Figure 2 depicts the SHSP and HSIP processes and the relationship between the SHSP and HSIP.

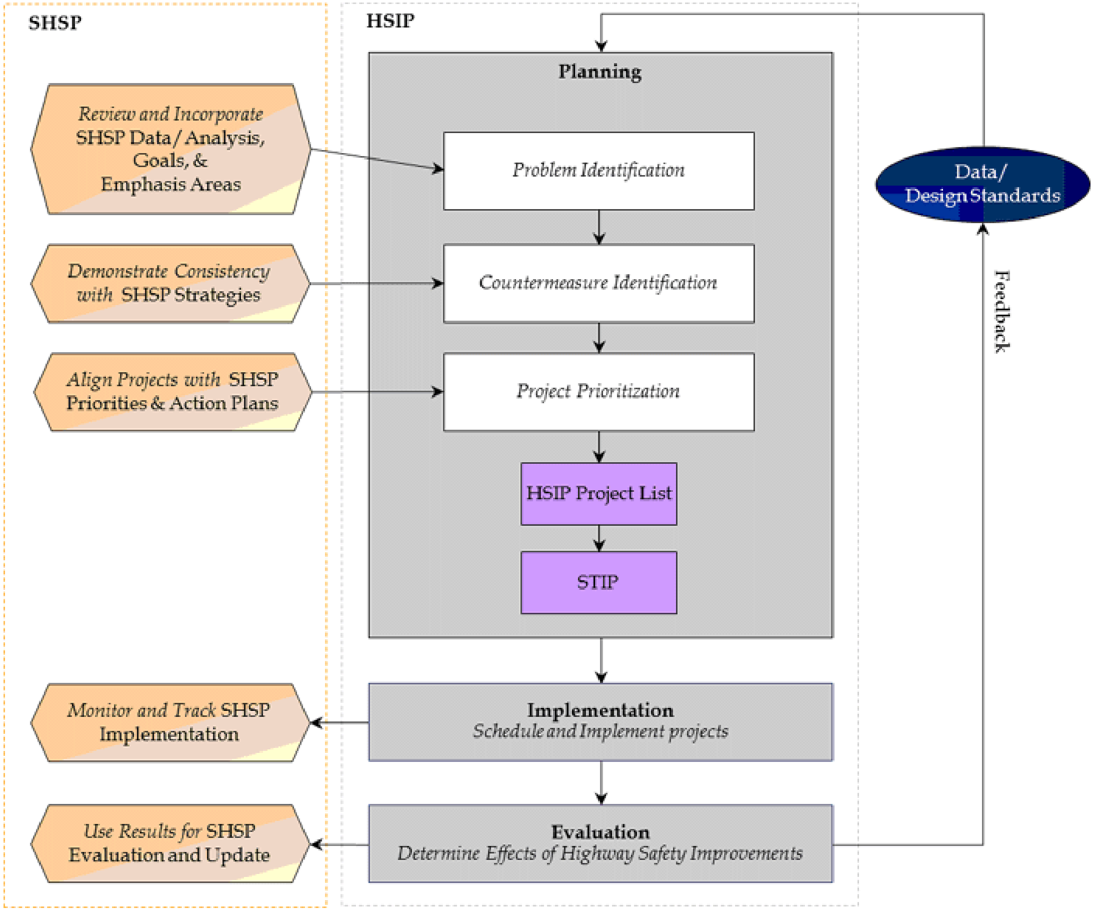


Figure 2. Graphic. SHSP and HSIP processes.[(2)]

Chapter 4 presents a process that agencies can use to prioritize roadway safety data collection. The process helps users determine the data elements and attributes of interest by identifying business needs, determining desired analysis capabilities, reviewing available data, and conducting a gap analysis. The Guide then provides details on considerations such as data usage in analyses, data-related costs, and system priorities to develop a relative priority among the selected data elements. Appendix A presents example applications of the prioritization method.

Chapter 5 discusses steps after prioritization including data management, data governance, and developing data business plans

Chapter 6 concludes with a summary of the Guide and directs readers to safety data resources.

Case studies and noteworthy practices appear throughout the Guide. Appendix B provides short summaries and links to all case studies featured in this Guide.

OBJECTIVE

Data availability and quality are key aspects of a successful data-driven safety program; however, it can be daunting to figure out where to begin with data improvement. The purpose of this guide is to provide agencies with a means to prioritize roadway safety data needs. The Guide builds upon FHWA's previous efforts in safety analysis, data quality, and data integration.

States can use this Guide as they develop strategic plans for safety data improvement. It aids with prioritizing data improvement projects incorporated into the State's Traffic Records Strategic Plan and SHSP. Those plans help make the case for funding and resources devoted to data improvement. Data improvement is a means to the end of more effective investment decision- making and ultimately, fewer fatalities and serious injuries (see Figure 1).

This Guide also helps agencies make the case for funding safety data improvement and safety analysis in the planning, programming, design, and maintenance phases of project development.

AUDIENCE

This Guide serves State and local agency staff involved with roadway and traffic data and agencies of all capability levels in safety management. Varying levels of capability are usually determined by the amount of data and statistical rigor that agencies use in analysis.

The target audience includes the following:

- State, Tribal, and local safety and traffic engineers, planners, and analysts.
- Data managers and IT staff.
- Project managers.
- Traffic Records Coordinating Committee (TRCC) members

Additional audiences include consultants, LTAPs, and TTAPs who serve the safety data collection, management, and analysis needs of State and local agencies.

CHAPTER 2—INTRODUCTION TO MIRE

This chapter provides an overview of MIRE, the MIRE FDE, and MIRE Management Information System (MIS) as resources for States considering improvements to their roadway inventory data. In October 2010, FHWA released a report entitled *Model Inventory of Roadway Elements—MIRE Version 1.0*. MIRE Version 1.0 provides a comprehensive listing of roadway and traffic elements for a robust data inventory. In 2016, FHWA finalized and released the MIRE FDE in three roadway categories: Non-Local Paved Roads, Local Paved Roads, and Unpaved Roads.

The Guide references the MIRE and MIRE FDE data definitions in the data requirements listed in later chapters. This chapter provides information so that readers can make efficient use of the MIRE resources as they work to prioritize specific data elements.(3,4,5,6)

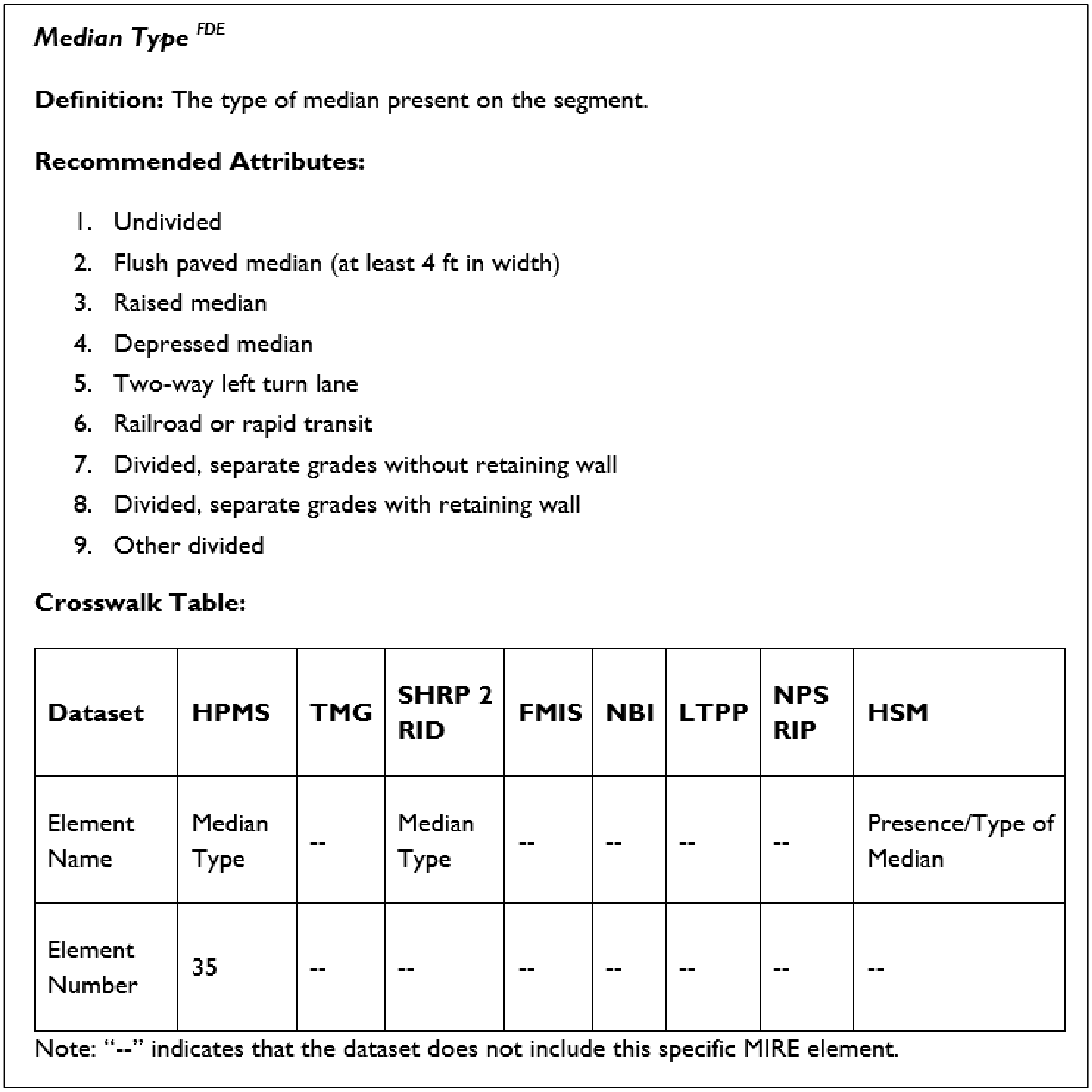
MIRE

MIRE provides a recommended listing of over 200 data elements and a data dictionary of roadway and traffic data elements that support State and local DOTs' safety management efforts. MIRE provides a basis for a standard data inventory. Adopting the MIRE data elements can help agencies develop performance measures, improve data quality, and track safety outcomes. The 2017 MIRE Version 2.0 has some additional elements from MIRE Version 1.0, as well as some changes to the categories and data attributes.

MIRE provides definitions and recommended attributes for each element, as well as a crosswalk to other Federal data sets and systems, shown in Figure 3. Readers are advised to check the MIRE website for additional, up-to-date information and resources.(3)

MIRE FDE

The MIRE FDE is a subset of 37 roadway and traffic elements that are required to conduct enhanced network-level safety analysis. The HSIP requires States to collect the MIRE FDE on all public roads, as listed below. Title 23 CFR, Section 924, provides the updated listing of the MIRE FDE and calculates the associated costs and benefits of collecting the MIRE FDE.(7) The MIRE FDE include elements that are critical for States to conduct enhanced network-level safety analyses to support their HSIP. Some MIRE FDE and Highway Performance Monitoring System (HPMS) full extent elements that States submit for Federal-aid highways are equivalent.



Median Type *FDE*

Definition: The type of median present on the segment.

Recommended Attributes:

1. Undivided
2. Flush paved median (at least 4 ft in width)
3. Raised median
4. Depressed median
5. Two-way left turn lane
6. Railroad or rapid transit
7. Divided, separate grades without retaining wall
8. Divided, separate grades with retaining wall
9. Other divided

Crosswalk Table:

Dataset	**HPMS**	**TMG**	**SHRP 2 RID**	**FMIS**	**NBI**	**LTPP**	**NPS RIP**	**HSM**
Element Name	Median Type	--	Median Type	--	--	--	--	Presence/Type of Median
Element Number	35	--	--	--	--	--	--	--

Note: "--" indicates that the dataset does not include this specific MIRE element.

Figure 3. Graphic. Example of a MIRE data element.(8)

The three categories are based on the functional classification and surface type of the roadway and include:

- Non-local paved roadways (37 data elements).
- Local paved roadways (9 data elements).
- Unpaved roadways (5 data elements).

Non-local paved roadways subcategories are: roadway segments, intersections, and interchange/ramps. Additional information on the MIRE FDE is available in FHWA's Guidance for State Safety Data Systems.(9)

MIRE-RELATED GUIDES AND REPORTS

There are several products related to MIRE that can accompany this Guide to inform roadway safety data priorities to help State and local agencies improve the collection, maintenance, linkage, and use of their safety data.

The *MIRE Fundamental Data Elements Cost-Benefit Estimation* report discusses the economic effectiveness of MIRE FDE data collection.(10) The Guide can assist agencies in justifying data collection of MIRE FDEs for all public roads.

The *MIRE Data Collection Guidebook* provides State and local agencies practical recommendations and methods for MIRE data collection.(11) The guidebook describes existing and emerging methodologies to collect and process roadway inventory data. For each MIRE element, the guidebook provides specific guidance on how the element may be collected. Further, the guidance includes recommended accuracy and any special considerations regarding the definition including if it is one of the MIRE FDEs. *MIRE Element Collection Mechanisms and Gap Analysis* is another source of information about the data collection process.(12) The *MIRE MIS Lead Agency Data Collection Report* documents different methods used by lead agencies to develop an intersection inventory.(13) It includes examining existing roadway data within an agency, collecting additional MIRE data, developing data collection tools, and documenting challenges faced and lessons learned.

The *Development of a Structure for a MIRE Management Information System* report summarizes the efforts of gathering MIRE data into an MIS.(14) The report discusses how to develop a conceptual structure for a MIRE MIS. The suggested MIRE MIS is a relational database that could tie into a GIS to aid in data entry, querying, and spatial analysis. Users can link the MIRE MIS with the various roadway-related databases that DOTs currently use without interfering with operational uses of these databases. For example, agencies could gather data from and interface between intersection data, bridge inspection and appraisal databases, traffic data, and so forth. The report also identifies several scenarios for implementing a safety MIS based on testing the framework using New Hampshire and Washington State safety data.

The *Performance Measures for Roadway Inventory Data* guide reviews each of the data quality performance measures defined by National Highway Traffic Safety Administration (NHTSA): timeliness, accuracy, completeness, uniformity, integration, and accessibility.(15) The guide also recommends modifications and additions to the existing NHTSA performance measures specific to the MIRE data elements.

CHAPTER 3—ANALYSIS METHODS, APPLICATIONS, AND DATA REQUIREMENTS

Transportation agencies use safety data to inform decision-making and measure safety performance. Other business areas within these agencies focus on planning, alternatives analysis, design, construction, operations, maintenance, or other functions. Safety data can support decision making in each of these areas, as safety is a factor in nearly all projects. This chapter focuses on the importance of these analytic uses when prioritizing data needs and presents a spectrum of applications for using safety data in various safety management approaches and safety analysis throughout the project development process.

The two categories in this chapter are: network-level analyses, which require a minimum level of data for all sites, and project-level analyses, which require detailed data for specific sites of interest. Network-level analysis is a planning function that agencies conduct during safety planning (including the SHSP), the crash-based roadway safety management process, and the systemic approach.

Throughout Chapter 3, the Guide summarizes various capability levels in analysis:

- **Basic** methods evaluate observed crashes and use Crash Modification Factors (CMFs) related to the observed crashes. The basic methods introduced in this Guide include assessing historical crash data, applying CMFs to observed crash frequency, and comparing relative CMF effectiveness. Note that while there may be even more “basic” methods that do not take advantage of CMFs, the decision to characterize this as a basic level is deliberate. Safety analyses that consider *only* crash frequency or severity will allow agencies to identify locations with relatively high crash counts. Agencies will select countermeasures to address the elevated crash frequencies. The CMF-based approach to countermeasure selection does not require any further information. Thus, this Guide assumes that the basic level of safety decision making can take CMFs into account so long as location-specific crash frequency is available. This reasoning applies equally well in cases where only the most serious crashes are counted (e.g., just fatal crashes, or fatal plus serious injury crashes). Agencies using a crash-frequency-only safety decision-making method are encouraged to take advantage of the CMF Clearinghouse to predict the effectiveness of safety improvement countermeasures.

- **Intermediate** safety analysis methods include the basic use of SPFs and result in the more statistically reliable predicted average number of crashes. Examples of intermediate methods and applications include SPFs based only on annual average daily traffic (AADT) or using SPFs with countermeasure CMF adjustments. This is an improvement on the basic methods because it allows decision makers to compare the site’s crash experience to a performance threshold. As with the basic method, this

Guide assumes that CMFs can be used to quantify the impacts of specific countermeasures and design alternatives.

- **Advanced** safety analysis methods result in the most statistically reliable expected average number of crashes. Advanced methods include the use of SPFs weighted with observed crashes in the empirical Bayes (EB) or full Bayes methodologies. Analysts can use the long-term expected or excess expected crash frequency for each facility type when judging if a site holds promise for safety improvement. Again, CMFs can estimate the effects of treatment alternatives. The difference between advanced and intermediate methods is that the advanced methods control for regression to the mean and other factors. This allows decision-makers to select sites, or systemic improvements, that promise the greatest crash reductions possible given the resources available.

Agencies can use this chapter as a resource for identifying their desired analysis capabilities and related considerations when prioritizing data needs. Agencies selection of analysis types is critical in determining the corresponding data requirements and their specific data needs. That list of data needs forms the basis for prioritization decisions.

NETWORK-LEVEL SAFETY ANALYSIS

Transportation agencies oversee a network of roadways and are responsible for providing safe and efficient mobility to their users. By conducting network-level safety analysis, agencies develop strategic safety improvement initiatives and plan infrastructure improvements on roads and at intersections. Network-level analysis requires data across the entire jurisdiction—a complete crash database along with geographic, geometric, and operational information on their roads and intersections. Depending on the quality and availability of data, agencies may select different capability levels of analysis—each of which has its own set of data requirements. The following sections categorize network-level analysis by SHSP and performance management, crash-based safety management, and systemic safety management approaches.

Planning and Performance Measurement

High-level planning analyses include those that support SHSPs, performance measurement, and policy development. The goal of these analyses is to identify, track, or evaluate network-wide safety issues and emerging problems. Agencies need a network-wide crash database to conduct these analyses, and should maintain at least a minimum level of roadway and traffic data for all sites to better understand the role of facility types and roadway characteristics and their relationship to crash risk. The MIRE FDE and supplemental data sets support the analyses described here.

Strategic Highway Safety Plan Development and Performance Measurement

A State's SHSP serves as a comprehensive transportation safety plan that provides strategic direction for highway safety advancement and improvement efforts. The SHSP also serves as a master resource document for other State and local safety plans. Multidisciplinary teams of subject matter experts develop SHSPs to include strategies and goals regarding engineering, enforcement, education, and emergency medical services (EMS). States then establish comprehensive performance-based highway safety programs with consistent safety goals and objectives that span many public and private agencies. FHWA's SHSP website presents additional useful information and guidance.(16)

Developing and implementing the SHSP is a data-driven process. Most States develop their SHSP using a process similar to the following:

1. Use statewide crash data to examine crash types and contributing factors that are highly represented in fatal and serious injury crashes.
2. Set SHSP emphasis areas based on the highest priority areas for the State.
3. Form multidisciplinary stakeholder groups to identify specific, achievable improvement strategies within each emphasis area for the five-year duration of the plan.
4. Set goals and performance targets within each emphasis area or for each strategy.

State, regional, local, and tribal safety data are essential to identifying and prioritizing the plan's emphasis areas (e.g., the list of safety issues where the State sees the greatest need for improvement). Analysts use experience and data to identify opportunities for improvements within each emphasis area. Using more data allows agencies to develop more targeted strategies for specific types of roads, populations, cultures, or regions.

Continuous monitoring of implementation progress through data-driven performance measures and target setting helps managers evaluate progress overall and within each emphasis area. Performance measurement also assists stakeholders in prioritizing countermeasures and future directions. The process of recurring data analysis helps States allocate resources to safety projects and initiatives that have the greatest potential for reducing fatalities and serious injuries.

Performance measures and targets help stakeholder agencies and champions effectively measure progress toward achieving the goals of the SHSP, HSIP, and other safety programs and initiatives. As required by the FAST Act and FHWA rulemaking, safety performance measures and targets should be aligned among stakeholder agencies' safety plans. Tracking performance and setting targets for each emphasis area also allows leaders, partners, and the public to understand the magnitude of the problem, the importance of implementing effective countermeasures, and stakeholder commitment. Realistic targets should be established based on the countermeasures and resources available to stakeholder agencies. The *FHWA Safety Target Setting Final Report* provides detailed guidance on establishing evidence-based targets to help States develop and update fatality targets.(17)

Collaboration is essential to the SHSP development process. The SHSP collaborative process is a potential starting point when gathering stakeholders for setting data priorities. The multidisciplinary nature of SHSP development, and the involvement of State, tribal, and local agencies, means that the selected emphasis areas and specific strategies reflect the varied concerns of all stakeholders. The prioritization process should account for the needs of all stakeholders as the team determines which data improvements to pursue and in what order.

Data to Support Strategic Highway Safety Plans

Stakeholders need data to analyze network crash trends and patterns when developing and implementing an SHSP, but the approaches to developing SHSPs vary across States. Crash, injury surveillance, roadway and traffic, vehicle, driver, enforcement, and behavioral data are pertinent to developing the SHSP. Data needs depend on data availability and the level of analysis that the agency plans to use in developing the SHSP.

The minimum data requirement for a basic analysis capability level is a network-wide crash database, which allows analysts to identify the types of crashes and contributing factors in fatal and serious injury crashes. Intermediate analysis uses roadway data to investigate what facility types or roadway characteristics are overrepresented within each emphasis area and target specific strategies on those facilities. Advanced analysis incorporates supplemental datasets, such as a horizontal curve inventory or citation database, to further diagnose and understand system-wide issues and then develop tailored strategies to address those problems. Table 1 presents a summary of the data needs for SHSP analyses.

Table 1. Analysis capabilities and data requirements for SHSP analysis and performance measurement.

Analysis Level	Crash Location and Severity	MIRE FDE	Supplemental Data
Basic (e.g., proportions of statewide crash types and contributing factors)	X		
Intermediate (e.g., consider roadway facility types where crashes are overrepresented)	X	X	
Advanced (e.g., incorporate supplemental datasets to identify targeted strategies)	X	X	X

Basic analysis explores and summarizes the crash inventory to rank high proportions of crash types and contributing factors across the State or within regions and other jurisdictions. Crash reports capture crash-related data used in these analyses. Analysts summarize the data across the State or regions. Depending on the crash data availability and quality, the data should allow States and local agencies to set data-driven emphasis areas, such as intersection crashes or pedestrian crashes. Table 2, based on a review of all State SHSPs, lists the most common crash types and contributing factors in SHSPs, as of 2016.(18)

Table 2. Most common crash types and contributing factors in SHSPs.

SHSP Crash Types and Contributing Factors
Roadway or Lane Departure
Intersections
Occupant Protection
Impaired Driving
Teen or Young Drivers
Speeding or Aggressive Driving
Pedestrians
Motorcycles
Bicycles

Data improvement is another common emphasis area in SHSPs. Establishing data improvement as an emphasis area in SHSPs formally documents the need for improvement and allows HSIP spending on data improvement projects.

Analysts should be aware of the limitations and boundaries of their crash database while interpreting trends to support safety decisions. For example, if the crash database was incomplete in certain years or certain data attributes tend to be inaccurate, analyses should try to account for those limitations in the analysis, if possible. Note each crash may include contributing factors related to multiple emphasis areas, such as an intersection crash involving an impaired driver that was not wearing a safety belt.

After selecting emphasis areas, stakeholders develop strategies to address and improve safety related to each area. The results of a basic analysis generally do not provide more information about where, when, or how the issue is prevalent. Stakeholders rely on their experience, other plans, and anecdotal evidence to select applicable strategies that target the overall problem. Stakeholders also decide how to measure their progress in each area or per strategy, which determines the data needs for calculating those performance measures.

Intermediate methods integrate roadway inventory data in the analyses to develop appropriate and achievable strategies by conducting analyses that identify the facility types, roadway characteristics, populations, or areas that are overrepresented within the overall emphasis area problem. For example, if pedestrian fatalities and serious injuries are concentrated on urban arterials, an agency could focus specific strategies on improvements for those facilities that may be more effective than generic strategies applicable to all roads. It is important to understand the magnitude of the problem, where the safety issues are occurring, and how to guide investment of resources. The MIRE FDEs include basic geometric data, geographic information, and traffic volume to assess crash trends by roadway type rather than for the network as a whole. Conventional network screening analyses with the MIRE FDE can also supplement the SHSP analyses.

The most advanced analyses involve additional supplemental data sets to provide the capability for more in-depth system diagnosis. Based on Table 2, agencies may find different data sets useful, including intersection inventories, horizontal curve inventories, pedestrian and bicycle facility inventories, citation and adjudication records, and transportation systems management and operations data. Several States are integrating multiple datasets into the State databases to bolster existing analysis. Appendix B, which provides links and information about the case studies in this Guide, contains several case studies that describe the ways that States and local agencies have developed the data resources needed for intermediate and advanced safety analysis.

Crash Characteristic Data Map Book – Arizona

In preparation for their SHSP updates, Arizona developed a detailed crash characteristic data map book. The book presents a high-level overview of crash types associated with characteristics. It also presents guidance on where efforts can be implemented to reduce crashes.(A)

The *NCHRP Report 500, Vol 21: Safety Data and Analysis in Developing Emphasis Area Plans* provides procedures for basic and higher-order safety planning and analysis used to develop emphasis areas.(19) FHWA's SHSP Community of Practice and Noteworthy Practices websites are valuable resources for developing and improving SHSPs.(18,20)

Data to Support Performance Measurement

Federal rules require some agencies to develop performance measures for various programs. The FAST Act requires States to establish safety performance targets for the following five safety performance measures:

- Number of fatalities.
- Number of serious injuries.
- Rate of fatalities per hundred million vehicle miles travelled (VMT).
- Rate of serious injuries per hundred million VMT.
- Number of non-motorized fatalities and severe injuries.

FHWA has published guidance for State and local agencies developing safety performance targets, stemming from the FHWA HSIP Performance Measure Rulemaking.(21) Most agencies supplement these measures with others that pertain to their safety improvement initiatives and emphasis areas. Agencies may also track each of these across regions or various types of roads in addition to statewide measures.

Data for safety performance measurement is essentially the same as the data needed for developing emphasis areas and strategies. At a basic level, tracking progress in reducing system-wide target crashes can provide a basic indication of success. However, it may be difficult to track performance on specific strategies when only working with a crash database. Incorporating the MIRE FDE and facility types allows for an increased level of performance tracking, where an agency could measure progress on meeting goals across each facility type or within the facility type that they have targeted with recent improvements. Additional data sets further enhance a State's ability to consider interactions, variations, and context within a sample of crashes that they could not assess with only a crash inventory.

A major consideration in safety performance measurement is integrating data across agencies so everyone within a jurisdiction can track the same measures and see the same trends and progress.

Crash-Based Approach to Roadway Safety Management

The crash-based approach to roadway safety management focuses on identifying the sites across a network with the highest potential for safety improvement, diagnosing the concerns at those sites, and implementing strategies to target those issues.

Overview of the Roadway Safety Management Process

The crash-based approach is well-defined in the FHWA HSIP Manual and AASHTO HSM Part B as the roadway safety management process and is incorporated in several software packages such as AASHTOWare Safety Analyst™, AgileAssets Safety Analyst, and Vision Zero Suite. Figure 4 depicts the roadway safety management process as outlined in the HSM.

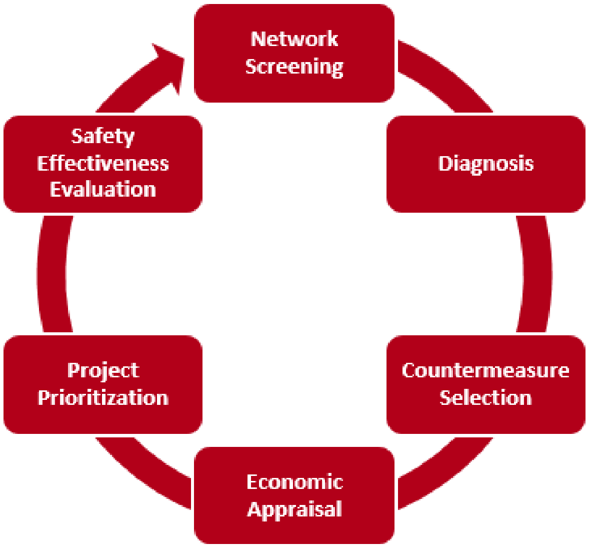


Figure 4. Graphic. Roadway safety management process.

Agencies conduct network screening to identify sites across a State or local network with potential for safety improvement. Analysts then conduct further investigation at the highest ranked sites to identify sites with potential for projects and diagnose the issues at those sites using crash summaries, road safety audits, or other similar tools. Project managers and stakeholders select the most applicable countermeasures and conduct an economic analysis of the alternatives. The agency then implements the countermeasure(s) and evaluates the effectiveness of those improvements post-construction. The outcome of the crash-based approach is projects that are well suited to address or mitigate specific safety problems at sites with a demonstrated poor safety performance.

Data to Support the Crash-Based Approach to Roadway Safety Management

Safety management involves planning-level and preliminary design-level analyses and decision-making. The goal of network screening (Step 1 in Figure 4) is to identify the sites that warrant further investigation. It does not require very detailed or precise data for every site. The subsequent steps in the process analyze the top sites from the network screening to plan and begin designing justifiable and effective projects. After projects are constructed, agencies evaluate their effectiveness (Step 6) to inform future planning and project development. Steps 2 through 6 are also network-level analyses; however, these analyses require additional data only for selected sites. It is more important to have a minimum level of relatively basic data about each site at the start of the process, and seek out additional data for the sites that are selected as candidates for further investigation and potential project implementation. Agencies should consider how to best retain additional information collected for analyzing potential project locations. The data requirements for each step assume the data for the previous steps are available. For example, in Step 2 the Guide lists the extra data needed beyond those data used in Step 1 for the same capability level.

Crash-Based Safety Management Approach Case Study – Ohio

The Ohio DOT has embraced the opportunity to integrate AASHTOWare Safety Analyst™ within its existing safety management system. The software implements analysis methods from the HSM roadway safety management process. Ohio DOT had previously made efforts to collect and maintain required data, but the Department undertook several additional data gathering efforts to improve the quality and quantity of the available data. Ohio DOT also developed tools to automate the transformation of data into the required import data set. By improving the inputs and streamlining the data translation process, Ohio DOT benefits from analysis outputs that help direct funding to areas where improvements will have the greatest impacts.(C)

Network Screening

Network screening produces a list of sites with potential for safety improvement. Agencies rank sites by a measure of safety performance to develop a manageable list of sites for further investigation. The screening performance measure can be as basic as a count of total crashes. Advanced methods use crash, roadway inventory, and traffic volume data and compare each site's safety performance to a predicted performance threshold for that type of site. Intermediate and advanced methods use safety performance functions (SPF) as a performance threshold. SPFs are functions that help analysts predict the crash frequency of a site based on traffic volumes and roadway characteristics.

Table 3 presents the data sets that analysts use in calculating common screening performance measures, listed from most basic at the top to most advanced at the bottom. The advanced methods have the advantage of controlling for bias in crash data and the selection process. Readers should bear in mind that each measure could examine overall crash risk or represent a targeted crash type or severity.

Table 3. Data used to calculate network screening performance measures.

Performance Measure	Crash	Roadway	Traffic	Other
Average Crash Frequency	X	X		
Crash Rate	X	X	X	
Equivalent Property Damage Only Average Crash Frequency	X	X		Crash Costs
Level of Service of Safety	X	X	X	SPF
Excess Predicted Average Crash Frequency Using SPFs	X	X	X	SPF
Probability of Specific Crash Types Exceeding Threshold Proportion	X	X		
Excess Proportions of Specific Crash Types	X	X		
Expected Average Crash Frequency with EB Adjustments	X	X	X	SPF
Equivalent Property Damage Only Average Crash Frequency with EB Adjustment	X	X	X	SPF
Excess Expected Average Crash Frequency with EB Adjustments	X	X	X	SPF

A State's safety data system should assign location codes for all public roadways and use those same location codes for crashes, roadway information, and traffic volumes.(9) The minimum requirement for basic network screening is crashes locatable on the roadway network. Integrating crash and roadway data is accomplished using geolocated crash data and roadway data on a shared linear referencing system. Integrated crash and roadway data allows an analyst to identify locations with high concentrations of crashes using some form of linear or geospatial analysis.

An intermediate-level network screening analysis would include at least the MIRE FDE to allow screening by facility types. The MIRE FDE is basic site-level data and information about the site's facility type. The MIRE FDE is required for network screening using SPFs for analysis, which is critical to implementing a predictive analysis method. Intermediate-level analysis also should factor in crash severity to focus the analysis on safety performance measures.

Advanced network screening analysis uses expected crash frequency to measure performance, and may include roadway inventory elements beyond the MIRE FDE, such as a horizontal curve inventory or pedestrian facility database, to focus the screening even more on the crash types, facility types, and sites that are a high priority. *Reliability of Safety Management Methods: Network Screening* presents a justification for using advanced network screening methods and examines the worthiness of several network screening performance measures.(22)

Diagnosis

Diagnosis is the process of further investigating the sites identified in network screening to identify specific safety concerns and contributing factors at potential project sites. Basic diagnosis involves a traditional engineering study, including an office-based review of crash data, such as crash report documents, summary statistics, and collision diagrams. Intermediate diagnosis capability builds on basic analysis with a multidisciplinary team field study and road safety audit to observe site conditions and road user behaviors to identify underlying contributing factors that may not be obvious from the crash data alone. Incorporating human factors considerations with guidelines from *NCHRP Report 600: Human Factors Guidelines for Road Systems, Second Edition* and similar resources can further improve diagnostic capabilities.(23) Advanced-level diagnosis incorporates statistical methods to focus the diagnosis. For example, analysts can use crash data and MIRE FDE to develop statewide or regional average proportions of certain crash characteristics by facility type to compare the candidate site to baseline thresholds and identify safety problems or target crash types. The *Reliability of Safety Management Methods: Diagnosis* information guide describes advanced methods to support diagnosis.(24)

Countermeasure Selection

Following diagnosis, agencies select potential treatments (engineering-related or other) for each site of interest. Appropriate countermeasures target the underlying contributing factors identified in the diagnosis. Data used in countermeasure selection include crash data, budget and other program data, stakeholder input, and project-related factors (e.g., costs and environmental and right-of-way needs). Intermediate practice involves a list of common or preferred countermeasures by facility type along with preselected CMFs for those treatments. A standard countermeasure or CMF list promotes consistency and saves time in analysis. The *Developing a State CMF List* flyer provides guidance in developing lists of standard CMFs for an agency.(25) The CMF Clearinghouse is the most comprehensive source of CMFs and CMF-related knowledge. Although not current practice, recent research shows that States may need to calibrate CMFs to improve their accuracy for local application; however, several States have explored developing their own CMFs, rather than calibrating the published values.(26) Developing State-specific CMFs or calibrating national CMFs defines an advanced capability level.

The data needs for countermeasure selection focus on countermeasure feasibility (e.g., what improvements would work well at the site) and countermeasure effectiveness (i.e., inputs for specific CMFs). For example, if the diagnosis for an intersection showed a high proportion of left-turn crashes, the countermeasure selection stage might require data to conduct a signal warrant analysis. It is most cost-effective for agencies to collect this type of data on a project-by-project basis rather than for the entire network of sites. The *Reliability of Safety Management Methods: Countermeasure Selection* information guide describes various methods to support countermeasure selection.(27)

Economic Appraisal

Economic appraisal compares the relative benefits and costs of proposed alternatives or treatments. Analysts usually express benefits as the dollar value of the estimated lives saved as well as other injuries and property damage avoided (e.g., based on a CMF). Costs may include construction costs, maintenance costs, right-of-way acquisitions, and other costs incurred due to implementing the treatment. Common economic measures include benefit-cost (B/C) ratio, net present value, and cost-effectiveness. Economic analysis also allows project managers and designers to develop project budgets to maintain economic justification for safety improvement with known countermeasures and desired B/C ratio.

Data required to support economic appraisal include an estimate of the change in crashes by crash frequency and severity (converted to costs), projected construction and maintenance costs, and countermeasure service life. Agencies can compile lists of typical countermeasure costs, service life, and construction duration to standardize this step across their jurisdiction. Project costs should include the initial construction cost as well as costs for additional maintenance and rehabilitation activities incurred as a result of the project over the service life or analysis period. Benefits are the monetized crash reduction resulting from a countermeasure installation, usually with CMFs, using standard crash costs.

Economic appraisal is useful for project comparison and prioritization. Some potential countermeasures may not be justified from a safety perspective, nor is it always feasible, practical, or desirable to implement all economically justified countermeasures at a site. It is necessary to estimate the cost and expected benefits of each potential countermeasure and project to determine whether each strategy is justifiable.

Project Prioritization

Project prioritization results in an optimized portfolio of projects for a given budget. Agencies have different processes for prioritizing projects. Even within safety programs, safety benefits are usually not the only decision factor. Rankings based in part on project costs, safety benefits, project risk, project readiness, agency goals and performance targets, public perception and acceptance, and political influence, among others, can maximize the B/C ratio of the overall program for a given available budget.

Safety Effectiveness Evaluation

Agencies conduct safety effectiveness evaluation to quantify the actual safety benefits achieved from project implementation (e.g. a reduction in fatal and serious injury left-turn crashes). The evaluation provides critical feedback for future planning. Agencies can and should conduct evaluations at the project, countermeasure, and program levels.

The objective of project-level evaluation is to quantify the safety effectiveness of individual projects. For example, a project-level evaluation could analyze the safety impacts of a roundabout implementation project. Countermeasure-level evaluations focus on many installations of the same countermeasure across multiple sites to better estimate the effectiveness of installing that treatment in the future. For instance, a countermeasure-level analysis could determine the average safety effect of all roundabout installations across a State. These types of evaluations are useful in CMF development.

Project- and countermeasure-level evaluations have similar data requirements and capability levels. Basic analyses include simple before-after comparisons of observed crashes with no control for traffic volume, changes over time, or regression to the mean. Intermediate analyses incorporate comparison groups that begin to account for traffic volume and general changes over time, but would still not control for regression to the mean. Intermediate analyses may also look at changes in target crash types rather than the effect on total crashes. Advanced analyses fully account for traffic volume, changes over time, and regression to the mean as well as changes in target crash types. Examples of advanced safety effectiveness evaluation methods include empirical or full Bayesian methods.

Roadway data requirements for all evaluations include construction dates, implemented countermeasure locations, actual project costs, and estimated service life. Agencies also need crash frequency of targeted crash types before and after the countermeasure implementation. Intermediate and advanced analyses require information about other similar sites with and without the selected countermeasure. Advanced analyses require SPFs.

Empirical Bayes Analysis – Wisconsin

Wisconsin DOT developed a project evaluation process incorporating EB analysis into all HSIP project evaluations using the network-level SPFs from the AASHTOWare Safety Analyst™ software. Results from implementing the EB method for B/C analysis showed how a simple before-after evaluation can overestimate the safety benefits of a project.(B)

The objective of program-level evaluation is to determine the overall benefit or effectiveness of an entire safety program or a group of projects sharing a common focus or emphasis. Program evaluation could cover all similar projects within a program such as those focusing on intersections, roadway departure, or pedestrian safety. The goal of these analyses is to quantify the impact of the program on performance measures and the overall return on investment in projects. Additionally, an agency may use program-level evaluation to assess progress toward meeting specific performance goals in safety emphasis areas. For example, it may be appropriate to compare the number and cost of safety improvement projects targeting roadway departure to the number and trend in roadway departure crashes, injuries, and fatalities. Agencies can use this type of information in performance measurement and target setting.

Basic evaluations of an entire program can be somewhat simpler and compare all expenditures and benefits. The primary requirement is a list of the projects, costs (preferably by year), and benefits. Advanced program analyses use expected benefits calculated with more statistically rigorous methods. Evaluations may also focus on subsets of projects within a program that address each emphasis area, which requires agencies to designate each project with one or more program emphasis areas.

The *HSIP Evaluation Guide* and *Reliability of Safety Management Methods: Safety Effectiveness Evaluation* informational guide provide more detailed information about evaluation methodologies.(28,29) The *Recommended Protocols for Developing Crash Modification Factors* guide and *Guide to Developing Quality Crash Modification Factors* are useful references for countermeasure evaluations and CMF development.(30,31)

Table 4 summarizes the data needed to support most applications of the crash-based approach.

Table 4. Data to support the crash-based approach.

Component	Crash	Exposure	Roadway	Other
Network Screening	Crash counts by severity at the site level (intersections and segments)	Traffic volume and segment length	Area type (rural or urban), number of lanes, median type, intersection control, and number of legs	Safety performance functions (SPFs) or other thresholds by facility type
Diagnosis	Three to five years of police crash reports and details for each location	Traffic volume and turning movement counts	Traffic operations, roadway design, and roadside design features	Adjacent land use, road user behavior, and road user demographics
Countermeasure Selection	Three to five years of police crash reports and details for each location	Traffic volume and turning movement counts	Traffic operations, roadway design, and roadside design features	List of crash contributing factors and countermeasure details
Economic Appraisal	Expected change in crashes due to treatment	Current and future traffic volume	Site characteristics to identify suitable crash modification factors (CMFs)	Applicable CMFs, average crash costs, and service life of treatment
Safety Effectiveness Evaluation	Crash counts by severity before and after treatment for each site	Traffic volume before and after treatment for each site	Site characteristics to define a suitable reference group or comparison group	Treatment details, including location and implementation date; SPFs

Systemic Approach to Roadway Safety Management

The systemic approach targets system-wide safety problems and aims to implement countermeasures across the network to address those specific concerns. FHWA's Systemic

Safety Project Selection Tool (SSPST) presents one version of systemic safety analysis.(32) Other data-driven systemic safety analysis methods are implemented within software tools such as usRAP and AASHTOWare Safety Analyst™. Figure 5 shows the systemic process employed in the SSPST.

Figure 5. Graphic. Systemic project selection process. (32)

Practitioners have mostly followed the SSPST methodology shown in Figure 5 when implementing systemic safety improvement projects. The systemic project selection process follows a similar flow to the crash-based safety management process. An agency identifies focus crash types or common geometric and operational characteristics associated with higher crashes across the network, screens and selects candidate locations, and selects countermeasures to address roads with those characteristics. Alternatively, agencies may start with a countermeasure they want to implement (to address a specific crash type), and then determine the most appropriate locations to apply that countermeasure.

Agencies often use the systemic approach to address rural safety concerns where fatal and serious injury crashes are sparsely located or when crash and traffic volume data are not available. However, analysts may build upon this approach by incorporating site-based crash or exposure thresholds when the data is available to enhance the systemic analysis. Incorporating crash and exposure data reduces project risk and focuses investments on sites with the highest potential for crash reduction.

Funding Systemic Improvements – New Mexico

New Mexico identified proven countermeasures to streamline the wide implementation of cost-effective safety improvements on rural roads. Implementing this approach, the State applied low-cost systematic improvements to locations that might not otherwise have received funding in a crash-based approach due to their crash history.(D)

All systemic analyses begin with a system diagnosis in some form or another. Often, analysts look at system-wide crashes (or for a network or corridor) to identify focus crash types. Other times the process may start with selecting a countermeasure, and in this case it is likely that an agency already performed a system diagnosis (e.g., for the SHSP) or the countermeasure addresses a known priority safety issue such as roadway departure, intersection safety, or safety for pedestrians and bicyclists.

As with the crash-based approach, agencies should evaluate the safety and economic effectiveness of systemic projects post-construction. Systemic projects require data about more locations due to the wider implementation, so the evaluation can be more complex. However, the data requirements for the evaluations are the same for all projects.

Ultimately, the systemic approach results in projects well suited to improve high priority emphasis area safety problems across the network. The *Reliability of Safety Management Methods: Systemic Safety Programs* guide provides more details about systemic analysis approaches and suggests methods for balancing crash-based and systemic projects within improvement programs.(33)

Data to Support the Systemic Approach to Roadway Safety Management

The data requirements for systemic safety analyses vary depending on the level of sophistication a State or local agency adopts in their approach to analysis and decision-making, although some steps are common to all methods. The following discussion focuses on the analysis that is unique to systemic analysis.

System Safety Project Selection Tool – New York

The New York State DOT used the SSPST to identify locations that would benefit from deploying low-cost countermeasures. New York State DOT combined crash data with roadway inventory data to develop a crash tree diagram assessment of rural vs. urban, number of lanes, a divided or undivided indicator, and posted speed limit, which resulted in a focus facility type for systemic improvements. The crash and roadway inventory data was then used to select risk factors for the selected facility type.(E)

The data requirements for system diagnosis and selecting focus crash types are comparable to those for the SHSP emphasis areas analyses. Analysts should consider crash types that constitute a high proportion of fatal and serious injury crashes across the system or network. Tools such as crash summaries, crash tree diagrams (like the one shown in Figure 6), and crash distributions identify crash types that have disproportionately high number of crashes across the network or for a single facility type of interest. High-quality detailed site-level data is not required for this step. Incorporating the MIRE FDE and other supplemental datasets can help to hone not only the focus crash types and characteristics of the problem but also the best locations to implement the improvements.

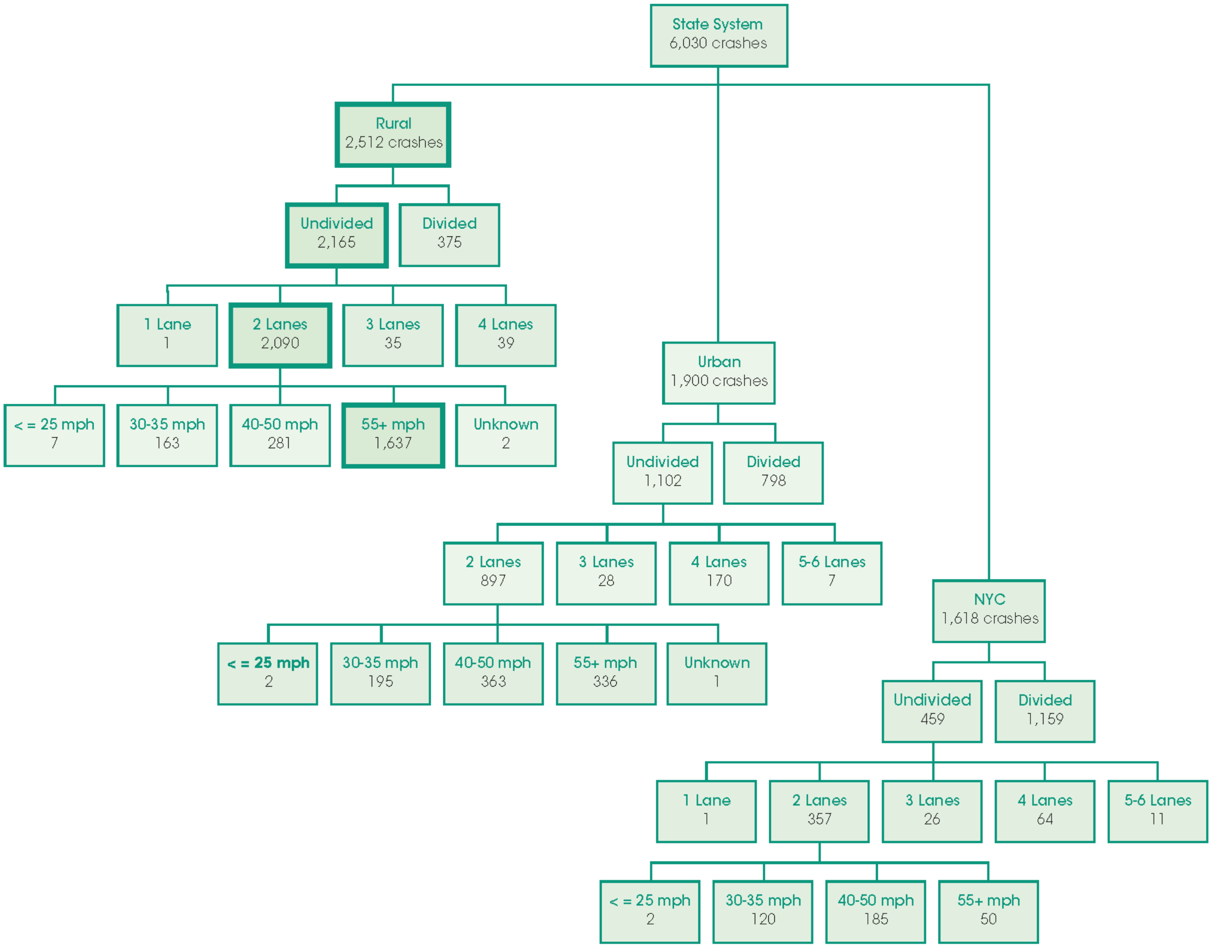


Figure 6. Chart. Example crash tree diagram for a State.(32)

Countermeasure selection in the systemic approach is based on system needs rather than a site-specific diagnosis, although some site-level review is necessary to ensure the countermeasures are appropriate. Figure 7 shows an example crash type distribution of 1200 crashes across intersections within a municipality. By identifying that turning maneuvers and rear end account for most crashes, an agency can select appropriate countermeasures to address those crashes. Typically, agencies favor lower unit cost countermeasures in the systemic approach so the agency can install the treatments across many sites. Selecting implementation sites with the highest B/C ratio can result in the highest economic effectiveness for the available budget.

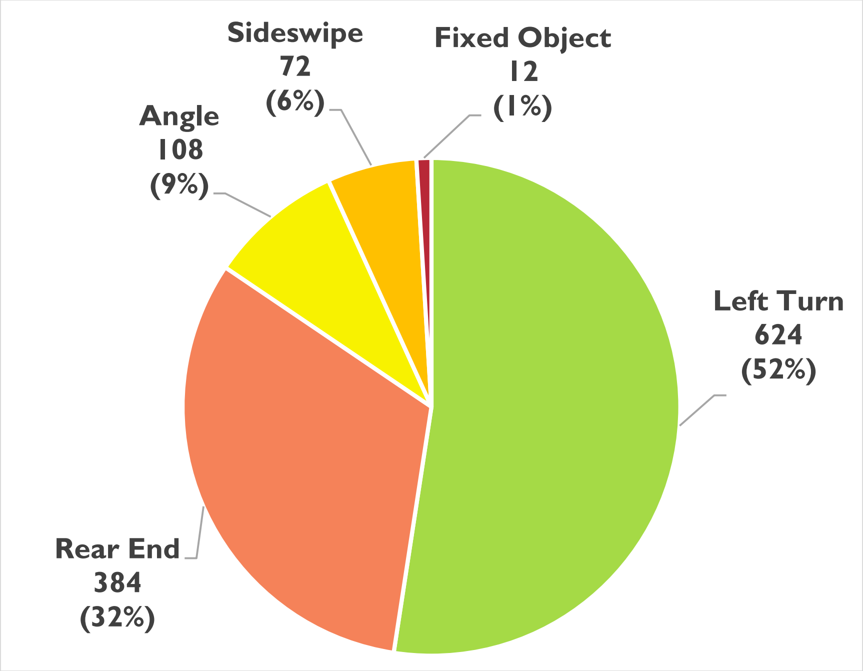


Figure 7. Chart. Example intersection crash type distribution for a municipality.(34)

Systemic evaluations abide by the same economic analysis, prioritization, and effectiveness evaluation methods and data requirements as site-specific projects. Agencies should try to collect implemented project and countermeasure data during project development and construction. In contrast to crash-based projects where it is clear what site the project was at, it is more important for agencies to track the locations of systemic projects during project development and implementation because it is more difficult to identify potentially hundreds or thousands of implementation locations throughout the State across multiple years. The State must have information on previously implemented improvement sites when deciding where to go next.

Data to Support Network-Level SPF Development and Calibration

Agencies typically develop network-level SPFs to model safety performance of facilities at a planning-level for network screening or to answer a specific question regarding policy or crash occurrence. Agencies characteristically develop network-level SPFs, using length and exposure as independent variables, for each facility type. That is, States most often develop separate SPFs for two-lane rural roads, urban interstates, and so on. The MIRE FDE represent the roadway data needs for developing network-level SPFs, including traffic volumes, that accompany a crash database with crash location information. Analysts develop SPFs using as many sites as possible to assure statistically significant results across all roadways and characteristics that are present within the network. Agencies may choose to develop their own SPFs or to calibrate previously published SPFs (e.g., from national resources). SPF development and calibration have the same data requirements; however, the data sample necessary for calibration is smaller than that used to develop SPFs from scratch. Agencies can use *The Calibrator* spreadsheet tool to calibrate SPFs and assess SPF compatibility and applicability.(35)

Summary of Network-level Safety Analysis

Network-level analysis is enabled by the breadth of data available about all sites across a network. Analysts need to be able to understand the crash types most prevalent across a network and to compare potential project locations to other similar sites within a network to identify the relative potential for improvement. As agencies conduct site-level diagnosis and begin to develop projects, their analyses require more data specific to the candidate site that are not needed for planning-level network screening. Ideally, as agencies collect site-level data they should save that data within a database for future evaluation of the implemented improvement. Agencies could use such a database to capture detailed site characteristics that they could use later in project-level analysis, as well as field notes and other observations that may be useful later.

Generally, for States with an all-public roads common highway base map, the basic network-level analyses require a crash data set. Intermediate-level analyses incorporate roadway and traffic data included in the MIRE FDE. Advanced analyses allow more flexibility and complexity in the analysis by factoring in other supplemental data sets such as a broader list of roadway inventory elements and other data.

PROJECT-LEVEL SAFETY ANALYSIS

The objective of project-level safety analyses is to examine the safety performance of site or project conditions and to optimize the safety of roadway designs. As an agency considers constructing a project, designing a project, or evaluating the effects of projects, project-level safety analyses help inform their decision-making and ultimately allow agencies to deliver better, more defensible, projects. Figure 8 depicts the project development process divided into sections that relate to various types of analyses.

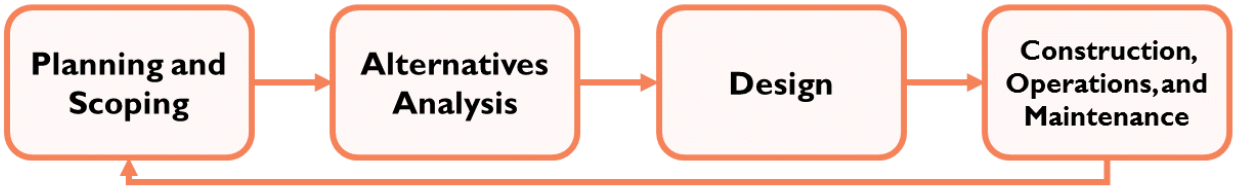


Figure 8. Graphic. Project development process.

Project-level analysis applications typically consist of predicting the safety performance in planning, alternatives analysis, design, and through construction, operations, and maintenance. Agencies interested in quantifying safety performance at an existing or proposed site can use SPFs and CMFs to calculate the predicted or expected safety performance for the geometric and operational characteristics of that site. Project-level SPFs are more complex than network-level SPFs, allowing for more comprehensive insight into the factors affecting safety. This helps designers understand the implications of design decisions and project managers to best communicate project effectiveness to stakeholders. Project-level analysis can also compare multiple alternatives to understand the tradeoffs in proposed designs. Finally, designers can use project-level analysis tools to optimize the design with quantitative means. *Integration of Safety in the Project Development Process and Beyond: A Context Sensitive Approach* and *Integrating the HSM into the Highway Project Development Process* provide many additional insights for agencies interested in safety analysis in the project development process.(35,37) The *Scale and Scope of Safety Assessment Methods in the Project Development Process* informational guide suggests safety assessment methods that may be suitable for answering safety performance-related questions that typically during each phase of the development process and for projects of various types.(38)

Several tools are available to analysts working with project-level safety analyses. HSM Part C is a resource for understanding the predictive method and provides SPFs and CMF adjustment factors for analyzing rural two-lane roads, rural multilane roads, urban and suburban arterials, freeways, and interchange ramps. HSM spreadsheets implement the SPF equations and process to organize and simplify the calculations for Chapters 10-12 and 18-19 of the HSM. The enhanced Interchange Safety Analysis Tool is a spreadsheet tool that implements the freeways and interchange ramp analysis methods. The IHSDM is a software application that faithfully implements the HSM Part C methods along with other design tools related to geometrics and operations. Other research through the National Cooperative Highway Research Program, State DOT research offices, and universities has developed SPFs and related analysis tools that are available when limitations in the HSM preclude conducting analysis. States have the option to develop their own SPFs and CMFs if published ones from other jurisdictions are not suitable. The *Summary of State SPF Calibration and Development Efforts* spreadsheet lists State-developed SPFs and States' SPF calibration factors.(39)

Sometimes agencies use only CMFs when complex analyses are not appropriate or other tools are not available. HSM Part D and the CMF Clearinghouse provide a wealth of CMF information that analysts may use for estimating changes in safety performance.

Project-level safety analysis requires data in two ways. SPF development and calibration procedures require detailed geometric and operational data for a sample of sites. Applying the predictive method in project development to assess the safety performance of standalone designs or to compare sites or designs of different facility types requires calibrated SPFs and detailed data inputs only for the project locations. Some analyses do not require calibrated

SPFs. Given these requirements, it is not necessary or prudent to collect this data for all sites across a network. Planners, designers, and safety analysts should compile data as projects enter the project development process, and agencies should build SPF data as the need arises and calibrate SPFs regularly.

Data to Support Project-Level SPF Development and Calibration

SPFs are an essential tool for project-level safety analyses. Most SPF development research uses data from a handful of States for a certain period, and there are issues introduced when transferring these equations to other States or jurisdictions. Calibration allows analysts to apply SPFs to jurisdictions and time periods not reflected in the modeling data set. Rather than calibrating SPFs from other jurisdictions, some agencies elect to develop their own SPFs with data from their jurisdiction.

A common question is whether agencies should calibrate or develop SPFs. In a way, this question is misleading. Agencies must calibrate SPFs regardless of whether the agency uses SPFs from other jurisdictions or they develop their own. The important consideration is whether SPFs from other areas are acceptable or if developing SPFs is necessary. There is more discussion on this topic in the *Safety Performance Function Decision Guide: SPF Calibration vs SPF Development.*(40)

The SPF equations serve as a baseline estimate of safety performance against which analysts may compare specific project sites. Developing and calibrating SPFs is the only function within project-level analysis that requires data for more sites than the candidate project location does, and therefore requires a substantial investment to collect, manage, and analyze that data. This is the largest need for data collection within project-level safety analysis. The data requirements to apply these tools are specific to the project, and the data are often already readily available or easy to collect as part of normal design practices. As with network-level analysis, agencies only need data to develop or calibrate SPFs for the facility types on which they plan to apply project-level SPFs.

Calibration adjusts the SPF to account for differences in several factors including crash experience, driver population, climate, culture, and crash reporting thresholds. The HSM recommends calibrating SPFs at least every two to three years. The calibration procedure requires detailed SPF data inputs for a sample of sites to calculate the predicted crashes at each site, as well as the historical crash data for the same sites. Each SPF uses a unique set of data elements. Agencies collect the necessary data for a random sample of sites to support calibration, and should maintain that data set in subsequent years. The only new data needed for future recalibration is the updated crash history and any revisions to the SPF data inputs (e.g., because of new construction) for the sample sites. More information regarding calibration is provided in the *User's Guide to Develop Highway Safety Manual Safety Performance Function Calibration Factors*.(41)

SPF development is a more flexible and exploratory process. Analysts develop SPFs for several reasons. When generally modeling safety performance of some facility type, analysts use data elements that they expect are related to the safety of the facility. In other cases, they may develop SPFs to better answer a specific question, such as determining an optimal roadway cross section for preventing roadway departure crashes of a given type of road, and limit the variables included in the model to those that help answer that question. More information is provided in the *Safety Performance Function Development Guide: Developing Jurisdiction-specific SPFs*.(42)

Data for Applying Project-Level Analysis

Data requirements for applying predictive methods in project-level analyses range from relatively basic geometric and operational data to finite details of project designs. However, the data are only required for each specific project location. As planners, designers, and analysts work on a project, they already collect and compile much of the needed data inputs through their normal processes (or the data needed to calculate the required inputs). The other data inputs may require special data collection. It is not necessary to undertake a region-wide data collection effort for this amount of data for each site across the network when agencies analyze so few sites with project-level safety analysis. IHSDM allow users to import much of the data for a project from civil design software.

The following subsections present some of the common analysis types and the data-related considerations for each.

Planning and Scoping

Analysts can apply project-level safety analysis tools during planning and scoping to identify which roadways aren't performing as they should, determine the scope and need of potential projects, and prioritize them. Project-level safety analysis can improve decision making for all highway projects early on in project development.

Interactive Highway Safety Manual Software – Idaho

Idaho used the IHSDM software's Crash Prediction and Policy Review modules to evaluate the safety and operational effects of existing traffic and roadway geometry on an 11-mile section of a corridor. The analysis resulted in a list of geometric deficiencies and specific locations needing further improvement. The project also resulted in a Corridor Plan Report to be included in the Statewide Transportation Improvement Program for future implementation.(F)

Alternatives Analysis

Nearly every project has multiple alternatives that planners or designers consider at an early stage in the project development process. Project-level analysis provides an opportunity for agencies to compare design alternatives from a safety perspective in a quantitative manner. Agencies can predict the number and severity of crashes for multiple design options at once, and then compare them side-by-side.

Highway Safety Manual Predictive Method – Florida

Florida used the HSM predictive method to analyze alternatives for a corridor widening project on an urban arterial in the Tampa area. Based on the analysis results, Florida was able to determine that a four-lane divided alternative was predicted to have a crash cost savings of approximately $4.2 million, in comparison to an alternative with five-lanes and a two-way left-turn lane. This further justified additional costs associated with right of way for the project.(G)

Design

Agencies can use project-level safety analysis to determine optimal design criteria, considering safety and cost. Applications in design phase can include evaluating design exceptions and incorporating performance-based practical design into traditional design analysis. For example, project-level analysis could indicate the optimal cross section when repainting centerlines and edgelines on rural roads by using SPFs to minimize the crash frequency on an average section.

Many agencies have seen value in using project-level safety analysis for justifying design exceptions. Design exceptions are situations where an agency seeks to build a roadway in a way that differs from existing design standards. Analysts can assess specific design parameters to evaluate their impacts on the proposed design. Rather than standards-based or subjective means of justifying design exceptions, project-level safety analyses provide a more quantifiable, defensible, and reliable means of evaluating design solutions. Agencies have demonstrated significant cost savings as a result of these practices.

Safety Analysis in Project Development – Louisiana

The Louisiana Department of Transportation and Development implemented safety practices into the project development process, resulting in a safety focus from the beginning of a project's life. Louisiana's designers and engineers use crash data, the CMF Clearinghouse, and B/C analysis to select the alternative with the highest return on investment. An alternatives analysis with the IHSDM software led to design exception that justified a low-cost countermeasure instead of a costly curve straightening project on Interstate 10. They've also integrated safety into maintenance and work zone safety.(H)

Construction, Operations, and Maintenance

Agencies can also apply project-level safety analysis later in the project development process. Detailed analyses can help maximize the safety performance of traffic control plans during construction or work zone designs and operations. After construction, agencies can use safety analysis tools to help monitor how the project is operating, comparing safety performance to what was predicted and then refining the tools for future use. Agencies can also use safety analysis tools to identify future maintenance needs. Information collected during maintenance efforts can benefit future project-level safety analysis for other projects.

Maintenance Teams Support HSIP – Arkansas and Arizona

Arkansas DOT recognized the extensive knowledge maintenance staff has of the roadways and now uses these crews to analyze crash sites and recommend next steps for addressing related safety issues. Similarly, Arizona DOT Engineering districts use maintenance records to identify potential safety concerns if specific sites are repeatedly being reported for maintenance.(I)

IMPLEMENTING SAFETY ANALYSIS THROUGHOUT THE PROJECT DEVELOPMENT PROCESS

The preceding sections of this chapter address the situation where an agency develops safety improvement projects that they select and plan with safety analyses. The same analyses are applicable to other types of projects, such as those for condition improvement (i.e., pavement rehabilitation), capacity and operational improvements, and economic development.

Agencies make safety decisions during planning and design, although the safety implications of the choices may not be explicitly recognized. Quantitative safety analyses allow planners and designers to use data to drive safety decisions. Regardless of the project's purpose, agencies can predict the anticipated number and severity of crashes based on the SPF specific to that facility type and apply any relevant CMFs to raise or lower the expected crash counts accordingly.

Agencies can analyze projects to distinguish which produce a project with better anticipated safety performance, in the same way that agencies currently quantitatively analyze the impacts of cost, environmental factors, right-of-way, asset condition and maintenance, operations, and other considerations. These analyses can occur in planning to weigh safety in programming decisions for all projects or later in project development to drive more defensible design decisions.

The application of project-level safety analysis to justifying design exceptions on all types of projects is also valuable to the credibility of the process. Agencies can use safety analysis to optimize the design, considering both safety and cost. Planners, project managers, and maintainers can also better consider the complete life cycle costs and benefits of all projects to improve their stewardship of public resources and funding.

CHAPTER 4—PRIORITIZING DATA ELEMENTS

This Guide will help agencies prioritize data needs for safety planning and program management as well as in the broader consideration of safety in all highway programs and projects. While safety improvement programs may be a more familiar domain for State and local safety staff, projects in the HSIP are not the only projects that address or influence safety. There is a much greater level of investment in projects under other programs. The consideration of safety in all highway projects is essential to reach the goals of achieving a significant reduction in fatalities and serious injuries.

The overall prioritization process begins with identifying business needs and a gap analysis of available and required data elements. Users will prioritize the subset of target data elements based on many factors and preferences including data requirements for desired analyses, funding considerations, regional and jurisdictional considerations, and potential for data sharing. Agencies can set priorities for data collection efforts as well as data elements that they should maintain at a high quality. These considerations fit within a data governance framework in which subject matter experts, data providers, data managers, and IT staff work together to define data needs, set data standards, and, ultimately, establish data priorities.

Agencies should consider all information available to them when prioritizing data needs. Appendix A presents two example applications of the prioritization method presented below with varying levels of existing data, desired capabilities, and complexity.

IDENTIFYING DATA TO PRIORITIZE

The beginning steps of the prioritization process formulate the subset of data sets or elements that support the agency's business needs and desired analysis capabilities. It is not necessary to prioritize all potential data; rather, it is best to determine realistic priorities commensurate with an agency's goals and resource constraints. MIRE is a helpful resource for agencies in identifying potentially useful data elements and their importance in analysis, as well as developing their own dictionary of roadway elements.

Figure 9 presents the prioritization process. The first four steps prepare for prioritization in the fifth step.

Figure 9. Flow chart. Data prioritization process.

Step 1: Define Business Needs

The first step of the process is to define the agency or organization's current and future business needs. A business needs analysis should document and map out business functions in terms of users and services they provide. The later steps in the prioritization process will benefit from a complete business needs analysis of safety, asset management, planning, design, operations, and other areas that would potentially use safety data (although focusing solely on safety program needs may be appropriate for some agencies).

Agencies can define business needs in several ways. A straightforward method is to first list the business areas and types of data users across the organization. Agencies can define business areas by the various bureaus or sections within their agency, or by the needs of each highway program that the agency supports. Then, work with each business area or user group to identify how they use (or potentially could use) safety data to perform the job functions they are already doing, as well as what safety data they would need to better incorporate safety into their business practices.

Agencies can use the following process to document future business needs:

1. Determine why a change to existing processes is necessary.
2. Explain the problems that changing existing practices will solve.
3. Define the goals for implementing the change.
4. Outline the expected outcomes and benefits to all users from the change.

By working through these steps, managers should have a complete understanding of the business needs and justification for improving data to support a change in business processes.

From a safety perspective, agencies' existing business needs revolve around implementing SHSP emphasis area strategies and developing and implementation of the HSIP. Many agencies also have other ongoing safety initiatives within the organization. Existing safety programs are an excellent springboard for improving data and prioritizing data needs. Future business needs may represent improvements to the delivery of these programs. For example, an agency may decide to collect new data that allows them to plan more specific safety improvement strategies within an SHSP emphasis area or implement advanced project selection methods that allow an agency to spend HSIP resources more wisely.

The following are examples of safety-related business needs:

- A State is preparing for a major update to their SHSP. The State is interested in collecting additional data that may help to more effectively analyze crash patterns and trends for selecting emphasis areas, develop related strategies and goals, set realistic performance targets, and measure performance.

- A State's SHSP identifies roadway departure, intersections, and pedestrians as emphasis areas that collectively contribute to a majority of fatalities and serious injuries. A local agency is interested in collecting additional data to advance their capabilities to analyze these safety problems and more effectively develop safety improvement projects.
- A transportation agency responsible for the design of highway facilities has identified a strategic goal to integrate quantitative safety analysis into the design process and improve the expected safety performance of projects. The agency is interested in collecting and maintaining data to support the use of safety performance functions and crash modification factors in the project-level planning, alternatives analysis, and preliminary and final design phases of project development.

Generally, agencies have safety data needs in other business areas. Agencies that own roads or are responsible for highway design and maintenance have roadway safety data needs throughout planning, programming, and the project development process. Safety stakeholders and agencies responsible for non-engineering initiatives have different needs that focus on crash events and driver data. It is helpful to formalize these needs and document them to guide the rest of the process. This first step—defining the business needs—lays the groundwork for identifying a subset of data elements to prioritize in later steps.

In most States, roadway departure and intersection crashes are major roadway-related crash concerns and play a role in data prioritization. For example, in the peer exchanges following the *United States Roadway Safety Data Capabilities Assessment* in 2012, States ranked intersections and horizontal curves as the data inventories they would most like to develop.(43)

Step 2: Identify Desired Analysis Capabilities and Data Requirements

Next, given formalized business needs, stakeholders should build on the previous step by identifying as specifically as possible any analyses that an agency would like to start doing or the analyses they would like to conduct at a more advanced level. Whereas the prior step aimed at identifying general business needs and priority areas for safety data, this step should start to focus those in terms of analysis capabilities that an agency will need safety data to support or develop.

SHSPs, data plans, or program assessments often identify areas for data or analysis improvement. However, if an agency has not defined specific areas for improvement, it may help to start this step by reviewing their current analysis practices and trying to identify where there are realistic opportunities to improve. Chapter 3 presents various analysis types and levels of capability within each analysis as considerations for working through this step.

A formal, agency-wide data governance process is an ideal way to develop all the necessary documentation describing existing data assets. For agencies already engaged in formal data governance, inventories already exist or are in the planning stage. For agencies where this would be a new project starting from scratch, it may be possible to use safety data as the test case to pilot or accelerate the process. It is also possible, although not ideal, for safety practitioners to conduct the review themselves without the benefit of a data governance group or formal process. The agency may wish to seek technical assistance and involve its many stakeholders through the State's Traffic Records Coordinating Committee (TRCC), the SHSP planning group, or other existing working group dealing with safety data and decision making.

The list of desired data elements should be comprehensive and not omit data that the agency has already. Users should not leave elements off the list if a business unit is not currently prepared to make use of the information, as future needs are also important to consider. Later steps will help prioritize between maintaining existing data and collecting new elements.

In this step of identifying desired analysis capabilities and data requirements, the following are special considerations when developing new data inventories or collecting data to support the implementation of software analysis tools:

- **Developing roadway data and asset inventories:** Each type of site, asset, or data set has different data elements that pertain to it. Pedestrian and bicycle facilities, intelligent transportation systems (ITS), roadside hardware, road signs, and other assets have unique subsets of data that describe those features.

  Agencies should identify the data sets and inventories that they are interested in developing to guide the selection of elements to make up those data sets. At this stage, users should list all potential data elements that could be included in these inventories and then prioritize the data elements in a later step.

Horizontal Curve Database – Tennessee

The Tennessee DOT created a horizontal curve database with approximately 40,000 miles of roadways with curves. Tennessee DOT uses the horizontal curve database to provide quick, data-derived answers to public concerns, make data-driven decisions, quantify potential benefits from both systemic and spot improvements, and compare curves with similar characteristics to help prioritize projects.(J)

- **Developing data to support software analysis tools:** Agencies may need additional data to develop, implement, or expand implementation of software analysis tools. Every software package or tool has unique data requirements and data dictionary. Agencies implementing software tools should review the software documentation to determine the required data, optional data, data definitions, network requirements, and other data considerations such as storage, maintenance, and integration. Paying attention to this information will save time and help organize data needs. If the software implementation represents the desired analysis capabilities for the agencies, then the agency will only need to collect the data required or used by the software.

Many software tools have modules or separate functions that require different sets of data. In some cases, agencies may decide to use only some capabilities of a software tool or start with some and develop more of the capabilities over time. The list of desired data elements should encompass those elements needed to support the desired analysis capabilities.

Step 3: Catalog Available Data

The next step is to identify and catalog currently available data, where the data is stored, the responsible group or person within the organization, and the data quality. Data can be stored in many forms such as database tables, static computer files, pictures, video, or physical documents. Each of these has a varying level of accessibility and timeliness. Agencies should conduct a review of data quality, as accessible data formats are not always more timely, complete, or accurate.

Users should contact data owners to discuss data quality and accessibility. In some cases, users may not have access to the data or the data may require a usage agreement. These are important factors in prioritizing data collection and maintenance efforts.

Users may find it helpful to first look within their agency to determine the data maintained within the organization and then look outward to partners and other stakeholders to investigate their available data. All State DOTs have some existing databases including a road inventory, HPMS database, and traffic count database. State DOTs are also developing or have submitted to FHWA a linear referencing system (LRS) for the All Road Network of Linear Referenced Data. These are good places to start cataloging safety data resources. Ideally, the data catalog will expand to include information about systems that support business functions like asset management, planning, design, operations, maintenance, and other units outside of the safety office. These groups have data that are needed for some safety analyses. They also may need some of the safety data if they are going to help the agency meet a goal of considering safety throughout these multiple business processes. A common point among all these units is geographic location of sites—spatial data describing each roadway segment, intersection, and interchange. Enterprise-wide GIS with other spatial tools and databases can form the backbone for all location-based analyses and decision-making.

Step 4: Conduct Gap Analysis

Agencies should next conduct a gap analysis between the desired and available data elements to determine the subset of data elements that the agency needs to prioritize. The gap analysis will help an agency determine the elements that they need to collect and the currently available elements needing improvement. Figure 10 illustrates what a simple gap analysis may look like for basic intersection data. The intent is to map between available and desired data to identify any differences, or gaps. The gaps in this example are highlighted in Figure 10.

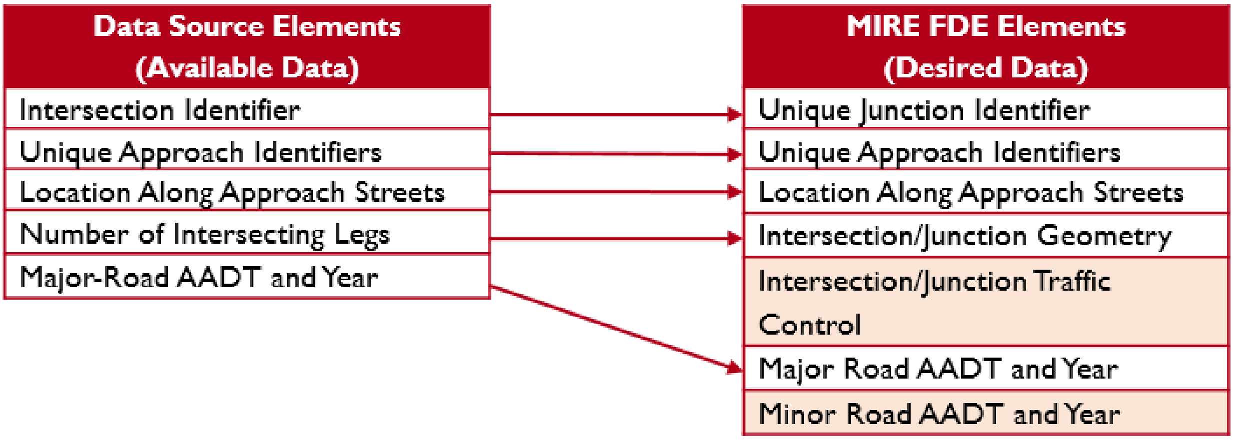


Figure 10. Graphic. Simple gap analysis example.

After determining the gaps, it is important for users to note whether each element is required, desired, optional, or otherwise potentially useful to the desired analyses. Users should also explore the optional ways to obtain the data (e.g., data collection or extraction methods) in this step. Finally, the gap analysis should note where existing data needs improvement in accuracy, timeliness, completeness, uniformity, accessibility, or integration to meet users' needs (i.e., rather than focusing solely on collecting new data).

The gap analysis results in a subset of data to prioritize.

Step 5: Prioritize Data

The final step in the prioritization process is to prioritize the data that the agency needs to collect and maintain. Agencies may decide to use numerical or relative priority ranking systems to assist in the process. Appendix A provides example prioritization scenarios that demonstrate the prioritization process and considerations that agencies may have. The following section discusses the six major considerations that affect data priority.

PRIORITIZATION CONSIDERATIONS

After an agency identifies the desired data elements, they must prioritize them. Every agency faces resource constraints and a tradeoff between using resources to improve data or support construction projects, maintenance, or other safety initiatives. Agencies can use data priorities to allocate resources on the most pressing needs. Along with data collection and maintenance costs, considerations such as data uses and potential collaboration with other agencies play a role in establishing priority. Figure 11 shows six main considerations in data priority. Depending on the agency and its specific goals and needs, some of these considerations may play a larger role in the prioritization process. The following subsections walk through these considerations and provide case studies and example scenarios to show how agencies can use these considerations to help make decisions.

Users may find it useful to prioritize based on some relative priority system, such as a five-point scale where a low priority is 1 and high priority is 5 (see Appendix A, Example 1). It is helpful to understand what elements have a similar priority and show differences in priority between other elements. An advantage to a simple scoring scheme is that it lends itself to gathering prioritization inputs from a broad spectrum of stakeholders. One possibility is that the stakeholders could meet to discuss the data needs and each person scores each candidate data element based on their individual priorities. A composite score for each data element results in a value representing the relative priority set by each group. Joint review of the outcome can resolve any concerns, such as a low score given to a business-critical data element for one business unit.

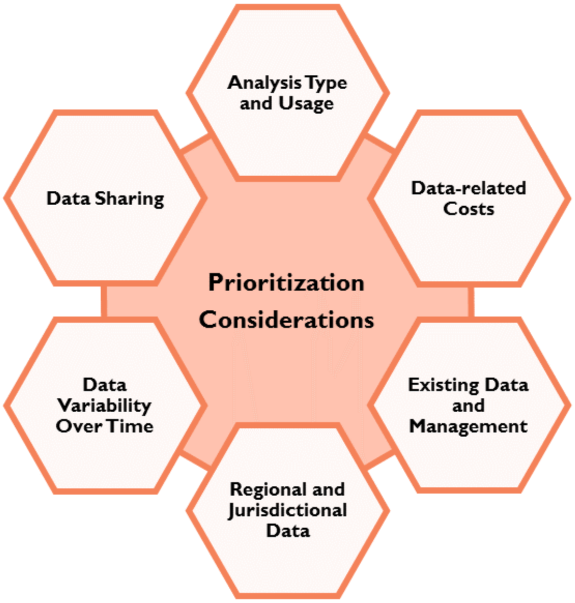


Figure 11. Graphic. Main considerations in prioritization.

The “prioritization prompts” at the beginning of each of the following subsections provide sample questions related to that prioritization consideration. Answering these questions should help users prioritize their data needs.

Prioritizing Data by Analysis Type and Usage

Prioritization prompts:

- What data are required for the type of analysis we want to perform?
- What data are not required but could improve our analyses?
- What is the purpose of collecting and using the data?
- What is the minimum level of data needed to describe an asset and its location?
- What additional elements (i.e., beyond the minimum level of data) may be useful in other applications or for partner agencies?
- What elements are more (or less) important in design and operational calculations and considerations?

The simplest and most straightforward factor in determining priority is what the desired analysis is and how the analysis uses the data elements. Agencies may value certain types of analyses more than others, and the data requirements for those analyses would be higher priority for them. Each element has varying importance within a data set, and nearly every data element is important for some analysis function. The relative importance of each element depends on what the element describes, how the analysis uses the data element, and the goals of each agency using the data. These distinctions play a large role in the priority of data elements. Each agency will need to decide what is important to them and prioritize data accordingly.

For example, one agency’s strategic goals may reflect a need to begin conducting higher-level network screening and evaluations, while another may lean toward integrating project-level analysis into design. In either case, the agency should prioritize the data requirements for those analyses above other data so that the agency can begin conducting these analyses sooner with adequate data and tools. Other factors that may influence whether an agency prioritizes certain types of analysis more than others are training, willingness, availability of the analysts or designers to implement new analyses, and how much data the agency needs to collect to support those analyses (i.e., are there only a few missing elements or is a large collection effort required).

Agencies can think about the relative importance of data in many ways. Most analysis manuals and guides have a list of required, desired, and optional data inputs, along with whether an analyst needs actual measured data or if it is acceptable to use default values. In the absence of such guidance, agencies can consider whether there is an equation or other tool that uses the data element or attribute as an input. If not, there may not be a reason to collect the data unless there is a plan to analyze the data in another way (e.g., within data summaries, performance measures, or developing new analyses).

Data elements that are required for analyses are the highest collection priority, regardless of cost, to achieve a desired capability level. Agencies may determine some data elements are desirable—not required, but have moderate priority as they may provide some helpful analysis capabilities and insights. Lower priority optional data have varying importance and may only provide minor enhancements or make tools easier to use without improving analyses.

Each agency will have a different priority for the elements needed for their desired analyses. It may be necessary to look into more detail about their impact on predicting safety performance and risk. For example, most data required in project-level analyses are used in calculating CMFs. Each CMF affects the analysis results differently, and those with a wider range of values have a greater potential to impact the analysis results and ability to describe the risk of a site. Agencies may feel more comfortable making some assumptions about data with CMFs that have a smaller variability and lesser impact on analyses.

MIRE also lists a relative priority rating for each data element. "Critical" elements are necessary for agencies to conduct basic safety management analyses. Elements ranked as "value added" are those elements that would otherwise be beneficial, provide helpful analysis capabilities, or important elements that safety analysis tools will likely use in the future but are not crucial to using current versions of such tools.

When developing new data sets and inventories that very few, if any, available tools are able to consume—such as a horizontal curve inventory—the decision of which data elements are needed is more subjective.

Using Data-Related Costs to Prioritize Data

Prioritization prompts:

- How will the data collection method affect the costs for each element?
- How will data maintenance and management requirements affect the cost?
- Is it feasible and necessary to spread data costs across multiple years to lessen the budgetary impacts?
- Is there an opportunity to share data collection costs with partners?
- How can we reduce costs by aligning data collection with other activities (e.g. new construction or hardware upgrades)?

One of the most important factors that agencies should consider is the costs and estimated level of effort for data collection and management. Resource constraints are the most common reason that agencies do not collect more data. Between data collection and data maintenance, collection usually takes the most resources and is therefore the primary cost consideration in prioritization.

Data collection includes collecting new elements, collecting new attributes for existing elements, and updating old data sets. Data collection costs are largely dependent on the data collection method and network coverage (i.e., the number of sites that need data).

The *MIRE Data Collection Guidebook* presents the following data collection methods:

- Manual Collection (“foot on ground”).
- Ground-based Imaging (with or without LiDAR).
- Aerial Imaging (with or without LiDAR).
- Data Mining.

Manual collection involves methods where data collectors visit each site to collect data. Manual collection is time consuming, susceptible to poor weather conditions, and exposes collection staff to traffic or other potentially harmful conditions, making this method relatively inefficient with higher labor costs. However, manual data collection is also highly accurate, especially for data elements requiring visual inspection or simple measurements, and typically has low costs for equipment and data reduction.

Ground-based imaging is generated from an instrumented vehicle, and data collectors use the imagery to collect various data. This method is moderately efficient, requiring skilled crews to drive the roads to get the imagery as well as a substantial data reduction and post-processing effort. Collecting ground-based imagery is inefficient in poor traffic conditions and unfavorable weather. However, data collection with this method can result in high data accuracy, especially for data elements needing visual inspection of feature presence and type (e.g., number of lanes, signs, roadside hardware and conditions, traffic control, non-motorized facilities, etc.). Ground-based imagery (e.g., Google Street View) is free or low-cost from several vendors for higher order roadways and more commonly on local roads. There is a high capital cost to obtain or contract a vehicle to collect the imagery when it is not available. Regardless of the cost of the imagery, data collection with ground-based imagery has moderately high data reduction costs.

Comprehensive Roadway Data – Utah

Utah DOT completed the first-of-its-kind data collection of the entire State roadway network using LiDAR, which created three-dimensional models of the roadways. Utah DOT used these data to develop asset inventories and as a basis for safety analyses. Ultimately, Utah DOT was able to improve data management of roadway assets and provide comprehensive data to many types of analysts.(K)

Aerial imaging methods involve gathering data from aerial photogrammetry. Data collectors work in the office, and data collection from aerial imagery can be highly efficient. Aerial imagery is free from a number of vendors, but has moderate to high costs when such imagery is not available or the quality is poor and the agency needs to buy imagery or hire a vendor to collect the imagery. Readily available aerial imagery can have tree cover, discoloration, or other issues that limit accuracy or prohibit collection. Higher level of accuracy in aerial imaging typically carries higher costs. Data collection with aerial imagery is preferable for collecting geographic location information or plan view dimensions, such as cross section widths and length of auxiliary lanes.

Data mining is the process of using readily available data to compute or extract other data elements or attributes. Highway agencies can derive new safety data from existing asset inventories, operational data, as-built plans, records, pictures, video, and other information. The level of effort and usefulness of this method depends on the existing data quality and type.

Table 5 presents a summary comparison of the various data collection methods.

These data collection methods are not mutually exclusive. In many cases, supplementing one method with another as part of a data collection program or project provides a higher level of efficiency and lower cost. Additionally, an agency could collect data quickly with one method at lower accuracy and correct errors over time with a higher accuracy method to balance costs and not wait for the highest accuracy data before conducting analyses.

Table 5. Comparison of data collection methods.

Collection Method	Efficiency	Accuracy	Capital Costs	Labor Costs	Risk to Collection Staff
Manual Methods	Low	High	Low	High	High
Ground-Based Imaging	Moderate	High	Varies	Moderate	Moderate
Aerial Imaging	High	Moderate	Varies	Moderate	Low
Data Mining	High	Moderate	Low	Varies	Low

Agencies can consider whether it is reasonable to use data mining along with various assumptions about certain elements to generate a baseline of data, which future data collection could improve upon. For example, determining intersection traffic control is difficult without ground-based imagery or foot on ground data collection. If an agency has an inventory of traffic signals or controller hardware with traffic signal locations, it may be reasonable to assume the majority of the remaining intersections have stop control on the minor road as a starting point, especially for State routes. An agency could apply this assumption and have reasonable estimates of traffic control for intersections almost immediately. Further data collection efforts could correct the attributes as needed.

Another example is related to the collection of AADT. Traffic volume is costly to measure; however, regression analyses, travel demand models, ITS infrastructure, and other methods for estimating traffic volume have shown promising results and may be worth considering as an alternative to a relatively costly short count collection program for all roads. FHWA's *Traffic Monitoring Guide* has more information about collecting traffic volume data.(44)

Finally, collection costs vary by the number of sites. For instance, some elements are only relevant in urban areas or for freeways. Others are costly to collect for the whole system, so the agency may elect to collect the data only for State routes or across certain regions. The *MIRE Fundamental Data Elements Cost-Benefit Estimation* guide discusses specific costs and a cost estimation methodology that agencies can apply to other data.(10)

Overall data collection costs are related to the collection method and the desired coverage and accuracy of the data. Once an agency collects data, data owners should maintain the data so it remains timely and accurate.

Using Existing Data and Management Needs to Prioritize Data

Prioritization prompts:

- Is more investment needed to update existing systems prior to investing in new data?
- Is it more effective to improve existing data or data management processes than to collect new data?
- How should we balance resource allocation for new data collection and continued data maintenance?

Most State and local roadway inventories and other databases were not originally developed to support safety analyses, and do not always cover all important data elements and attributes. However, all agencies should have at least some basic roadway data elements already available to them, such as geographic location information, surface type, and cross section data. Agencies may prefer to prioritize improvement and maintenance of data elements collected or partially collected before collecting new data. Often there is potential to make available data more accurate, complete, and timely. Spending resources on new data adds to the resources needed to maintain all data, and the level of investment in data maintenance may not have been sufficient in the first place if available data are not satisfactory for analysis. Consider that developing a system for effective data management and maintenance before collecting new data may be beneficial.

Using Regional and Jurisdictional Data Needs to Prioritize Data

Prioritization prompts:

- Do certain regions or jurisdictions have a greater need for safety improvements?
- Is it important to prioritize building upon data for the State system, or to collect baseline data for all sites in regions with more limited data (e.g., local roads)?

Sites within certain regions or jurisdictions may have varying priorities for safety and data depending on the extent of the system, strategic goals, and distribution of crashes across sites. One aspect of this is the number of sites for which the agency needs the data. For example, a rural State may have relatively few intersections with traffic signals compared to stop control. It may be easier and cheaper to collect data for the traffic signals before launching a large-scale data collection effort for the stop-controlled intersections, resulting in a higher priority for data needs at signals.

The priority in this area is unique to each agency. The following examples further demonstrate hypothetical situations affecting data priority.

1. If 70 percent of serious crashes in a State occur on local roads, local data collection and maintenance could take on higher priority for that State.
2. A State needs to collect some additional data to increase their network screening capability to advanced level. The agency could prioritize collecting data for roads on the State system because they likely have LRS and HPMS coverage already and those roads can serve as a good starting point for a complete data set. Over time, the agency could collect data on local roads where data needs and costs are higher.
3. States that have established regional, county, and local safety plans may place a higher emphasis on collecting data elements outside of the State system. This often leads to greater interagency cooperation and data sharing between local agencies and the State.

County Safety Plans – Minnesota

Minnesota has developed individual safety plans for each to the State's 87 counties. This process helped identify curves with 500 to 1,200 foot radii to consider for systemic improvements.(L)

Data Variability Over Time

Prioritization prompts:

- How do data elements vary over time?
- Do available data sources provide accurate representations of past and current roadway conditions?
- Should collection of geometric or operational roadway data elements be higher priority?

Another factor that agencies should consider is the variability of data over time. Geometric data are inherently more static, often representing unchanging conditions over many years. On the other hand, operational characteristics are constantly changing. While a single data point for the number of through lanes on a road may be accurate for several past decades, the AADT for the same roadway changes annually.

Safety analysis is most accurate when a database contains a history of roadway conditions that allows analysts to understand the roadway characteristics present at the time of each crash. Agencies may derive some benefit from collecting operational data sooner and more regularly to develop a record of more data points. In contrast, an agency might collect geometric data once and only update the data as construction or other changes occur.

Using Data Sharing Considerations to Prioritize Data

Prioritization prompts:

- Do other agencies or business areas have a need for any data?
- Would other agencies lead or support data collection and maintenance efforts?

Finally, it is important for agencies to consider intra-agency and inter-agency uses for data. Other groups or partner agencies may have some use for the same data that the lead agency needs. The following is a list of groups and applications that share some data needs with safety analysis:

- Asset management and maintenance.
- Planning.
- Traffic engineering.
- Transportation systems management and operations and ITS.
- Environmental and right-of-way.

These other uses can bring additional returns on the investment in data collection and maintenance, and thus an agency could decide that the elements that have other potential uses have a higher priority. This is especially true when the other groups or partner agencies can help provide resources to support or lead the data collection and maintenance efforts. Conversely, data elements that only one agency will use may be lower priority.

SUMMARY OF PRIORITIZATION

As described in this chapter, the data prioritization process involves several steps with many considerations for States. Throughout the process, States should be deliberate with all stakeholders when making decisions. The initial step is developing a subset of elements to prioritize by answering questions about the agency's business and data needs. This may include identifying the intention, use, minimum level needed for further analysis, additional elements to collect, and information the State needs to answer those questions. States should also consult the myriad of available resources—such as the *MIRE Data Collection Guidebook*—for more information during each step of the process.(11)

Once States have identified the data elements of interest, they should work with partner agencies to prioritize the needed elements. Considerations in prioritization include the cost to collect, the use of the elements, and the potential for collaboration with partner agencies. This process often requires financial and staffing investments—both at the beginning of the process and throughout its lifespan for ongoing data collection and maintenance. Some States may view data prioritization as a long or overwhelming process, but investing resources and time on the front end will lay the groundwork for developing useful, sustainable data systems for the future to support safety analyses.

CHAPTER 5—MOVING BEYOND PRIORITIZATION

Data prioritization, as discussed in Chapter 4, is one component of a larger data management life cycle and governance framework. When prioritizing data, agencies should work with inter-agency and intra-agency partners and stakeholders who could help develop data priorities and provide additional insights from other areas of the agency to inform the process. Enterprise-level data governance, data management structure, and resource constraints influence safety data priorities. After developing data priorities, the agency should move to collection and maintenance of the data. The *Guide for State DOT Safety Data Business Planning* presents the data life cycle in Figure 12. This data life cycle is guided by formal data governance and planning.

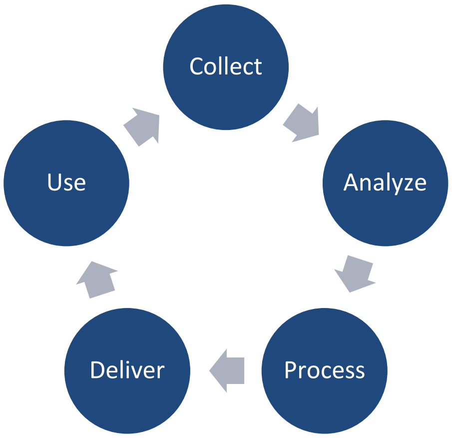


Figure 12. Graphic. Data life cycle.(45)

Data prioritization is most likely a precursor to data collection efforts. Chapter 4 highlights the need to consider factors relating to all steps of the data life cycle in prioritization including collection costs, analysis usage, processing and data mining, and collaboration. This chapter discusses steps after prioritization including data governance and developing data business plans. The *Guide for State DOT Safety Data Business Planning* provides more information on these topics.(45)

DATA COLLECTION AND INTEGRATION

Following data prioritization, agencies plan future data collection and maintenance efforts for the newly prioritized data. Agencies should have some estimate of data collection and maintenance costs from the prioritization process, and can compare those to their budget to determine how much of the data they can afford to collect and determine a schedule for data collection efforts.

Agencies can collect various data elements all at once or collect elements over time to build a dataset. Budget and staff limitations are the major limitations for data collection activities. Given the necessary resources and a greater urgency, a single data collection effort to gather all data elements of interest may be more desirable. Alternatively, an agency may decide to balance data collection costs over multiple years by collecting the higher priority and cost-effective data elements earlier (or data for higher priority networks or regions). This lets the agency begin conducting the more important analyses sooner, leaving the lower priority data collection for later years.

Agencies should explore the tradeoffs of how to schedule and plan data collection efforts. Generally, if resources are limited, it will be most cost effective for agencies to limit or split data collection efforts by the number of sites included in the effort, rather than the number of elements. In other words, if an agency undertakes a data collection effort using aerial imagery, they should collect all desired data elements that can be collected with aerial imagery for each site that data collectors visit, rather than collecting only some elements for each site and revisiting the same sites later to get the rest of the elements.

Similarly, agencies should explore the similar elements that can be collected together, or those that can be collected once and then used in or translated to multiple data sets. Agencies should decide whether to build each dataset independently or concurrently.

The next step for most agencies is to draft a Data Collection Action Plan to document the results of the prioritization, lay out specific action items and a timeline for data projects, and garner buy-in as future efforts proceed.

Developing a Data Collection Action Plan

Data Collection Action Plans are the roadmap for an agency to go from their current status to their final, desired status in terms of data. The agencies participating in data activities should decide what specific contents and level of detail go into the Data Collection Action Plan.

Table 6 and Table 7 are excerpts of an example Data Collection Action Plan for data collection and enhanced analysis for a State DOT. These tables represent the specific steps toward reaching the goal of collecting MIRE FDE on all public roads (Goal 1). General actions are categorized in two steps: contract services and database preparation (Action 1) and implement MIRE FDE with Statewide accessibility (Action 2).

Table 6. Action plan excerpt for Goal 1, Action 1.

Step #	Description	Preceding Tasks	Following Tasks	Who?	Start Date	End Date	Status
1.1.1	Develop collection contract	None	1.1.2	DOT	1/17	3/17	Done
1.1.2	Hire vendor	1.1.1	1.1.3	DOT	3/17	4/17	Done
1.1.3	Approve initial test data	1.1.2	1.1.4, .6	DOT	4/17	5/17	Started
1.1.4	Establish database	1.1.3	1.1.4	DOT	6/17	8/17	Not started
1.1.5	Establish quality control (QC) Plan	1.1.4	Action 2	DOT	8/17	10/17	Not started
1.1.6	Train DOT Staff`	1.1.3	1.2.4	DOT	7/17	8/17	Not started
1.1.7	Train selected local staff	1.1.6	1.2.5	Local	9/17	10/17	Not started

Table 7. Action plan excerpt for Goal 1, Action 2.

Step #	Description	Preceding Tasks	Following Tasks	Who?	Start Date	End Date	Status
1.2.1	Collect MIRE FDE on all roads	1.1.5	1.2.2	DOT	10/17	12/18	Not started
1.2.2	Complete QC	1.2.1	1.2.3	QC Group	11/17	03/19	Not started
1.2.3	Implement GIS	1.2.2, .3	Action 3	GIS Group	11/17	04/19	Not started

This example Data Collection Action Plan excerpt shows each goal and its associated actions to achieve the goal. For each goal and action, the plan shows a series of steps with a brief description of what is to take place. The steps follow a logical sequence shown in the list of preceding and following tasks at each step. This shows the critical path for the data collection process. The responsible party or parties are listed in the "Who?" column. This identifies the responsible agency and any needed partners. Start and end dates show the planned schedule of steps. They also help to show which tasks can run in parallel. A status indicator shows how much of the project is completed, and gives managers an easy way to identify when steps are in danger of not being completed on time.

This example is not prescriptive. It resembles an example State's plans to improve roadway and crash data over a period.

Using and Maintaining a Data Collection Action Plan

A Data Collection Action Plan should include the agency's goals, their corresponding actions, and the steps to complete each action. Agencies should update and modify the plan as projects progress and as the agency's goals change over time. Agencies should designate a champion to compile relevant information from stakeholders and to continually maintain the plan, beyond the simple tracking shown in Table 6. The champion should be able to, at any time, provide managers with an update on overall progress and specific information about any steps in the plan. With this structure, managers should know if the goals are met, if projects are completed on time, and if there are problems that their staff need to overcome to facilitate progress. Project management techniques and tools are beyond the scope of this Guide; however, agencies are familiar with standard management methods and should consider managing the Data Collection Action Plan the same way they would any project management task. The example in Table 6 has the necessary information to implement a critical path method, Gantt charts, or other project management methods. Agencies should modify the Data Collection Action Plan contents to suit their own project management methods.

The Data Collection Action Plan could easily feed into a larger Data Business Plan that documents enterprise data vision, goals, objectives, and actions; guides data management practices; and identifies opportunities to use data to improve business operations. The two plans together address the State's need for improved data and improved analyses to support safety decision making.

DATA GOVERNANCE AND PARTNERSHIPS

Data governance represents a formal structure of authority over the processes of data collection, storage, security, inventory, analysis, quality control, reporting, and visualization. These processes have a potential influence on data priority in a limited resource environment. Formalizing data priorities, data governance, and data activities in a Data Business Plan is a practice that encourages successful implementation and maintenance. The agency's Data Business Plan should include their safety data priorities. This will support future data collection and updates, agency performance management, and target setting.

Safety data stakeholders should collaborate with those involved in data governance at the agency to promote integration of safety data with other data sets. Numerous partners, from within the agency and with external partners, are involved in successful data systems. Data governance provides a necessary framework for these diverse partners to work together. In many States, the TRCC fosters this collaborative structure and articulates the data governance. Figure 13, from National Cooperative Highway Research Program (NCHRP) *Report 666: Target-Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies* (Figure 2.4), below, presents an example data governance structure.(46)

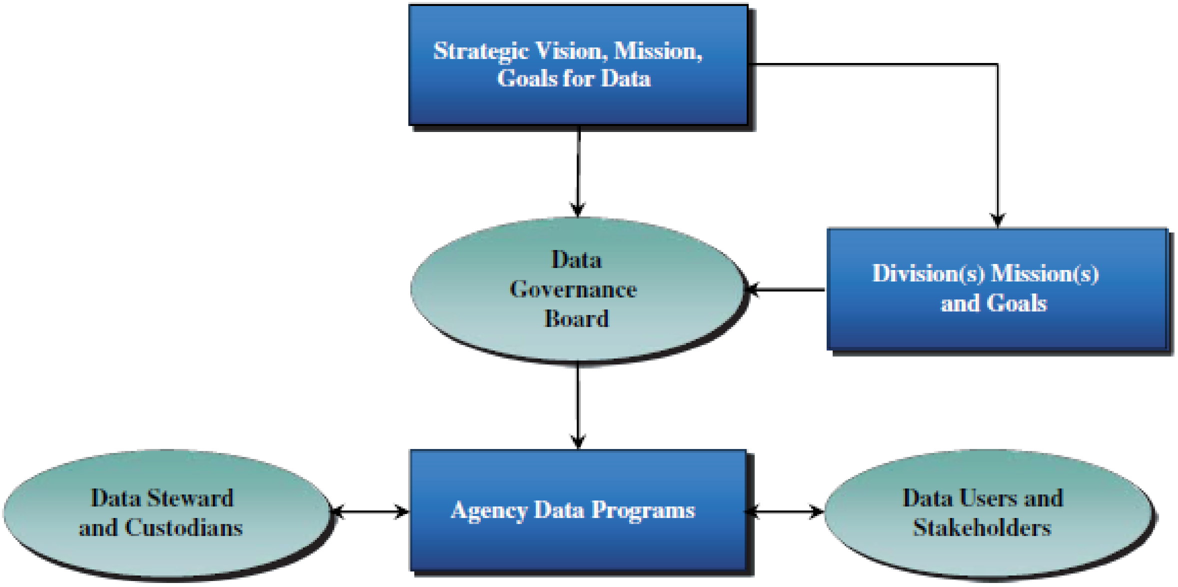


Figure 13. Chart. Standard data governance model.(46)

Incorporating safety data as part of an agency's enterprise-level data efforts provides opportunities to leverage the resources in other business areas and improve data accessibility throughout the organization.

Data Governance Development – Utah

The Utah DOT is one of many agencies using innovative tools to manage its data. Utah DOT shares and manages data using its centralized data portal, UGate. The data on UGate is downloadable and accessible; most is available to the public. Utah DOT engineers use UGate data in their safety analysis tools. As the agency develops UGate 2.0, the expansion of technology combined with the visibility of the data means that any data quality or data management issues are increasingly perceptible. Therefore, data governance has become a high priority for Utah DOT.(M)

Additional Resources

There are several resources that agencies can use when considering data integration as a strategic initiative. The following resources provide guidance, assistance, and needs assessments:

- Roadway Data Improvement Program (RDIP):
  http://safety.fhwa.dot.gov/rsdp/technical_detailed.aspx
  The RDIP provides assessment and technical assistance on roadway data collection and

standards. The program addresses data sharing, management, governance, and integration. It also covers analytic tools and their use in safety management.

- Crash Data Improvement Program (CDIP):
  http://www.nhtsa.gov/Data/Traffic-Records
  The CDIP provides assessment and technical assistance on crash data collection and standards. The program addresses data management, data quality, performance measurement, and data integration.

- Every Day Counts Round 4 (EDC-4): Data-Driven Safety Analysis (DDSA):
  https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/ddsa.cfm
  EDC-4 DDSA employs state-of-the-practice, evidence-based methods and analytic tools to provide agencies with the means to quantify safety impacts of agency projects and decisions. It includes predictive and systemic analyses to identify sites with the best potential for safety improvement and roadway features that correlate with specific crash types. The DDSA model leads to informed decision-making, targeted investment, and improved safety.

- State Safety Data Capabilities Assessments:
  http://safety.fhwa.dot.gov/rsdp/perspectives_rpt.aspx
  https://trid.trb.org/view.aspx?id=1301939
  The Safety Data Capabilities Assessments are now entering the second round. In the first round (see links above), the States, plus District of Columbia and Puerto Rico, participated in assessments of their roadway inventory data collection, data analysis tools and uses, data management, and data interoperability and expandability (including data integration). The second-round capabilities assessment will update the information from the first round, and add a new assessment of safety performance management.

- Traffic Records Assessments:
  https://www.transportation.gov/government/traffic-records/traffic-records-assessments
  Traffic Records Assessments (TRAs) are designed to follow the *Traffic Records Program Assessment Advisory* (DOT HS 811 644). TRAs cover the six core traffic records systems (crash, roadway, driver, vehicle, citation and adjudication, and injury surveillance), plus data management, traffic records coordination, and data integration. States are assessed on a five-year cycle using a standardized process and a team of subject matter experts to develop a final status report with a list of improvement opportunities.

- Performance Measures for Roadway Inventory Data:

  The *Performance Measures for Roadway Inventory Data* guide reviews each of the data quality performance measures defined by NHTSA: timeliness, accuracy, completeness, uniformity, integration, and accessibility.(15) The guide also recommends modifications and additions to the existing NHTSA performance measures specific to the MIRE data elements. Furthermore, the guide enumerates a series of suggestions for data-related business practices that can lead to the successful implementation of data quality performance measures and improved roadway data.

CHAPTER 6—SUMMARY

The *Priorities in Roadway Safety Data Guide* is the capstone of more than five years of related projects aimed at helping States, Tribes, and local agencies develop complete data to support advanced safety analysis and decision-making. This Guide follows and promotes the data driven approach to safety decision making as described in Chapter 1. The philosophy is simple: better data leads to more informed decision-making, leading to efficient use of resources, which results in reduced fatalities and injuries. Chapter 1 also describes the legislative and policy context for States working with local agencies to develop all-public-roads data to support decision-making. This includes, but is not necessarily limited to, the core safety data sets of roadway inventory, traffic volume, and crash data. This Guide is not prescriptive with respect to which agencies lead the projects, how the partnering agencies work together to develop and achieve a set of shared goals, or how the agencies implement the desired data and analyses. The Guide includes examples chosen deliberately to illustrate multiple paths to success.

Chapter 2 describes the MIRE and MIRE FDE, which are great starting points for agencies beginning to prioritize data needs. Collaborating agencies should consider MIRE and related products as guides in conducting a data gaps analysis and when determining the data needs for specific analyses and analytic tools.

Chapter 3 explores the wide variety of analyses that decision-makers may rely on to allocate safety resources at the State, Tribal, and local levels. This chapter is also not prescriptive. It offers Guidance on how to implement advanced safety analyses with specific focus on the data needed to support those analyses and tools. Project-level and system-wide safety approaches are included so that partner agencies can identify data needs for any of the advanced analytic approaches recommended by FHWA, AASHTO, and others in already-published resources.

Chapter 4 describes methods for prioritizing data elements for collection and maintenance. The model is of an inclusive process addressing needs throughout safety, engineering, planning, design, operations, and maintenance. Partner agencies, and offices within those agencies, should work together to identify, prioritize, and obtain the data needed for all their operations. The Guide promotes safety as a consideration throughout all processes that affect roadways. Chapter 4 explains how to conduct a data gap analysis among all relevant stakeholders and arrive at a logical set of data priorities that can be reflected in a Data Collection Action Plan and an enterprise Data Business Plan.

Chapter 5 describes Action Plans as the basis for achieving a set of defined data collection and management goals. The Action Plan is a companion to existing strategic planning efforts (such as the SHSP, the HSP, and the Traffic Records Strategic Plan). The Action Plan focuses entirely on implementation. It shows what the steps are to achieve the data collection and analysis goals established by the partner agencies. The Action Plan is a dynamic document subject to updates as projects progress and situations change the list of desired activities.

Finally, this Guide is a practical resource. Partners among States, Tribes, and local agencies can use the Guide to establish their own safety data business plans, conduct their own gap analyses, identify their own training needs, and develop their own paths to data integration and availability. The examples provided in this Guide are all drawn from existing projects in State, Tribal, or local agencies. The Noteworthy Practices described in the Guide are posted on the RSDP website.(47) The site links to additional resources, such as full project reports and other guides on related topics such as data business planning and data integration. This Guide also includes a list of references that partner agencies can use to find out more information. The intention was not to duplicate the existing guides but to provide a handy reference and sufficient explanatory material to help agencies implement data prioritization.

APPENDIX A: EXAMPLE APPLICATIONS

This Appendix presents two hypothetical examples to illustrate potential applications of the Guide. The first example represents a relatively simple application where a city is prioritizing general data collection efforts with limited resources to expand their analysis capabilities. The second example describes a more complex prioritization of data elements within an intersection inventory.

While these examples portray simplistic applications of the Guide for hypothetical situations, users can identify similar types of considerations when prioritizing data among their partner agencies.

Example 1: Local Data Priorities

Background

A State maintains a complete inventory of State-maintained roads, with minimal data on local roads. The State has no intersection inventory and sparse data on pedestrian facilities from maintenance records. All safety analysis tools and data sets developed by the State DOT are available to local agencies within the State. The State has not developed or calibrated any SPFs. The State offers some financial assistance to municipalities for collecting data on their public roadways to integrate into the statewide road inventory.

The State's SHSP identifies roadway departure, intersection, and pedestrian crashes as infrastructure-related emphasis areas and highlights local data collection as an important strategy across multiple emphasis areas. The other SHSP emphasis areas are related to driver behaviors and enforcement.

The fastest-growing city in the State hears recurring concerns from residents and business owners that the transportation system is lacking connectivity between residential, commercial, and recreational areas. The city expects retail development to rise over the next couple of years to accommodate the growing population within the town and the surrounding areas. Residents have expressed the desire to expand non-motorized facilities. There is a need to understand the safety impacts of the city's growth.

Given the situation, the city identified an opportunity to increase its safety analysis capabilities through local data collection efforts. The city has limited resources for safety analysis, but has the technical capabilities to collect and manage data. The city hopes to improve its safety analysis capabilities to understand the safety impacts of the new infrastructure and maintain a high level of safety for its residents and visitors throughout a period of economic growth. Since the city does not have a large budget for making safety improvements other than maintenance of existing facilities, targeting the right projects is crucial. The city recognized that the data it collects will improve the State's analysis capabilities to identify potential improvements in the jurisdiction.

Identifying Data to Prioritize

The city decides to use the prioritization process in this Guide to prioritize databases that will support safety analyses. The first four steps determine the data needs that the city will prioritize.

1. **Define Business Needs:** The city currently focuses its safety-related efforts on maintaining existing infrastructure and works with the State when the State identifies opportunities for safety projects in the city. The city has identified a need to understand the impacts of new infrastructure construction and growth. The city would also like help improve the State's capability to identify safety concerns.

2. **Identify Desired Analysis Capabilities and Data Requirements:** The city identified project-level safety analysis as the driving reason for collecting new data and expanding analysis capabilities. This level of analysis requires SPFs and detailed data for project sites. The city also has secondary goals of collecting basic roadway inventory data across its network and analyzing the safety impacts of non-motorized facilities.

3. **Catalog Available Data:** The State has a complete road inventory for State-maintained roads that contains sparse local data, no intersections, and some pedestrian facility data that is not readily accessible. The city currently does not maintain roadway data other than maintenance records and some maps. SPFs are not available.

4. **Conduct Gap Analysis:** The city needs calibrated SPFs to conduct project-level analyses. The city also needs roadway and intersection data for most of its network and an inventory of pedestrian facilities to support its secondary safety analysis goals.

5. **Prioritize Data:** See the *Prioritization Considerations* section, below.

The city identified a goal of conducting project-level safety analysis for new developments to understand the impacts of growth, particularly the result of higher traffic volumes. Advancing project-level analysis capabilities would allow the city to respond to the public's safety concerns and would support the city's planning efforts and policy development. The city would also like to increase its capabilities in identifying safety issues, developing safety improvements projects to mitigate safety issues, and prioritizing projects if the budget can support that.

City transportation staff listed the following actions needed to support their future goals:

- Collect roadway segment data to fill in gaps in the State inventory.
- Collect local intersection inventory.
- Collect local pedestrian facility inventory.
- Collect local bicyclist facility inventory.
- Calibrate urban SPFs from the HSM.
- Digitize maintenance records of guardrail, road sign, and pavement marking locations.

Prioritization Considerations

The next step in the process is to prioritize the city's data needs. The Guide lists the following six prioritization considerations.

- Analysis type and usage.
- Data-related costs.
- Existing data and management.
- Regional and jurisdictional data.
- Data variability over time.
- Data sharing.

In this situation, the city is most concerned about the costs and data usage in analysis (i.e., the importance of the analyses that the data feed into). Data sharing with the State is an important secondary consideration. City staff determined the other factors are not as important at this time. The following sections capture the city's prioritization considerations for each data need.

Roadway Segment Inventory Data Collection

The State's roadway segment inventory is sparse on local roads, and this data collection would enable the city and State to identify and plan safety improvements across the city. However, the city's ability to construct new projects is severely limited by its budget. This information is also costly to collect and maintain, but the structure of the State's inventory provides a starting point for this data collection effort.

Intersection Inventory Data Collection

Like the roadway segment inventory, an intersection inventory is costly and has limited potential utility for the city. Unlike the segment inventory, the State does not have an intersection inventory to serve as a starting point for the city, and the potential for data sharing is lower than with the segment data.

Pedestrian and Bicycle Inventory Data Collection

Pedestrian and bicycle facility information will assist the city in analyzing the safety impacts and connectivity for non-motorized transportation. The city is interested in the facilities that intersect or are adjacent to the roadway, and would focus first on the location and type of those facilities. These data cost less to collect than segment and intersection inventory data because there are fewer facilities, but the process still requires manual data collection and entry. These data may have some use to other agencies.

Calibrated SPFs

Calibrating SPFs for all facility types is an intensive effort that carries a relatively high cost. The city does not have the capability with in-house staff to calibrate SPFs; however, the SPFs are required for their highest priority goal of analyzing impacts of growth and new development. Some data sharing is possible, but locally calibrated SPFs are not useful outside of the city or region for which they are calibrated.

Digitized Maintenance Data

The city has information about the location of guardrails, road signs, and pavement markings in its paper maintenance records. This information is not readily accessible for analyses and requires manual interpretation and data entry to digitize the location and condition of assets. This information can be used for future maintenance and safety considerations during safety analysis. Although other agencies would not use the data, the city's primary responsibility in highway safety is maintenance of existing facilities and a digitized maintenance database would improve its ability to do that.

Prioritization Results

The city used a tabular rating system to apply priorities to each data need. The city staff ranked each data need on a scale of 1-5, with 5 representing the highest priority, most important, lowest cost data needs. As shown in Figure 14, the overall score is based on the weighted sum of the individual rankings, with data costs and analysis usage weighted twice as much as data sharing.

Overall Score = 2 x (Data Cost Rank) + 2 x (Analysis Usage Rank) + (Data Sharing Rank)

Figure 14. Equation. Example prioritization ranking equation.

Table 8 shows the results of the data prioritization.

Table 8. Example 1 Prioritization Results.

Data Need	Data Costs	Analysis Usage	Data Sharing	Overall Score
Segment Inventory	2	3	5	15
Intersection Inventory	1	2	4	10
Pedestrian/Bicycle Data	3	1	3	11
Calibrated SPFs	4	5	2	20
Digitized Maintenance Records	5	4	1	19

Based on the results in Table 8, calibrated SPFs are the highest priority for the city, followed by digitized maintenance records. Calibrated SPFs are needed for the most important analyses to the city, and are estimated to cost more than digitizing existing maintenance records but less than collecting roadway inventory data. Digitizing maintenance records requires the least funding but is less important and has the least potential for data sharing. The segment inventory has the second highest cost and is less important to the city, but has the highest potential for sharing with the State. Non-motorized facility and intersection inventories are the lowest priorities due to their cost and lesser importance for analysis.

Conclusion

The city decides to move forward with developing calibrated SPFs and digitizing maintenance records. They also decide to start the process of expanding their segment inventory; their short-term efforts will focus on filling gaps in the State inventory to support SPF calibration.

Example 2: State Data Priorities

Background

A State has identified roadway departure safety, intersection safety, and data improvement as emphasis areas in its SHSP. The State has elected to prioritize data collection efforts to improve safety analysis capabilities regarding roadway departure and intersection safety. The State has also identified a need to collect the MIRE FDE in accordance with the FAST Act.

The State has a linear referencing system (LRS) base map of all public roads that meets the requirements of the HPMS and the All Road Network of Linear Referenced Data (ARNOLD). A State maintains a roadway segment inventory for non-local (i.e., by functional class) roadway segments and all ramps. Segment inventory data for local roads is limited. The State does not currently have an intersection inventory or a horizontal curve inventory. The State maintains approximately 20 percent of sites. Table 9 presents the number of sites in the State, categorized by maintenance type and MIRE FDE category.

Table 9. Number of sites in the State by maintenance and MIRE FDE category.

Maintenance Type	Non Local Paved Segments	Local Paved Segments	Non Local Intersections	Local Intersections	Non Local Horizontal Curves
State maintenance	9,000	27,500	4,000	12,000	2,000
Tribal or local maintenance	36,000	110,000	16,000	48,000	8,000

The State would like to conduct system-wide network screening to identify locations for potential for improvement in roadway departure and intersection safety. The agency has analysts and analysis tools capable of conducting network screening analysis with SPFs for paved roads and curves, but not unpaved roads. The State has decided to improve its safety management processes by collecting and maintaining the MIRE FDE on all public roads, as well as collecting a basic inventory of horizontal curves.

Identifying Data to Prioritize

The State decides to use the prioritization process in this Guide to prioritize their data collection efforts. The first four steps determine the data needs that the State will prioritize.

1. **Define Business Needs:** The State has a desire to provide higher levels of roadway departure and intersection safety on all public roads. The State would like to collect the MIRE FDE and a horizontal curve inventory to support system-wide network screening.

2. **Identify Desired Analysis Capabilities and Data Requirements:** The State already conducts some advanced network screening analysis for non-local paved roads. However, the lack of local road data, a complete intersection inventory, and a horizontal curve inventory limits their capability to make more informed project decisions and target investments for most sites across their network.

3. **Catalog Available Data:** The State maintains an incomplete road inventory and has the MIRE FDEs for all interchange ramps. The State has a video log of non-local roads and aerial imagery of all public roads available to them.

4. **Conduct Gap Analysis:** The State conducted a gap analysis between available and desired data. Table 10 summarizes the State's existing roadway segment, intersection, and horizontal curve data coverage across sites (i.e., 100% indicates all roads have the desired data elements, 0% indicates no roads have data) in comparison to desired data elements by maintenance type and MIRE FDE category. For this example, assume that each site either has all data elements or no data elements.

Table 10. Available segment, intersection, and horizontal curve data coverage.

Maintenance Type	Non Local Paved Segments	Local Paved Segments	Non Local Intersections	Local Intersections	Non Local Horizontal Curves
State maintenance	100%	70%	0%	0%	0%
Tribal or local maintenance	100%	20%	0%	0%	0%

From the gap analysis, State staff listed the following actions that they need to take to support their future goals.

- Collect MIRE FDE for local paved roads.
- Collect MIRE FDE for non-local intersections and local intersections.
- Collect MIRE data elements for horizontal curves on non-local paved roads.

5. **Prioritize Data:** See the *Prioritization Considerations* section, below.

The State identified a goal of conducting network-level safety analysis for all paved public roadway segments, intersections, and curves. Advancing network-level analysis capabilities will allow the State to improve decision-making during planning and scoping, resulting in improved delivery of roadway departure and intersection improvement projects to support the SHSP.

In preparation for prioritization, the State compiled Table 10 through Table 12, representing the data elements and preferred data collection method for local paved road data elements, intersection data elements, and horizontal curve data elements, respectively. "Assign" indicates that the State can assign the data attributes directly; no data collection is needed.

Table 11. MIRE FDE for local paved roads.

Mire FDE (MIRE 1.0 Number)	Collection Method
Type of Governmental Ownership (4)	Assign
Begin Point Segment Descriptor (10)	Assign
End Point Segment Descriptor (11)	Assign
Segment Identifier (12)	Assign
Functional Class (19)	Assign
Rural/Urban Designation (20)	Data Mining
Surface Type (23)	Aerial Imaging
Number of Through Lanes (31)	Aerial Imaging
AADT (79)	Field Collection

Table 12. MIRE FDE for intersections with paved roads.

Mire FDE (MIRE 1.0 Number)	Collection Method
AADT (79) [For Each Intersecting Road]	Field Collection
AADT Year (80) [For Each Intersecting Road]	Assign
Unique Junction Identifier (120)	Assign
Location Identifier for Road 1 Crossing Point (122)	Data Mining
Location Identifier for Road 2 Crossing Point (123)	Data Mining
Intersection/Junction Geometry (126)	Aerial Imaging
Intersection/Junction Traffic Control (131)	Aerial Imaging
Unique Approach Identifier (139)	Data Mining

Table 13. MIRE data elements for non-local horizontal curves on paved roads.

Curve Elements (MIRE 1.0 Number)	Collection Method
Curve identifiers and Linkage Elements (107)	Data Mining
Curve Feature Type (108)	Aerial Imaging
Horizontal Curve Degree or Radius (109)	Aerial Imaging
Horizontal Curve Length (110)	Aerial Imaging
Horizontal Curve Direction (114)	Aerial Imaging

Prioritization Considerations

The next step in the process is to prioritize the State's data needs. The Guide lists the following six prioritization considerations.

- Analysis type and usage.
- Data-related costs.
- Existing data and management.
- Regional and jurisdictional data.
- Data variability over time.
- Data sharing.

For this example, the State is most concerned about the analysis type and usage as well as data-related costs. Data sharing and data variability over time are secondary considerations. Jurisdictional considerations and existing data improvement are not important to this prioritization effort. The following sections capture the State's prioritization considerations related to their identified data needs.

The State aims to prioritize data collection efforts on local paved roads, intersections, and non-local curves.

Analysis Type and Usage

All the State's data needs represent the minimum data to conduct enhanced network screening for each site. The analyses require each element before analysis is possible. However, there is some difference in priority related to site types. The State wants to prioritize roadway segment collection over intersection and curve elements to complete the segment inventory for all public roads. The agency is also able use local roadway segment data subsequently in data mining efforts for intersections. Intersection data are the next priority due to their inclusion in the MIRE FDE requirements. Therefore, horizontal curve data are the lowest priority relative to segment and intersection data elements.

Data-Related Costs

Data collection costs are dependent on the collection method and number of sites. Table 11 through Table 13 indicates the need for Data Mining, Aerial Imaging, and some Field Collection of AADT data. Data mining is based on existing data and the LRS base map. Aerial imagery for all public roads is available. Using the summary in Table 5, the State identified the priorities in Table 14.

Table 14. Data-related cost priorities.

Data Collection Method	Relative Cost	Relative Priority
Data Mining	Low	High
Aerial Imaging	Medium	Medium
Field Collection	High	Low

Table 15 lists the number of sites for which the State must collect data in each category using the information from Table 9 and Table 10.

Table 15. Data collection sites by site category.

Site Category	Number of Sites
Local paved roads	96,250
Non-local intersections	20,000
Local intersections	60,000
Non-local horizontal curves	10,000

Data Variability Over Time

The State decides that operational data is a relatively higher priority than geometric data to start building a history of data points in AADT.

Data Sharing

There is potential to share segment, intersection, and curve data with local agencies for the roads those agencies maintain.

Prioritization Results

Rather than using a scoring system to apply priorities to each data element, State staff got together to discuss a plan and schedule for data collection efforts based on the prioritization considerations. Table 15 presents the results by site type and data collection method.

Table 16. Prioritization results by site type and data collection method.

Site Type	Data Mining	Aerial Imaging	Field Collection
Local paved roads	High	Medium	High
Non-local intersections	Medium	Medium	N/A
Local intersections	Medium	Medium	Low
Non-local horizontal curves	Low	Low	N/A

The State aims to use these results to plan and schedule data collection efforts. The data collection effort is expected to take several years due to resource constraints. The State considered coordinating simultaneous collection with aerial imaging for segments and intersections. However, due to funding limitations, the State decided to collect local road data prior to intersection data since the efforts will span several years regardless.

The following presents the tentative schedule for data collection efforts. Some efforts may span multiple years.

1. Begin planning and conducting an AADT data collection program for local roads.
2. Collect local paved road elements with data mining.
3. Collect local paved road elements with aerial imaging.
4. Collect non-local and local intersection data with data mining.
5. Collect non-local intersection data with aerial imaging.
6. Collect local intersection data with aerial imaging.
7. Collect horizontal curve data with data mining.
8. Collect horizontal curve data with aerial imaging.

Conclusion

The State has decided to move forward with prioritizing data that can be collected with the same method. The State set general data priorities by site type and data collection method, leading to a plan for data collection efforts to improve their roadway departure and intersection safety analysis capabilities.

APPENDIX B: CASE STUDIES

A. **Arizona Strategic Highway Safety Plan. Appendix C: Crash Characteristic Data Map Book.** https://azdot.gov/docs/default-source/about/az-shsp-appendix-c-crash-characteristic-data-map-book.pdf?sfvrsn=2

Arizona DOT developed a crash characteristics data map book to present a high-level overview of crash types associated with characteristics. The data map book also presents guidance on where efforts can be implemented to reduce crashes.

B. **Wisconsin Empirical Bayes Analysis.** "University Conducting HSIP Project Evaluations Using Empirical Bayes" from HSIP Noteworthy Practice Series: HSIP Project Evaluation FHWA-SA-11-02. https://rspcb.safety.fhwa.dot.gov/noteworthy/pdf/FHWASA1102_hsip_proj_eval.pdf

Wisconsin DOT developed a project evaluation process incorporating EB analysis into all HSIP project evaluations using the network-level SPFs contained in the AASHTOWare Safety Analyst software. Results from implementing the EB method for B/C analysis showed how a simple before-after evaluation can overestimate the safety benefits of a project.

C. **Ohio Safety Analyst™:** Implementing a New Roadway Safety Management Process with Safety Analyst™ – OH 2010. http://safety.fhwa.dot.gov/hsm/casestudies/oh_cstd.pdf

The Ohio DOT has embraced the opportunity to integrate Safety Analyst™ software into its existing safety analysis system to increase the quality of its network-level data analysis. In order to take advantage of the benefits of Safety Analyst™, Ohio DOT improved its data collection and management processes. The immediate advantage of Safety Analyst™ is the ability to apply the HSM screening methods, analyze specific subtypes of locations, and compare multiple screening methods.

D. **Funding Systemic Improvements – New Mexico:** Developing Methodologies for the Prioritization of Systemic Safety Improvements – NY 2015. https://rspcb.safety.fhwa.dot.gov/noteworthy/html/hsip_in_nm.aspx?id=179

New Mexico identified proven countermeasures that did not require a crash history for justification to streamline the wide implementation of cost-effective safety improvements on rural roads. Implementing this approach, the State applied low-cost systematic improvements to locations that might not otherwise have received funding due to their low crash histories.

E. **Systemic Planning Process – New York:** Applying Systemic Planning Process to Lane Departure Crashes on State Highway System – NY 2013. http://safety.fhwa.dot.gov/systemic/pdf/sfty_ny.pdf

The New York State DOT used the Systemic Safety Project Selection Tool to identify sites where safety could be improved by deploying low-cost countermeasures on roadways with a high crash risk rather than just focusing on specific sites with a history of severe crashes. The Tool is beneficial because it provides a process to identify locations that would benefit from safety-related improvements that would not otherwise be identified through the traditional site-specific analysis process.

F. **Interactive Highway Safety Design Model - Idaho**: Highway Safety Manual Case Study 1: Using Predictive Methods for a Corridor Study in Idaho – ID 2011. https://rspcb.safety.fhwa.dot.gov/noteworthy/html/datacollect_id.aspx?id=82

Idaho used the IHSDM software to conduct a detailed project-level corridor study of an 11-mile section. The analysis resulted in a list of geometric deficiencies and specific locations needing further improvement.

G. **Highway Safety Manual Predictive Method – Florida:** Florida Uses Predictive Methods found in the Highway Safety Manual (HSM) for Alternative Selection in Florida – FL 2012. https://rspcb.safety.fhwa.dot.gov/noteworthy/html/datacollect_fl.aspx?id=88

Florida used the HSM predictive method to analyze alternatives for a corridor widening project on an urban arterial in the Tampa area. They were able to estimate the safety and economic benefits of each alternative.

H. **Safety Analysis in Project Development – Louisiana**: 2014 Safety Analysis in Project Development – LA 2014. https://rspcb.safety.fhwa.dot.gov/noteworthy/html/datacollect_la2.aspx?id=136

The Louisiana Department of Transportation and Development has implemented safety practices into the project development process, resulting in a safety focus from the beginning of a project's life. Practices include incorporating low-cost countermeasures in the design stage and analyzing the Transportation Management Plan in the construction phase for potential countermeasures to increase work zone safety.

I. **Maintenance Crews Support HSIP – Arkansas and Arizona**: Maintenance Crews Step in to Support the HSIP. Arkansas and Arizona – AR and AZ 2015. https://rspcb.safety.fhwa.dot.gov/noteworthy/html/safetyculture_ar_az.aspx?id=177

Arkansas DOT recognized the extensive knowledge maintenance staff have of the roadways and now uses these crews to analyze crash sites and recommend next steps for addressing related safety issues. Similarly, Arizona DOT Engineering districts use maintenance records to identify potential safety concerns if specific sites are repeatedly being reported for maintenance.

J. **Horizontal Curve Database – Tennessee:** Tennessee's Horizontal Curve Database – TN. http://safety.fhwa.dot.gov/rsdp/downloads/fhwasa16048.pdf

As part of an extensive effort to complete its roadway network inventory, the Tennessee DOT recorded each horizontal curve on the system. Tennessee DOT compiled and stored the data in a horizontal curve database. This case study describes the challenges and successes in developing and using the horizontal curve database in Tennessee.

K. **Comprehensive Roadway Data – Utah:** Collection and Use of Roadway Asset Data in Utah – UT 2014. http://safety.fhwa.dot.gov/rsdp/downloads/utahiidarcasestudy.pdf.

This case study describes the successes and ongoing challenges related to statewide data collection to support asset management, safety, and planning activities in Utah. This report has relevance for State DOTs as an example using new technologies and enhanced data management practices to create a multipurpose resource. The example may be extended to local agency participation as well. The project proved effective for managing roadway assets for Utah DOT, which has improved data storage to allow all Utah DOT divisions to access the data and improved pavement and sign management.

L. **Systemic Safety Improvement Based on Risk Assessments at a County Level – Minnesota.** http://safety.fhwa.dot.gov/systemic/pdf/SystemicinPractice_Minnesota.pdf

Minnesota has taken a different approach through the development of safety plans for each of the State's 87 counties. The safety plans disaggregate the severe crash types by each of the AASHTO SHSP emphasis areas to identify emphasis and target crash types at the regional level. Minnesota DOT has selected crash surrogates for various facility types to use in the risk assessment. Locations identified and included in the plans can be submitted for project funding through the HSIP.

M. **Safety Data Processes and Governance Practices – Utah**. http://safety.fhwa.dot.gov/rsdp/downloads/utah_case_studyFinal.pdf

This case study describes the Utah DOT's experience with incorporating data governance into the development of its data systems. Utah DOT shares and manages data using its centralized data portal, UGate. As Utah DOT works to develop UGate 2.0, data governance has become a high priority for the agency. The UGate 2.0 structure resembles a data governance framework, and Utah DOT is in the process of organizing a data governance board to review expenditures and data stewardship.

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