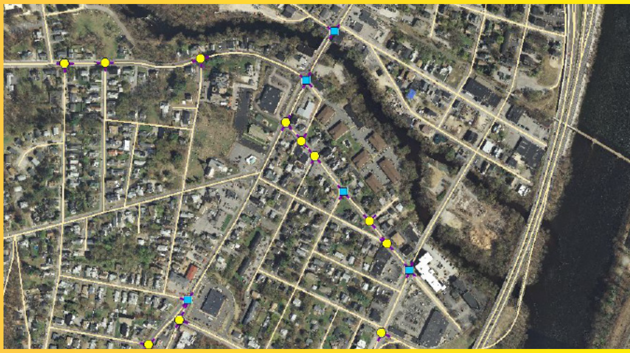
Benefit-Cost Analysis of Investing in Data Systems and Processes for Data-Driven Safety Programs: **Project Report**



FHWA Safety Program

U.S. Department of Transportation
Federal Highway Administration

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Investment in roadway safety saves lives

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The Federal Highway Administration (FHWA) Office of Safety commissioned this study to develop guidance on methodologies that State and local Departments of Transportation (DOTs) could implement to make the case for investing in data collection, data systems, and processes. This report establishes the first of its kind benefit-cost analysis (BCA) methodology to quantify the economic returns from investing in safety data improvements.</td></tr>
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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)

ACRONYMS

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
B/C	Benefit-Cost
BCA	Benefit-Cost Analysis
CMAT	Crash Mapping Analysis Tool
DOT	Department of Transportation
EB	Empirical Bayes
EPDO	Equivalent Property Damage Only
FARS	Fatality Analysis Reporting System
FDE	Fundamental Data Elements
FHWA	Federal Highway Administration
FTE	Full Time Equivalent
GIS	Geographic Information System
HPMS	Highway Performance Monitoring System
HSIP	Highway Safety Improvement Program
HSM	Highway Safety Manual
IDAS	Intelligent Transportation System Deployment Analysis System Tool
ITS	Intelligent Transportation System
LOSS	Level of Service of Safety
LRS	Linear Referencing System
MAIS	Maximum Abbreviated Injury Severity Score
MIRE	Model Inventory of Roadway Elements
MPO	Metropolitan Planning Organization
NHTSA	National Highway Traffic Safety Administration
NOAA	National Oceanic and Atmospheric Administration
NPV	Net Present Value
OMB	Office of Management and Budget
PDO	Property Damage Only
PORTS	Physical Oceanographic Real-Time System
QALY	Quality Adjusted Life Years

SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SAVER	Safety, Analysis, Visualization, and Exploration Resource
SHRP2	Strategic Highway Research Program 2
SHSP	Strategic Highway Safety Plan
SPF	Safety Performance Function
TEV	Total Entering Volume
TRB	Transportation Research Board
USDOT	United States Department of Transportation
VAC	Value of Avoided Crashes
RSDP	Roadway Safety Data Program
OHPI	Office of Highway Policy Information

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EXECUTIVE SUMMARY

According to the U.S. Department of Transportation, motor vehicle crashes result in more than $230 billion in costs to society every year *(1)*. Efforts by State Departments of Transportation (DOTs) in recent years have yielded significant improvements in roadway safety outcomes. Between 2005 and 2010, the number of fatalities in motor vehicle crashes dropped from 43,510 to 32,885, the lowest level of fatalities since 1950. The number of fatalities per 100 million vehicle miles traveled fell from 1.46 to 1.11 during the same time period *(2)*.

Moving forward, economic constraints will limit the ability of States to make continued progress on crash reduction through the implementation of safety improvements. Therefore, States must allocate the scarce public resources available for roadway safety improvements judiciously to those projects that have the highest payout in terms of reduced fatalities and injuries per dollar spent.

Deciding to invest in data is often a challenge for transportation agencies. State transportation agencies often face budget constraints and pressure to use their limited resources on more tangible projects than data and information collection. Data investments often compete for funding with roadway projects and improvements to the infrastructure. Infrastructure improvements are visible to the driving public and often have immediate safety impacts; the impact of data investments may not be as obvious to the public. Investments in safety data, however, inform States' decision-making process regarding which safety improvements can have the most impact and where the improvements can be most effective.

The Federal Highway Administration (FHWA) Office of Safety commissioned this study to develop methodologies that State DOTs can implement to make the case for investing in data collection, data systems, and processes. This report establishes the first of its kind benefit-cost analysis (BCA) methodology to quantify the economic returns from investing in safety data improvements.

Benefits of Safety Data

The existence of available data and processes offers significant benefits throughout the safety improvement process. As shown in Figure 1, improvements in the data collection effort drives more informed decision-making. This results in more robust network screening, improved ranking of safety improvement candidate locations, and better countermeasure selection. Improved knowledge on the effectiveness of proposed countermeasures will help decision makers to target investments more towards those interventions that provide the highest returns in reduced crashes and fatalities relative to the project cost.

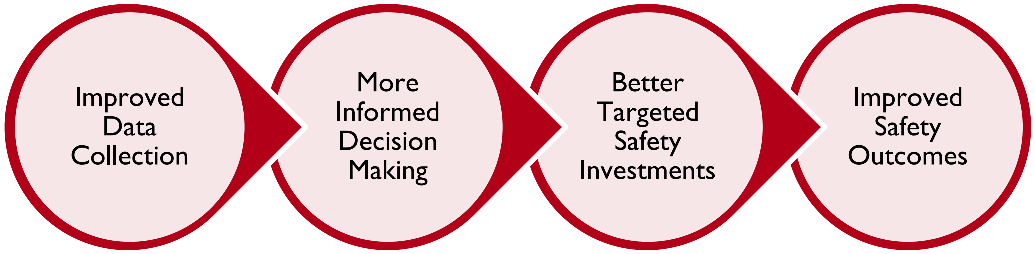

Figure 1. Role of Improved Data Collection Efforts in Safety Outcomes.

The BCA methodology described in this report will enable an analyst to quantify the impacts of specific data and process investments. For example, having readily available safety data during the project identification stage reduces the staff time needed to identify potential sites. In the absence of the data collection system, staff may need to undertake time-consuming, indirect estimate techniques to derive and double-check the information needed to identify potential safety improvement projects. When multiple offices within the same agency use the same or similar data elements, agency staff may duplicate this effort due to the absence of an officially accepted dataset. An agency can save time across multiple offices through the collection of additional data elements.

Table 1. Potential Benefits of Safety Data Investments.

Stage	Step	Benefit from Data Investments
Planning	Project Identification	• Reduced staff time due to existence of list of potential sites. • More rapid deployment of safety improvement due to quicker identification of potential sites for safety improvement projects.
	Countermeasure Selection	• More appropriate and more optimal selection of countermeasures for sites.
	Project Prioritization	• Improved ability to target those sites with the highest crash reduction potential.
	New Projects	• Some projects may not be able to be undertaken without the additional information provided by data.
Implementation	Implementation	• Earlier implementation.
Evaluation	Evaluation	• Reduced staff time due to more efficient evaluation of efficacy of safety improvements.

In addition to the change in the number of staff hours required to undertake the project identification process, additional data collection would reduce the lag between the beginning of a safety improvement initiative and the actual implementation of safety improvements on a State's roadways. The Highway Safety Improvement Program (HSIP) decision-making process involves identifying the problem sites, selecting appropriate countermeasures, prioritizing projects, programming the funding, and completing construction. The lack of a data collection system and readily available data creates a lag in this process. The time spent collecting and analyzing data delays the implementation of countermeasures. To evaluate the potential impact of faster project programming resulting from the availability of data, the BCA methodology establishes a procedure to estimate the benefits of avoiding excess crashes.

Costs of Data Investments

The BCA methodology also details the process for estimating the potential costs of investments. As summarized in Table 2, State DOT analysts can use this methodology to quantify the following categories: investment costs, operations and maintenance costs, and data analysis costs. Cost information was compiled from the *Market Analysis of Collecting Fundamental Data Elements to Support the Highway Safety Improvement Program* published by FHWA in June 2011. This document provided an estimate of the potential cost to States in developing a statewide location referencing system and collecting the Fundamental Data Elements (FDE) on all public roadways. States undertaking a benefit-cost estimate of their safety data collection program may choose to utilize estimates derived in this study, or replicate the approach using local resources.

Table 2. Potential Costs of Safety Data.

Type of Costs	Unit of Analysis
Investment Costs	• Roadway. • Intersection. • Ramp. • Location Referencing System.
Operations and Maintenance Cost	• Roadway. • Intersection. • Ramp. • Location Referencing System.
Costs for Coding and Locating Crashes	• On a per crash basis.
Other Costs (i.e., Data Storage, Cost of Analysis)	• By other unit.

The cost estimations developed in this report allow analysts to calculate the additional costs for States to gather the data that they are not already collecting through the Highway Performance Measuring System (HPMS), or other efforts. The report's methodology was conservatively based on the assumption that all data collection beyond HPMS requirements would be new collection. Individual States' cost estimates would vary by the circumstances in each State.

Conclusions

The methodology established in this study is the first of many steps that will ultimately provide States with the best information and knowledge available to facilitate safety data investment decision-making. This study and its companion document, a *Decision-making Guidebook*, which provides a step-by-step guide on how to complete and customize the methodology, will serve as a new tool to help guide analysts seeking to explore and understand the costs and benefits of roadway safety data investments. The methodology is a solid foundation for future research and tool-development, and will continue to evolve as analysts apply it to the unique circumstances of each State.

CHAPTER 1—INTRODUCTION

According to the United States Department of Transportation (USDOT), motor vehicle crashes result in more than $230 billion in costs to society every year *(1)*. Moreover, over 32,000 people died in motor vehicle crashes in the United States in 2010. These statistics reveal that motor vehicle crashes in the United States are costly on both and economic and personal level, and that action is warranted to improve roadway safety conditions.

This was the impetus behind the passage of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), which was signed into law on August 10, 2005 (Public Law 105-99). SAFETEA-LU established the Highway Safety Improvement Program (HSIP) in order to achieve a significant reduction in traffic fatalities and serious injuries on public roads through the implementation of infrastructure-related highway safety improvements.

The country as already made significant improvements in roadway safety since the passage of SAFETEA-LU in 2005. Between 2005 and 2010, the number of fatalities in motor vehicle crashes dropped from 43,510 to 32,885, the lowest level of fatalities since 1950. The number of fatalities per 100 million vehicle miles traveled fell from 1.46 to 1.11 during the same time period *(2)*.

Individual States are limited in the resources available to make continued progress on crash reduction through the implementation of safety improvements. States must judiciously allocate the scarce public resources available for roadway safety improvements to those projects that have the highest payout in terms of reduced fatalities and injuries per dollar spent. A number of tools have emerged to help State Departments of Transportation (DOTs) identify safety issues and provide recommendations for improvements. These include the Highway Safety Manual (HSM), its related software, SafetfyAnalyst, and the Interactive Highway Safety Design Model. Additional tools include models developed at the State level, such as Michigan's RoadSoft, and Iowa's Safety, Analysis, Visualization, and Exploration Resource (SAVER) and Crash Mapping Analysis Tool (CMAT). To achieve accurate results, these models all require quality roadway, traffic, and crash data.

The Federal Highway Administration (FHWA) Office of Safety's mission is *to reduce highway fatalities by making our roads safer through a data-driven, systematic approach and addressing all "4Es" of safety: engineering, education, enforcement, and emergency medical services*. Safety analyses have expanded beyond just crash data with the development of sophisticated analysis tools and methods. The need for improved crash, roadway, and traffic data is vital. Using these data together can help agencies make decisions that are fiscally responsible and improve the safety of the roadways for all users.

1.1 OVERVIEW OF THE STUDY'S PURPOSE & IMPLICATIONS

Deciding to invest in data is often a challenge for transportation agencies. State DOTs often face budget constraints and pressure to use their limited resources on more tangible projects than data and information collection. Data investments often compete for funding with roadway projects and safety improvements to the infrastructure. Infrastructure improvements are visible to the driving public and often have immediate safety impacts; the impact of data investments may not be as obvious to the public. However, investments in safety data can inform States' during their decision-making process as to which safety improvements can have the most impact, and where those improvements can be most effective.

The FHWA Office of Safety commissioned this research to develop guidelines on the methodologies that agencies can apply to determine the benefits of investing in data, data systems, and processes for achieving a data-driven safety program. This is a crucial next step to help the FHWA Office of Safety achieve its goal of reducing highway fatalities by providing decision-makers the tools they need to make informed decisions through an evidenced-based approach to safety implementation. The components of this research included:

- *Safety Data Investment Benefit-Cost Analysis Methodology*. This study establishes a methodology to quantify the potential impacts of investment in safety data improvement.

- *Decision-making Guidebook*. A Guidebook, developed in conjunction with this report, demonstrates how to apply the methodologies to a generally acceptable state-of-practice decision-making process. It provides a step-by-step approach for representatives of State transportation agencies to follow and customize the methodology based on their level of existing data.

- *Final Report*. This document serves as a Final Report. It details each phase of the research process that developed the benefit-cost methodology and the Guidebook. It includes the results of a comprehensive literature review on the economic costs and benefits of investing in roadway safety data. It also provides a detailed description of the methodology's key assumptions and identifies specific data elements required to complete the analysis.

The intent of this work is to assist States in understanding the value of investments in data collection, and justify the decision to invest in additional data collection efforts. If a State DOT is uncertain of the value of data collection, or if a State is having difficulty justifying the allocation of resources to data collection projects, analysts can implement this methodology to assess the potential impacts of investments in data improvement.

1.2 REPORT ORGANIZATION

The remainder of this report is organized into the following chapters:

- Chapter 2 provides an overview of the Fundamental Data Elements (FDEs) and presents the results of the literature review on the topic of benefits and costs of data investments.
- Chapter 3 details the benefit-cost analysis (BCA) methodology developed for assessing the investments in data collection.
- Chapter 4 provides an overview of the inputs required to perform the BCA and identifies both the benefits and costs.
- Chapter 5 presents the conclusions of this study and the key recommendations for developing additional tools to assist State transportation analysts.

CHAPTER 2—FUNDAMENTAL DATA ELEMENTS (FDE)

2.1 OVERVIEW

Recent safety policies require the use of data in roadway safety planning, but do not prescribe the use of a particular set of data elements. The 23 Code of Federal Regulations, in application of SAFETEA-LU, requires that States develop comprehensive, data-driven safety plans, known as Strategic Highway Safety Plans (SHSPs). States use these plans to analyze highway safety problems and opportunities, and evaluate the accuracy and priority of proposed improvements. As such, the SHSPs rely on accurate and timely safety data. However, this SAFETEA-LU requirement did not specify the kind of data to collect, the breadth and scope of the data collection effort to be undertaken, or the means by which States prioritize their data collection efforts. The lack of guidance within this SAFETEA-LU requirement led to a discussion between the FHWA and State DOTs regarding what data elements States should collect to develop SHSPs. This issue was also taken up by the Government Accountability Office in their report 09-035, *Highway Safety Improvement Program, Further Efforts Needed to Address Data Limitations and Better Align Funding with States' Top Safety Priorities regarding the HSIP (3).*

The FHWA has recommended several sets of data for use in analyzing safety issues. The most comprehensive list of data elements is the FHWA Model Inventory of Roadway Elements (MIRE), which includes over 200 roadway and traffic data elements intended to help transportation agencies improve their roadway and traffic data inventories. A full listing of MIRE data elements, as well as more information on MIRE, is available at www.mireinfo.org. Due to resource constraints, it is not feasible for most States to collect all of the MIRE elements. In response, FHWA held a series of workshops over the course of 2009 and 2010, and convened a Technical Working Group in 2010 and 2011 to determine the most relevant and useful subset of data elements for States to collect in support of the development and implementation of their State-level HSIPs.

This effort led to a consensus on a more limited set of data elements that State and local agencies should collect in support of their safety programs. First, States should develop a common statewide locational referencing system, such as a geographic information system (GIS) or linear referencing system (LRS), on all public roads. This will allow States to locate and rank high crash locations on all public roads in the State. As the States intensify their data collection programs, this system will allow them to link high crash locations with data on roadway conditions, geometry, and traffic data. Second, the group identified a subset of MIRE data elements, known as the Fundamental Data Elements (FDE), that are the most relevant and useful data for safety analyses. The full listing of these data elements is presented in Table 3.

Table 3. List of the FDE.

FDE	Definition
Roadway Segment	
Segment ID*	Unique segment identifier.
Route Name*	Signed numeric value for the roadway.
Alternative Route Name*	The route or street name, where different from route number.
Route Type*	Federal-aid/National Highway System (NHS) route type.
Area Type*	The rural or urban designation based on Census urban boundary and population.
Date Opened to Traffic	The date at which the site was opened to traffic.
Start Location*	The location of the starting point of the roadway segment.
End Location*	The location of the ending point of the roadway segment.
Segment Length*	The length of the segment.
Segment Direction	Direction of inventory if divided roads are inventoried in each direction.
Roadway Class*	The functional class of the segment.
Median Type	The type of median present on the segment.
Access Control*	The degree of access control.
Two-Way vs. One-Way Operation*	Indication of whether the segment operates as a one- or two-way roadway.
Number of Through Lanes*	The total number of through lanes on the segment. This excludes turn lanes and auxiliary lanes.
Interchange Influence Area on Mainline Freeway	The value of this item indicates whether or not a roadway is within an interchange influence area.
AADT*	The Average Annual Daily Traffic (AADT), or the average number of vehicles passing through a segment from both directions of the mainline route for all days of a specified year.
AADT Year*	Year of AADT.
Intersections	
Intersection ID	A unique junction identifier.
Location	Location of the center of the junction on the first intersecting route (e.g. route-milepost).
Intersection Type	The type of geometric configuration that best describes the intersection/junction.
Date Opened to Traffic	The date at which the site was opened to traffic.
Traffic Control Type	Traffic control present at intersection/junction.
Major Road AADT	The AADT on the approach leg of the intersection/junction of the major road.

Table 3. List of the FDE. (continued).

FDE	Definition
Major Road AADT Year	The year of the AADT data on the major road segment
Minor Road AADT	The AADT on the approach leg of the intersection/junction of the minor road.
Minor Road AADT Year	The year of the AADT data on the minor road segment
Intersection Leg ID	A unique identifier for each approach of an intersection.
Leg Type	Specifies the major/minor road classification of this leg relative to the other legs in the intersection.
Leg Segment ID	A unique identified for the segment associated with this leg.
Ramp/Interchange	
Ramp ID*	An identifier for each ramp that is part of a given interchange. This defines which ramp the following elements are describing
Date Opened to Traffic	The date at which the site was opened to traffic.
Start Location	Location on the roadway at the beginning ramp terminal (e.g. route-milepost for the roadway) if the ramp connects with a roadway at that point.
Ramp Type	Indicates whether the ramp is used to enter or exit a freeway, or connect two freeways.
Ramp/Interchange Configuration	Describes the characterization of the design of the ramp.
Ramp Length	Length of the ramp.
Ramp AADT*	AADT on the ramp.
Ramp AADT Year	Year of the AADT on the ramp.

* The full extent of the Highway Performance Monitoring System elements required on all Federal-aid highways and ramps located within grade-separated interchanges, i.e., National Highway System and all functional systems, excluding rural minor collectors and locals.

This set of FDEs was released to States in 2011 through an FHWA Office of Safety Guidance Memo, and in a separate report, *Background Report: Guidance for Roadway Safety Data to Support the Highway Safety Improvement Program*, which also provides information regarding potential uses of this data, estimated costs of collection, potential funding sources, and model performance measures *(4)*.

2.1.1 Actual and Potential Uses of the FDE

With respect to safety, the collection and analysis of this data is an essential part of the HSIP, including the developing an SHSP and the annual HSIP report. An HSIP generally consists of three components: planning, implementation, and evaluation *(5)*. The collection and analysis of safety data is an essential element of both the planning and evaluation of safety improvement measures. Figure 2 shows the steps of the highway safety improvement process:

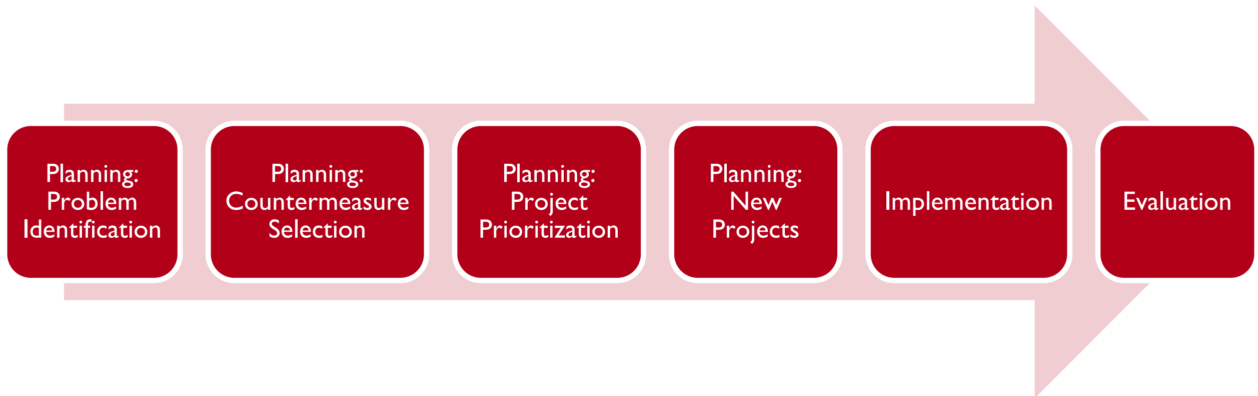

Figure 2. Steps in the Highway Safety Improvement Process.

Accurate and timely data are required to complete several of these steps, including the identification of sites, countermeasure selection, and project prioritization. Data are also integral to the evaluation of the effectiveness of countermeasures.

The first component, planning, is one of the most data intensive elements of the safety improvement process. Box 1 provides an overview of some of the most common methods for safety improvement location identification and prioritization methods.

Box 1. Example of Safety Problem Identification, Prioritization, and Countermeasure Selection Methods.

While SAFETEA-LU does not require States to use a specific method to identify and prioritize safety improvements, it does require States to "have in place a crash data system with the ability to perform safety problem identification and countermeasure analysis" *(6)*. The following are the 13 problem identification methods identified in the HSM. It should be noted that States are using additional methods not included in the HSM.

1. Average Crash Frequency – Sites are ranked based on the total number of crashes, or by a particular crash severity or type, during a given time period. The site with the highest number of crashes is ranked first.

2. Crash Rate – The crash rate normalizes the crash frequency based on exposure.

3. Equivalent Property Damage Only (EPDO) Average Crash Frequency – Each crash is weighted based on the crash severity and the equivalent property damage only crash cost.

4. Relative Severity Index – Average monetary crash costs are assigned to each crash at a site, and the total average crash cost for a site is compared to the average crash cost for the reference population.

5. Critical Crash Rate – A critical crash rate or threshold value is calculated for each site and compared to the observed crash rate. Sites with an observed crash rate greater than their critical crash rate are flagged for further investigation.

6. Excess Predicted Average Crash Frequency Using Method of Moments – With this method, the observed crash frequency for a site is adjusted based on the variance in the crash data and the average crash counts for a site's reference population, which is then compared to the average frequency of crashes for the reference population.

7. Level of Service of Safety (LOSS) – This method compares the observed crash frequency and/or severity to the mean value predicted for the reference population using a Safety Performance Function (SPF). The difference between the two values yields a performance measure that ranges between LOSS I and LOSS IV, with LOSS I indicating a low potential for crash reduction and LOSS IV indicating a high potential for crash reduction.

8. Excess Predicted Average Crash Frequency Using SPFs – This method represents the difference between the observed crash frequency for the site and the predicted crash frequency based on the SPF with information specific to the site.

9. Probability of Specific Crash Types Exceeding Threshold Proportion – This method is based on the probability that the long-term proportion of a specific crash type exceeds a threshold proportion for the site's reference population.

Box 1. Example of Safety Problem Identification, Prioritization, and Countermeasure Selection Methods. (continued).

10. Excess Proportion of Specific Crash Types – This is the difference between the observed proportion of a specific crash type for a site and the threshold proportion for the reference population.

11. Expected Average Crash Frequency with Empirical Bayes Adjustment – The expected crash frequency is calculated using a calibrated SPF, which is then weighted with the observed crash frequency using the Empirical Bayes (EB) method. The EB method accounts for regression to the mean bias.

12. EPDO Average Crash Frequency with EB Adjustment – This method combines the expected crash frequency method with EB adjustments and the EPDO crash frequency method. The expected crash frequency is calculated using a calibrated SPF and weighted with the observed crash frequency using EB, which is then weighted based on crash severity and the equivalent property damage only cost.

13. Excess Expected Average Crash Frequency with EB Adjustment – The expected crash frequency determined from an SPF is weighted with the observed crash frequency using the EB method. The resulting weighted crash frequency is then compared to the expected crash frequency using the SPF to determine the difference between the two values.

Adapted from Herbel et al., 2010 *(5)*.

Each of these problem identification methodologies has different data needs, strengths, and weaknesses. Table 4 summarizes the data needs of the 13 problem identification methods. Appendix A provides additional details.

Table 4. Data Needs for Safety Problem Identification Methods.

	Problem Identification Method	Data Inputs and Needs
1	Average Crash Frequency	• Crashes by type and/or severity and location.
2	Crash Rate	• Crash counts and location. • Average daily traffic volumes (ADT), total entering volume (TEV), or annual average daily traffic volumes (AADT).
3	EPDO Average Crash Frequency	• Crashes by severity and location. • Fatal, injury, and property damage over (PDO) crash weighting factors.
4	Relative Severity Index	• Crashes by type and location. • Crash costs by type.
5	Critical Crash Rate	• Crash counts and location. • AADT.
6	Excess Predicted Average Crash Frequency Using Method of Moments	• Crashes by type and location. • Traffic volume (AADT or ADT).
7	Level of Service of Safety	• A minimum of three years crash data. • Crashes by location. • SPF, overdispersion parameter, and all variable required for SPF.
8	Excess Predicted Average Crash Frequency Using SPFs	• A minimum of three years crash data. • Crashes by type, severity, and location. • Calibrated SPF.
9	Probability of Specific Crash Types Exceeding Threshold Proportion	• Crashes by type, severity, and location.
10	Excess Proportion of Specific Crash Types	• Crashes by type, severity, and location.
11	Expected Average Crash Frequency with EB Adjustment **	• A minimum of three years crash data. • Crashes by type, severity, and location. • Calibrated SPFs and overdispersion parameters.
12	EPDO Average Crash Frequency with EB Adjustment **	• A minimum of three years crash data. • Crashes by type, severity, and location. • Calibrated SPFs and overdispersion parameter. • Fatal, injury, and PDO crash weighting factors.
13	Excess Expected Average Crash Frequency with EB Adjustment **	• A minimum of three years crash data. • Crashes by type, severity, and location. • Calibrated SPF and overdispersion parameter.

Adapted from Herbel et al., 2010 *(5)*.
** Data Intensive Methods

Software developers are increasingly incorporating the methods for safety improvement selection and prioritization into the software models, which guide the analyst through the entire process. Some examples of software developed for this purpose include the American Association of State Highway and Transportation Officials (AASHTO) SafetyAnalyst, as well as models developed at the State level, such as Michigan's RoadSoft, and Iowa's SAVER and CMAT tools. These tools maintain the safety planning database, and may provide modules on network screening, diagnosis, countermeasure selection and evaluation, economic appraisal, and priority ranking.

The results of these analytical tools provide important inputs into the safety planning process and can help agencies develop prioritized safety improvement candidate lists (such as the HSIP "5 Percent" Transparency Reports) in support of the development of each State's SHSP. Models can also provide a common framework for analyzing safety improvements at the State, regional, and local levels.

It is important to note that the FDE (listed in Table 3) may be used in a wide set of roadway operations and planning functions. For example, these data elements might be helpful for asset management, pavement engineering, traffic engineering, local planners and metropolitan planning organizations (MPOs), county engineers, and emergency response units. Each of these entities will use the data in different ways to improve the efficiency of their business processes or the accuracy of their planning efforts. Benefits to these other entities are estimated for some, but not all categories, of benefits.

2.2 LITERATURE REVIEW

The literature review for this research effort focused on identifying literature pertaining to the economic costs and benefits of investing in data. This extensive search looked at sources within the transportation industry, and also expanded to fields outside of transportation including mathematics and statistics, forestry, medicine and health, ecology, water resources, and mining. The project team reviewed literature from these fields for any pertinent methodologies or findings that could be helpful to this research effort. The findings from this review, summarized in this section, contributed to the development the benefit-cost methodology detailed in Chapter 3.

The Colorado DOT conducted a study evaluating the statewide economic benefits of future transportation investments. The research investigated the benefits of additional transportation spending above what is needed to maintain current transportation performance levels. The researchers quantified certain benefits related to transportation improvements, including reduced congestion, pavement quality, safety improvements, and general system improvements. Other benefits (e.g., quality of life, new jobs, and better access to recreation) that they were unable to quantify for the economic analysis were still determined to have a positive impact *(7)*.

Several reports provided information on the cost of collecting roadway data. A 1998 report from the FHWA investigated the cost and quality issues associated with collecting and managing highway safety data *(8)*. In 2009, a North Carolina DOT research effort collected asset management data on 95 miles of roadway to determine the capabilities and limitations of automated roadway data collection systems. The researchers had various vendors collect a sampling of pavement, roadside, geotechnical, and bridge elements *(9)*. In a similar effort, the Transportation Research Board (TRB) Strategic Highway Safety Research Program (SHRP2) conducted a roadway data collection "rodeo" where vendors used mobile data collection units to collect over 100 roadway data elements *(10)*. Information from the vendors who participated in these data collection efforts was beneficial in developing cost estimates for the cost-benefit methodology.

FHWA recently published two reports on the previously mentioned FDE States should collect to support their safety programs. The Background Report provides information on the estimates of the costs of data collection, safety analysis tools and methods, and performance measures that should be implemented to achieve quality safety data *(4)*. The Market Analysis conducts an analysis of the potential cost to States in developing a statewide location reference system and collecting the fundamental data elements on all public roadways *(11)*. Data collection costs were collected from vendors and one State DOT. To determine the "benefits" of collecting safety data, the researchers estimated the number of fatalities and injuries that would need to be reduced in order to exceed the costs for a 1:1 and 2:1 benefit-cost ratio. The benefits estimations were determined for an average State for two different data collection scenarios. These two publications provided background information, as well as a starting point, for this research effort.

A recent study by Li et al. presented a methodology for a BCA of improving highway segment safety hardware over its life cycle. The researchers established a safety index by assessing the risk of vehicle crashes with safety-related attributes on the roadway segment. The researchers calculated an annual potential for safety improvements associated with improvements to the hardware and compared it to the number of collisions on the segment with and without hardware upgrades. The methodology outlined in this report relies on a sufficient amount of historical data, including vehicle crashes, highway system preservation, traffic operations, and expenditures, as well as data processing and analysis capabilities. Li's methodology was too specific for the purpose of this research effort, but is still relevant as it presents a vision on how future data efforts could be quantified, comparing locations without data and locations with data *(12)*.

The National Cooperative Highway Research Program (NCHRP) recently released the report, Determining Highway Maintenance Costs *(13)*. The report outlined a five-step process for an agency to determine the full cost of highway maintenance. The cost estimation included both line maintenance costs, and support maintenance costs. The line maintenance costs are the costs of completing the actual work, such as labor, equipment, and materials. The support maintenance costs include maintenance program costs (e.g., field management/supervision, program administration, training, building, and facilities), as well as enterprise support costs (e.g., executive management, planning, accounting, legal, human resources, and information technology). This report is applicable to roadway safety data, as data and data systems need maintenance and upkeep just like the transportation infrastructure. When determining the benefits of investing in roadway safety data, it is important to estimate the full cost of the data (collection, maintenance, updates, storage, etc.)

A 1997 article by Miller and Levy in the Injury Prevention journal introduced methods available for making a decision to invest in safety programs *(14)*. These methods included BCA, cost effectiveness analysis, and cost utility analysis. Two scenarios are used to walk the reader through the 11- or 12-step process for proper evaluation of the decision and investment strategy. The article cautions that, "When evaluating alternatives in a resource-constrained world, the highest benefit-cost ratio is not necessarily the best choice. An alternative may yield larger total benefits but at a slightly higher cost per unit of safety. When evaluating related alternatives, the incremental, rather than total cost and benefit, should be evaluated."

A 1997 paper by Moses and Savage investigated the BCA of two Federal programs to improve truck safety *(15)*. These programs were audits of the operating firms to investigate safety management practices and roadside inspections to check vehicles for compliance with Federal safety laws. To some degree, these audits and inspections were acts of data collection, which found vehicles that failed to comply with safety standards. One of the factors a State DOT should consider regarding safety data collection is the costs of acquisition of information and the mechanisms available for this acquisition. The lowest cost options that yield the best data are sure to improve any benefit-cost ratio by driving down the costs compared to other options. This paper discussed the steps taken to estimate the benefits of the audits in improved safety of the trucks and determine which, among two options, is the best (lowest cost, in this case) mechanism to acquire the information.

The Children's Safety Network provided an update in 2010 on "what works" for injury prevention *(16)*. While it did not discuss highway safety data, there was a section on motor vehicle safety intervention programs. The methodology used to determine "what works" included a BCA that presented the results in terms of benefit-cost ratio, and cost per quality adjusted life-years (QALY). The total benefits include the dollar value of medical costs, work loss, and lost quality of life costs. The cost per QALY includes only savings from medical costs and other tangible resources, but does not include quality of life savings. The paper reported Federal Road Safety Programs and Federal Traffic Safety Programs to have a benefit-cost ratio of 32.4 and 68.0, respectively.

The Intelligent Transportation System Deployment Analysis System Tool (IDAS) User Manual provides information about the costs and benefits of implementing Intelligent Transportation System (ITS) technologies, including safety-related benefits *(17)*. The IDAS safety sub-module estimates changes in the number and severity of crashes resulting from the implementation of ITS strategies. There are three types of incident management systems included in IDAS: (1) Incident Detection/Verification; (2) Incident Response/Management; and (3) Combination of Incident Detection/Verification/Response/Management. While the literature review implemented in the development of the IDAS tool did not find a statistically significant change in the overall crash rate related the deployment of incident management systems, the reduced time for incident detection/verification was shown to reduce the number of fatality crashes (with an increase in injury crashes).

Also from the ITS literature, the ITS Benefits and Costs Database of the USDOT Research and Innovative Technology Administration included a module on safety benefits of ITS technologies *(18)*. For example, the database reports that an Integrated Safety and Security Enforcement System for identifying high-risk heavy trucks contributed to a reduction of between 63 and 629 crashes, 16 and163 personal injuries, and about 7 fatalities per year.

A 2005 National Oceanic and Atmospheric Administration (NOAA) report presented a methodology for valuing the benefits from information *(19)*. The purpose of the study was to estimate the economic benefits from a Physical Oceanographic Real-Time System (PORTS®) installation. While the actual results of this particular study were not relevant to this effort, the methodology used to value the benefits from information was consulted for this study.

The authors of the NOAA report categorize benefits according to their ability to be quantified with varying degrees of confidence, ranging from those with direct observable evidence that can be quantified with a high degree of confidence, to those benefits that are more speculative and might only be realized with a change in how users use the data. Most benefits are quantified in the nature of avoided costs (increased producer surplus, or profit) for commercial operations and avoided costs or increased consumer surplus, including nonmarket benefits, for recreational users.

In the description of the methodology, the NOAA report provides an overview of the economics of information. In this description, the authors propose that the standard economic approach to valuing information requires:

- A description of the information being valued and of the state of knowledge about the phenomena or conditions it describes.
- A model of how this information is used to make decisions.
- A model of how these decisions affect physical outcomes.
- A model of how physical outcomes can be translated into economic outcomes.

Following this description, the NOAA paper suggests a model based on the Bayesian approach which describes various outcomes of a decision-making process in the presence of more or less information.

A 1996 report by van Wegan and de Hoog outlined an approach that combines the information commodity approach, activity-based costing, and graph modeling to determine the value of information systems for information management *(20)*. This method, however, is not designed to quantify benefits other than those that result from increased efficiency. It also does not involve the concept of uncertainty and risk in the analysis.

A paper by Ling et al. introduced the principles of information economics to guide decisions on information collection. The authors investigated how designers can calculate the bounds on the value of information using distributions with unknown parameters and imprecise probabilities to characterize the current state of information. The researchers made the case that this method can have an impact on engineering design by including more problem classes in formal cost-benefit analyses. By doing so, it can help guide expenditures for information gathering where decisions are largely based on difficult-to-characterize events *(21)*.

Most of the literature reviewed did not contain information directly relevant to developing a methodology for this type of cost-benefit analysis; however, there were a few resources that did provide useful information. The FHWA market analysis served as a base for this effort, while the information gathered from different types of BCAs that have been conducted were used to help develop a benefit-cost methodology detailed in the following chapter.

CHAPTER 3—BENEFIT-COST ANALYSIS METHODOLOGY

3.1 INTRODUCTION TO BENEFIT-COST ANALYSIS

BCA is a process used to assess the economic viability of projects. In BCA, an analyst estimates the total benefits and costs of a project, compares total benefits with total costs, and recommends the implementation of the project if benefits exceed the costs, often by an established ratio, such as 2:1. As adapted from FHWA's *Economic Analysis Primer (22)* the basic steps to BCA include:

1. Define scenario(s) for analysis.
    a. Establish objectives.
    b. Identify constraints and specify assumptions.
    c. Define base case and identify alternatives.
2. Establish the framework for analysis.
    a. Set analysis period.
    b. Determine appropriate discount rate.
    c. Define the level of effort for screening alternatives.
3. Analyze effects.
    a. Define the major categories of benefits and costs.
    b. Determine which benefits and costs are quantifiable.
4. Estimate benefits and costs.
    a. Generate predicted costs and benefits for each category of quantifiable benefit and cost.
    b. Convert into common units.
    c. Calculate present values.
    d. Calculate total net benefits.
    e. Evaluate risk.
5. Evaluate and make recommendations.
    a. Convert into common units.
    b. Evaluate risk.
    c. Calculate present values.
    d. Calculate total net benefits and costs.
    e. Calculate benefit-cost (B/C) ratio.
    f. Rank alternatives.
    g. Make recommendations.

Agencies can apply this standard approach to almost any significant investment project. The following section provides a description of how this approach would be applied specifically to the data collection projects associated with roadway safety.

3.2 BCA FRAMEWORK FOR SAFETY-RELATED ROADWAY DATA

Using the basic BCA approach outlined in the previous section, this section provides a framework for State and local transportation agency to conduct a BCA of their roadway safety program. The methodology established here is the first of many steps that will ultimately provide States with the best information and knowledge available to facilitate safety data investment decision-making. The framework proposes a set of potential benefits and costs, and a potential method to calculate these benefits and costs. Depending on the nature of the data collection programs, individual State and local agencies may need to adapt this approach to match the specification of their programs. A complete step-by-step implementation guidebook is available as a stand-alone companion to this report.

The remainder of this chapter discusses how to adapt the BCA methodology to the analysis of data collection projects associated with roadway safety. This includes the following procedures: (1) define the scenario; (2) establish the framework; (3) analyze the effects; (4) estimate the benefits and costs; and (5) evaluate and make recommendations.

3.2.1 Define Parameters and Scenario for Analysis

In order to conduct a BCA, the analyst first needs to define the objectives of the project to be undertaken and the constraints faced by the agency in undertaking the work. Defining the objective of the data collection project will help determine the scope of activity, and the benefits and costs of the project. For example, one project might have an objective focusing on the collection of data at intersections, while another might focus on ramp data. Determining the clear objective of the project will help limit the analysis to only those projects that most closely target the objectives sought.

It is also important to identify any constraints and assumptions that could affect what alternatives the agency might accept. For example, an agency may wish to perform a pilot data collection effort prior to implementation on a larger scale. Alternatively, an agency may have made the strategic decision to focus its data collection primarily on urban and Federal-aid roads, rather than on local roads.

On the basis of the defined project objectives and constraints, the analyst will define both a status quo case (base case), as well as one or more alternatives. The base case represents the continued operation of the current facility under good management practices but without major investments in data collection. As a central part of the BCA, the analyst will compare the projected benefits and costs of alternative projects, such as investments in data collection for roadway segments, intersections, ramps, or a linear referencing system, to those of the base case.

3.2.2 Establish the Framework for the Analysis

In order to conduct the benefit and cost estimates, the analyst will need to define the overall framework for the analysis. Elements of the framework include the project life, or the number of years over which the benefits and costs of the project will be evaluated, the appropriate rate at which to discount future streams of benefits and costs, and the appropriate level of effort for screening alternatives.

In a BCA it is important to define the life of the safety data collection program in order to distribute initial investments over the expected life of the investment, and to compare the stream of benefits over the same period. The cost estimates undertaken as a part of FHWA's *Market Analysis of Collecting Fundamental Roadway Data Elements* assumed a life-cycle of about 20 years *(11)*. This timeframe would allow for a 10-year roll out period for data collection (for non-Federal-aid roads) and an additional 10 years of implementation. Individual State DOT's project life of their data collection program may differ depending on the specifics of their program.

Future costs and future benefit streams are discounted to the current year using a common discount rate. If a State DOT has a specific assumption used to evaluate benefits and costs for other roadway investment projects, the analyst may choose to use this discount rate. If the State DOT does not have an established BCA discount rate, they may choose to adopt the 7.0% discount rate used in the FHWA *Market Analysis of Collecting Fundamental Roadway Data Elements (11)*, based on OMB guidance Circular A-94 *(23)*.

Also, it is important for the analyst to define the level of effort for undertaking the analysis prior to setting out to calculate benefits and costs. The effort spent on quantifying benefits and costs should be proportional to the expense, complexity, and controversy of the project. Smaller projects should attempt to use a less complex process. One way to reduce the effort on any BCA is to screen all alternatives prior to conducting the analysis to ensure that only the most promising alternatives are examined in detail.

3.2.3 Analyze the Potential Effects

The analyst will then consider the major effects of a project in terms of benefits and costs. This analysis should include both the implementation and operation of a project, and should lead the analyst to determine the major categories of benefits and costs. Benefits may include those directly targeted by a program, as well as secondary benefits that are likely to occur once an agency implements a project. Costs should include both the starting and operating costs of the project over the project life. In both cases, the analyst should estimate the benefits and costs over the life of the project. Benefits and costs can be put in monetary or non-monetary terms.

Table 5 includes some of the major categories of potential benefits of safety data programs. Table 6 lists some of the major categories of potential costs of safety data programs. These benefits and costs are based on the steps of the highway safety improvement process.

Table 5. Potential Benefits from Safety Data.

Stage	Step	Benefit from Data	Quantifiable?
Planning	Project Identification	• Reduced staff time due to existence of list of potential sites. • More rapid deployment of safety improvement due to quicker identification of potential sites for safety improvement projects.	Yes
	Countermeasure Selection	• More appropriate and more optimal selection of countermeasures for sites.	No
	Project Prioritization	• Improved ability to target those sites with the highest crash reduction potential.	Yes
	New Projects	• Some projects may not be able to be undertaken without the additional information provided by data.	N/A
Implementation	Implementation	• Earlier implementation.	Yes
Evaluation	Evaluation	• Reduced staff time due to more efficient evaluation of efficacy of safety improvements.	Yes

Table 6. Potential Costs of Safety Data.

Type of Costs	Unit of Analysis	Quantifiable?
Investment Costs	• Roadway. • Intersection. • Ramp. • LRS.	Yes
Operations and Maintenance Cost	• Roadway. • Intersection. • Ramp. • LRS.	Yes
Costs for Coding and Locating Crashes	On a per crash basis.	Yes
Other Costs (i.e. Data Storage, Cost of Analysis)	By other unit.	Yes

After the analyst creates an exhaustive list of potential benefits and costs, they will then determine which benefits and costs are quantifiable. The analyst must consider which are quantifiable with a reasonable level of accuracy, and which they can consider unquantifiable. Non-monetary benefits and costs, such as lives saved, may be quantifiable through assignment of a monetary value based on accepted sources. In addition, the analyst should consider the projects they would not be able to identify if the data collection effort is not undertaken.

For the benefits listed in Table 5, the analyst may consider that the following benefits would be quantifiable:

- **More efficient project identification.**
  - Reduced staff time.
  - Faster project programming.
- **Improved project prioritization.**
  - Better targeting of safety improvements.
- **Streamlined evaluation.**
  - Reduced staff time.

At this time, the improvement of countermeasure selection is not quantifiable. For the costs listed in Table 6, all might be considered quantifiable.

3.2.4 Data Availability and Estimation Methods

The method to calculate the benefits and costs of safety data will vary based on the amount of data available for a given State. A State that already collects all of the data elements for at least some of their system may be able to undertake some, or all, of the analysis using the data they already collect. These "High Data Collection States" may also choose to conduct an ex-post evaluation of the effectiveness of the data collection efforts already undertaken. Some "Medium Data Collection States" may collect some, but not all, of the FDEs. These States may choose to extrapolate the effects of the collection of these data elements to the collection of all data elements, or may choose to create a representative sample database of information borrowed from another State with a more extensive data collection program. Medium Data Collection States might also choose to conduct a pilot data collection effort on a small sample of roadways to gather sufficient data to undertake the analysis. A similar approach might be taken for "Low Data Collection States," which collect only the minimum HPMS required data.

To support the calculation of the benefits and costs of data collection for Low and Medium Data Collection States, it may make sense to create national average benefits to improve the ease and cost-effectiveness of this type of analysis in the future. Table 7 provides a synthesis of potential approaches for developing a dataset to undertake the analysis. When relevant, the following description of the proposed methodology for estimating benefits will also provide guidance on how States with different levels of data availability might adjust the proposed methodology to suit their needs.

Table 7. Potential Approaches to Developing Dataset for Analysis.

Category	Calculate benefits based on own data only	Collect representative sample of data from own State	Create representative sample of data from national or other State's data	Use national average benefits (not currently available)
High Data Collection	x			x
Medium Data Collection		x	x	x
Low Data Collection		x	x	x

Several States may not currently have the level of data required to estimate benefits in the manner prescribed in this memo. While it is always the best solution to use directly observed data to conduct an evaluation of benefits, in many instances efforts at data collection can be cost-prohibitive or subject to a variety of time constraints. With a national benefits estimator, States can adjust the national average values according to the particulars of their State.

As discussed above, one option to estimate benefits and costs is to construct a representative sample of roadways, ramps, and intersections from the other States' data. Agencies can use the methods described in the memo on pooled national data to derive national averages for benefits from specific types of data. With a generic national estimate on the benefits of data collection on a per-mile, per-ramp, or per-intersection basis, States could have a benchmark upon which to base their own investments in segment, ramp, and intersection data. As illustrated in Table 7, all States could benefit from having a national benefits estimator, whether they are classified as a having a high, medium, or low level of data collection.

A State might base their entire analysis on these national average benefits, or may use the national average benefits to fill in for gaps in data collection. If a State had no data, they could apply the national averages to their system by multiplying the average per-mile, per-intersection, or per-ramp benefit times the number of miles, intersections, or ramps. If a State had all required data for its road segments and ramps but not for its intersections, then it could use national average benefits from intersection data collection on a per-intersection basis to approximate the benefits from collection of intersection data for the State. This approach would yield benefit figures more accurate for their State than only applying the national average benefit figures.

This technique of transferring benefits from a similar source, in this case a national average instead of State-specific data, is a well-established practice in economics *(24, 25, 26)*. In many practical areas, adequate data does not exist to perform rigorous economic analysis. Instead of abandoning the analysis altogether for lack of data, proxy data are used that are as similar to the initially-sought data as possible.

A national benefits estimator can allow States to perform BCAs prior to expending resources on direct data collection. However, the development of a national benefits estimator is not covered in this project. Additional effort is required at the national level to determine the individualized benefits of investment in various safety data from pooled national averages.

3.3 ESTIMATING BENEFITS AND COSTS

Once the major categories of benefits and costs are defined, the analyst will calculate total benefits and costs of the project for each year of the project life, whether or not benefits and costs are monetary or non-monetary in nature. Some calculations may be straightforward, such as cost estimates based on the prices quoted by vendors. Other calculations may be more complex and will require the analyst to make certain assumptions. The following sections provide a suggested approach for calculating the most common quantifiable benefit and cost categories.

3.3.1 Benefits

According to the benefit framework described above, the analyst will quantify the following categories of benefits: more efficient project identification, faster project programming, improved project prioritization, and streamlined evaluation.

Reduced Staff Time from More Efficient Project Identification

There are two potential benefits of safety data during the project identification stage of the safety improvement process. The first is a reduction in the staff time needed to identify potential sites due to the existence of the database. Second, the initial stage of the safety improvement process will pass more rapidly since the agency will be able to identify projects quicker, and in turn implement the countermeasures quicker. This will reduce the time it takes to move from planning for safety improvements to the actual implementation of safety improvements.

The first benefit is more straightforward and is easier to calculate. In the absence of the data collection system, staff may need to undertake time-consuming indirect estimate techniques to derive and double check the information needed to identify potential safety improvement projects. For example, the Iowa DOT has one staff member fully devoted to developing reasonable information for missing roadway and intersection data based on derivation from other datasets and cross-checking. When multiple offices within the same agency use the same or similar data elements, this effort may be duplicated due to the absence of an officially accepted dataset. For example, the office of asset management may have one method of backing out the needed data, while the safety office may use another method. Time may be saved across multiple offices through the collection of additional data elements.

The analyst should speak to staff in relevant offices to see how they are coping with the lack of the targeted data elements. Through these conversations, the analyst should define how many yearly hours of full time equivalent (FTE) labor the agency would save, and assign an average hourly rate to this saved labor. Different offices might apply a common hourly rate, or may choose different hourly rates.

Table 8 provides an example of business process savings from data collection for an example State DOT. These rates are for exemplary purposes only to demonstrate how to do the necessary calculations. Agencies should not use them as defaults; agencies should use their own rates.

Table 8. Reduced Staff Time in Project Identification.

Department	Number of annual FTE Staff Hours Saved	Hourly Rate	Total Annual Savings
Safety Investment Planning	480	$95	$45,600
Highway Investment Planning	960	$95	$91,200
Asset Management	80	$95	$7,600
Traffic Engineering	80	$120	$9,600
Pavement Engineering	80	$120	$9,600
MPO and Local Planners	160	$95	$15,200
County Engineers	960	$95	$91,200
Emergency Response	160	$50	$8,000
Total	**2,960**	**---**	**$278,000**

Excess Crash Savings from Faster Project Programming

In addition to the change in the number of staff hours required to undertake the project identification process, additional data collection would reduce the lag between the beginning of a safety improvement initiative and the actual implementation of safety improvements on a State's roadways. The highway safety improvement program decision-making process involves identifying the problem sites, selecting appropriate countermeasures, prioritizing projects, programming the funding, and completing construction. The lack of a data collection system and readily available data creates a lag in this process. The time spent collecting and analyzing data delays the implementation of countermeasures. To evaluate the potential impact of faster project programming resulting from the availability of data, the analyst should estimate the excess crash savings. For this analysis, excess crashes are defined as the incidents that may have not occurred if safety projects were programmed more quickly than traditional time horizons due to the availability of data.

To develop the excess crash-savings estimates, the analyst will need to complete a multi-step process and collaborate with State DOT staff to develop assumptions and collect data. First, the analyst will need to determine the length of time from the identification of a safety problem location to the completion of construction of the improvement projects, and where the State needed to collect data for these projects. Project categories will include one roadway segment, ramp, and intersection improvement. The analyst will also compile before and after crash data for these sample sites. Data for two to three years before and after the project completion is required. This exercise will provide before and after reference points.

The analyst will then collaborate with DOT staff to develop an assumption of how much earlier, if any, programming decisions could have been made if the data elements were available. These assumptions will then be applied to the sample sites to calculate the number of crashes that, in theory, occurred as a result of the lag time. The following equation demonstrates this approach:

$$C_{ij} = L * (M_0 - M_1)_{ij}$$

Where:

C_{ij} = *Excess Crashes*

i = Crash severity by Maximum Abbreviated Injury Severity (MAIS) score

j = Infrastructure category (intersection, road segment, ramp)

L= Reduction in months of lag

M_0 = *Average monthly crashes prior to improvement*

M_1 = *Average monthly crashes after improvement*

The analyst will need to calculate these estimates by crash severity, according to the MAIS scale: 0-not injured, 1-minor, 2-moderate, 3-serious, 4-severe, 5-critical, and 6-maximum (fatal).

The value of avoided crashes used in this analysis is comprehensive; it includes numerous direct and indirect costs associated with crashes *(27)*. Included in this comprehensive value are the costs of:

- **Property Damage** – value of vehicles, cargo, roadways and other items damaged in traffic crashes.
- **Medical Expenses** – cost of all medical treatment associated with motor vehicle injuries.
- **Emergency Service Costs** – police and fire department response costs.

- **Insurance Administration** – administrative costs associated with processing insurance claims resulting from motor vehicle crashes and defense attorney costs.
- **Travel Delay** – value of travel time delay for persons who are not involved in traffic crashes, but who are delayed in the resulting traffic congestion from these crashes.
- **Legal Costs** – legal fees and court costs associated with civil litigation resulting from traffic crashes.
- **Workplace Costs** – costs of workplace disruption that is due to the loss or absence of an employee. This includes the cost of retraining new employees, overtime required to accomplish work of the injured employee, and the administrative costs of processing personnel changes.
- **Market Productivity** – present discounted value of the lost wages and benefits over the victim's remaining life span.
- **Household Productivity** – present value of lost productive household activity, valued at the market price for hiring a person to accomplish the same tasks.
- **Quality Adjusted Life-Years** – present discounted value of the reduction in the quality of life for a victim of a crash compared to the expected quality of life of an uninjured individual.

It is important to note that, as of the release of this report, the reference this information was based on is being updated. Values should be updated upon release of the updated resource. If an analyst were to decide to use a less comprehensive measure of the value of avoided benefits, these other aspects of the costs of crashes should also be estimated.

Using control data from sites with similar improvements, the analyst will scale down the total number of crashes so that only a proportion will be assumed as excess crashes. The analyst will then look at the past several years of highway safety improvements and estimate the average number of roadway segment, intersection, and ramp improvements per year. On this basis, the analyst can determine the system wide estimates of the excess crashes.

Finally, the analyst will monetize the costs of these excess crashes using the National Highway Traffic Safety Administration (NHTSA) comprehensive cash cost estimates *(27)*. Crash costs are measured by the MAIS scale, mentioned above. The resulting dollar values may then be considered the value of accelerated safety analysis and project programming resulting from data system investments. Further, as crashes are avoided from the timely implementation of safety improvement programs, discounting is an inherent part of this issue. Thus it is important to properly discount both the benefits and costs to present value once they have been monetized.

Excess Crash Savings from Improved Project Prioritization

SAFETEA-LU requires that States collect certain data elements deemed necessary to implement or improve upon existing Sate safety programs. However, if a State is uncertain of the value of data collection, or if a State is having difficulty justifying the allocation of resources to data collection projects, the following section provides an example of an approach a State DOT may take in order to determine the value of the information provided by data collection. Such an exercise should prove that more information provides States with a better basis for decision-making and more efficient resource allocation.

The collection of the FDE will help to improve project prioritization, contributing to better targeted safety investments and, as a consequence, improved safety outcomes. Figure 3 provides a visual representation of this relationship.

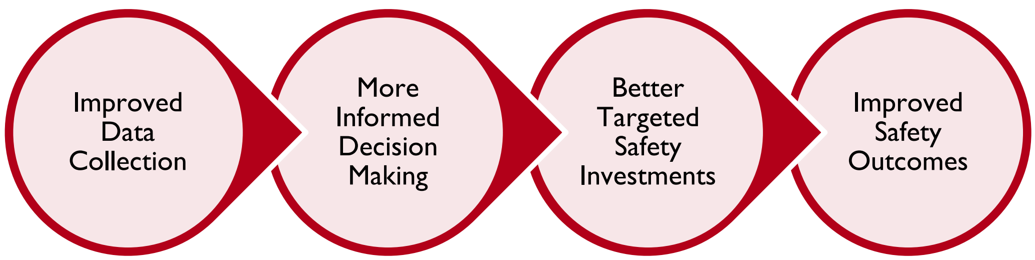

Figure 3. Role of Improved Data Collection Efforts in Safety Outcomes.

Agencies have a limited budget to allocate to safety improvement projects. It is important that decision makers have adequate information on the effectiveness of various safety improvements to improve safety outcomes. The improvements in decision-making will be the result of more robust network screening, safety improvement candidate location ranking, and countermeasure selection. Improved knowledge on the effectiveness of proposed countermeasures will help decision makers to better target investments towards those interventions which provide the highest returns in reduced crashes and fatalities relative to the project cost.

This analysis will only be useful if the data the State is planning to collect will enter into the project prioritization process. To assess the benefits of the availability of additional data for improved project prioritization, the analyst will need to conduct two sample evaluations of roadway safety improvement candidate locations, one with the additional data included in the safety data collection project, and one without the additional data.

An agency will need to meet a number of pre-conditions in order to estimate the benefits of data to improve project prioritization. First, the agency will need all data elements collected for a subset of roadways which have been involved in a safety improvement project at least two to three years ago. This could be a sample of roadways from the State's own roadway system that is comparable to the total set of roadways for which data will be collected. The agency might gather the data through alternative means (such as Google Earth) on a sample of roadway segments, intersections, and ramps in order to undertake the analysis. Alternatively, if the agency has not yet collected, or does not yet collect the relevant data elements, they may need to access the data of another agency to conduct the analysis. This “borrowed” data sample should be comparable to the roadways for which the agency will collect the data. This borrowing approach could provide States with an illustration of value of investments in data collection and a justification for allocating resources to additional data collection efforts, without the State first having to invest in a data collection project of its own. This may be particularly appealing to States that have not often invested many resources in the past for data collection.

The analyst should apply this comparative analysis to a data set that includes a list of sites where the agency has made safety improvements, and for which there are two to three years of crash performance data, both before and after the safety improvement. The analyst should identify the cost of the safety improvements at each of these sites. For the purpose of this report, this process was done only on roadway segments. In actual application, the analyst would repeat this process for intersections and ramps.

The analyst will begin by applying the method for safety improvement candidate prioritization and selection that the agency has used in the past, without the assistance of the additional data elements. This method may include one or some combination of the methods described in Box 1 on page 12. The analyst should base the ranking of sites on the crash record and road characteristics prior to the safety improvement. The application of the method will result in a ranking of sites.

The analyst will then conduct a second ranking exercise, using the new method for safety improvement candidate prioritization and selection that incorporates the additional data. Again, the analyst should rank the sites based on the crash record and road characteristics prior to the safety improvement. This may include a variation of one of the previously mentioned methods, or the use of a specialized tool, such as SafetyAnalyst.

Depending on the scope of the evaluation, the analyst will compile a table with information for the top 20 to 50 sites in both ranking exercises. This table should include the following information:

- Average annual frequency of road crashes on each segment by crash category prior to the safety improvement (with at least two to three years of data).
- Average annual frequency of road crashes on each segment by crash category after the safety improvement (with at least two to three years of data).
- Cost of the safety improvement.

- Locally accepted average cost of crashes by type.

Using the two rankings, the analyst will set a fixed budget for safety improvements, for example $15 million. This budget should be set in proportion to the size of the sample of roadways used. For example, if the sample is ¼ of the size of the list normally examined for roadway safety improvement planning, then the budget should also be about ¼ of the annual budget available for safety improvement. Working from the highest to the lowest ranked project on the old ranking list, the analyst will add projects until they reach the $15 million threshold. This will be the bundle of interventions selected using the old data and methods, referred to as the "old bundle". Again, working from the highest to the lowest ranked project on the new ranking list, the analyst will add projects until they reach the $15 million threshold. This will be the bundle of interventions selected using the new data and methods, referred to as the "new bundle".

Table 9 shows an example of this creation of the new and old bundles. The highlighted cells show the improvements that have been selected under the two ranking .methods.

Table 9. Sample of Ranking Exercise

Road Segment Number	Ranking Old Method	Ranking New Method	Cost of Safety Improvement
1	6	4	$500,000
2	17	13	$400,000
3	13	14	$475,000
4	11	11	$400,000
5	2	1	$1,250,000
6	14	17	$450,000
7	4	5	$1,750,000
8	9	2	$200,000
9	16	3	$200,000
10	7	6	$1,950,000
11	19	18	$500,000
12	20	19	$15,000
13	18	20	$450,000
14	5	7	$1,000,000
15	12	15	$500,000
16	1	8	$3,000,000
17	8	10	$1,750,000
18	3	9	$3,000,000
19	15	12	$400,000
20	10	16	$600,000

For the old bundle and the new bundle, the analyst will calculate the total crash reductions by category associated with these bundles, and assign a monetary value to this crash reduction, based on the accepted value of crash by type.

Table 10 shows a list of all the ranked road segments with information on the change in average annual crashes associated with an improvement to that road segment.

Table 10. Crash Performance of Ranked List.

Road Seg. No.	Ranking Old Method	Ranking New Method	Average Annual Crashes 2-3 Yrs Before Improvement			Average Annual Crashes 2-3 Yrs After Improvement			Change in Average Annual Crashes		
			MAIS 0-1	MAIS 2-4	MAIS 5-6	MAIS 0-1	MAIS 2-4	MAIS 5-6	MAIS 0-1	MAIS 2-4	MAIS 5-6
A	B	C	D	E	F	G	H	I	J = G – D	K = H – E	L = I – F
1	6	4	3	8	0	1	6	0	-2	-2	0
2	17	13	3	7	0	1	6	0	-2	-1	0
3	13	14	3	7	0	1	6	0	-2	-1	0
4	11	11	6	10	0	3	9	0	-3	-1	0
5	2	1	0	8	6	0	7	5	0	-1	-1
6	14	17	3	7	0	1	6	0	-2	-1	0
7	4	5	16	8	0	7	2	0	-9	-6	0
8	9	2	3	7	0	0	6	0	-3	-1	0
9	16	3	2	7	0	2	6	0	0	-1	0
10	7	6	19	3	4	21	5	3	2	2	-1
11	19	18	20	7	0	19	6	0	-1	-1	0
12	20	19	3	5	0	2	5	0	-1	0	0
13	18	20	20	7	0	19	6	0	-1	-1	0
14	5	7	3	10	0	1	6	0	-2	-4	0
15	12	15	3	7	0	1	6	0	-2	-1	0
16	1	8	2	5	4	2	1	3	0	-4	-1
17	8	10	3	5	2	2	8	1	-1	3	-1
18	3	9	11	5	4	11	4	3	0	-1	-1
19	15	12	3	7	0	1	6	0	-2	-1	0
20	10	16	7	8	0	0	7	0	-7	-1	0

Table 11 aggregates the total crash reduction potential by crash type associated with the new and old bundles of safety improvements. As shown in the table, the old bundle of interventions was more effective at reducing minor crashes than the new bundle. The old bundle is associated with an average annual reduction of 19 MAIS category 0-1 crashes, compared with a reduction of 17 crashes by the new bundle. In contrast, the new bundle is more effective in reducing moderate crashes. The new bundle is associated with a reduction of 20 MAIS 2-4 level crashes compared with a reduction of 16 by the old bundle, and a reduction of 8 MAIS 5-6 crashes for the new bundle, compared with 5 for the old bundle. These numbers are referred to as the marginal change in excess crashes. The analyst will then multiply the number of excess crashes by the cost of the relevant crash severity to determine the monetary value of the crash reductions associated with that bundle. As shown in Table 11, the old bundle is associated with avoided crashes worth $37,720,318, while the new bundle is associated with avoided crashes worth $56,309,275.

Table 11. Comparison of Crash Reduction Potential of New and Old Bundles.

Method	Total Avoided Crashes by Severity			Value of Avoided Crash (VAC) by Severity			Total VAC
	MAIS 0-1	MAIS 2-4	MAIS 5-6	MAIS 0-1	MAIS 2-4	MAIS 5-6	
Old	19	16	5	$12,811	$691,351	$5,283,059	$37,720,318
New	17	20	8	$12,811	$691,351	$5,283,059	$56,309,275
Difference	**-2**	**4**	**3**	**---**	**---**	**---**	**$18,588,958**

Source: MAIS Values provided by NHTSA.

The difference between the value of the avoided crashes of the old and new bundles is the value of the new safety data for improvement in safety for commercial and personal vehicles on an annual basis. As shown in Table 11, the value of data in improving roadway safety via improved decision-making is about $19 million for the sample of roadways in this example. Table 13 (on a subsequent page) provides the entire ranking and valuation process in a single spreadsheet.

The analyst will need to expand the value of the sample to represent the total value for the entire roadway system. This expansion factor will be the same factor used to determine the budget size for the ranking exercise. For example, if the sample used in the ranking exercise would be ¼ of the size of the list normally examined for roadway safety improvement planning, then the expansion factor for the benefits should be four. Table 12 demonstrates the application of the expansion factor to the annual benefit estimate from the sample.

Table 12. Value of Data in Decision-Making for Entire System.

Method	Total Value of Crash Reduction of Sample	Expansion Factor	Estimated Total Crash Reduction for System
Old Method	$37,720,318	4	$150,881,270
New Method	$56,309,275	4	$225,237,100
Difference Old and New Method	**$18,588,958**	**4**	**$74,355,830**

Suggestions for adapting this methodology to Low and Medium Data States are described in Box 2.

Box 2. Estimating Improved Roadway Safety Benefits for Low and Medium Data States.

States with relatively small data collection programs may not have sufficient data to conduct this analysis for even a small sample of roadways. If funds are not available to undertake a small data collection effort to conduct this analysis, a Low or Medium Data State may construct a sample from a High Data State. The analyst constructing this sample should, as much as possible, select the road segments and intersections to be included that match the characteristics of the State's own system. For example, the analyst may want to ensure that the percent of rural and urban road segments are roughly equivalent between the sample and the State's road system.

This process of constructing a sample data set, or collecting data on a sample of roadways, may be expensive and time consuming. If there is sufficient interest among State DOTs, it may be a good idea to construct national multipliers for improvements in roadway safety related to data. These national multipliers could be constructed on a per-mile, intersection, and ramp basis, to allow the benefits to be scaled up or down to any size State. Separate multipliers might be obtained for roadways and intersections of different types. Additionally, adjustment factors could be proposed for States with certain distinctive attributes (mountainous, extreme weather conditions, etc.).

Table 13. Sample of Base Case and Alternative Case Decisions on Safety Improvements.

Seg. No.	Old Rank	New Rank	Cost of Safety Improvement	Average Annual Crashes 2-3 Yrs before Improvement			Average Annual Crashes 2-3 Yrs After Improvement			Change in Average Annual Crash			Value of Reduction per Crash Type			Total Value of Crash Reductions	Value/Cost Ratio
				MAIS 0-1	MAIS 2-4	MAIS 5-6	MAIS 0-1	MAIS 2-4	MAIS 5-6	MAIS 0-1	MAIS 2-4	MAIS 5-6	MAIS 0-1	MAIS 2-4	MAIS 5-6		
A	B	C	D	E	F	G	H	I	J	K = H – E	L = I – F	M = J – G	N = K * VAC1	O = L * VAC2	P = M * VAC3	Q = (N+O+P)	
1	6	4	$500,000	3	8	0	1	6	0	-2	-2	0	-$25,622	-$1,382,702	$0	-$1,408,324	-2.82
2	17	13	$400,000	3	7	0	1	6	0	-2	-1	0	-$25,622	-$691,351	$0	-$716,973	-1.79
3	13	14	$475,000	3	7	0	1	6	0	-2	-1	0	-$25,622	-$691,351	$0	-$716,973	-1.51
4	**11**	**11**	$400,000	5	8	1	3	5	0	-2	-3	-1	-$25,622	-$2,074,053	-$5,283,059	-$7,382,734	**-18.46**
5	2	1	$1,250,000	0	8	6	0	7	5	0	-1	-1	$0	-$691,351	-$5,283,059	-$5,974,410	-4.78
6	14	17	$450,000	3	7	0	1	6	0	-2	-1	0	-$25,622	-$691,351	$0	-$716,973	-1.59
7	4	5	$1,750,000	16	8	0	7	2	0	-9	-6	0	-$115,299	-$4,148,106	$0	-$4,263,405	-2.44
8	9	2	$200,000	3	7	0	0	6	0	-3	-1	0	-$38,433	-$691,351	$0	-$729,784	-3.65
9	**16**	**3**	$200,000	0	8	2	2	6	0	2	-2	-2	$25,622	-$1,382,702	-$10,566,117	-$11,923,197	**-59.62**
10	7	6	$1,950,000	19	3	4	19	4	3	0	1	-1	$0	$691,351	-$5,283,059	-$4,591,708	-2.35
11	19	18	$500,000	20	7	0	19	6	0	-1	-1	0	-$12,811	-$691,351	$0	-$704,162	-1.41
12	20	19	$15,000	3	5	0	2	5	0	-1	0	0	-$12,811	$0	$0	-$12,811	-0.85
13	18	20	$450,000	20	7	0	19	6	0	-1	-1	0	-$12,811	-$691,351	$0	-$704,162	-1.56
14	5	7	$1,000,000	3	10	0	1	6	0	-2	-4	0	-$25,622	-$2,765,404	$0	-$2,791,026	-2.79
15	12	15	$500,000	3	7	0	1	6	0	-2	-1	0	-$25,622	-$691,351	$0	-$716,973	-1.43
16	1	8	$3,000,000	2	5	4	2	1	3	0	-4	-1	$0	-$2,765,404	-$5,283,059	-$8,048,463	-2.68
17	8	10	$1,750,000	3	5	2	2	8	1	-1	3	-1	-$12,811	$2,074,053	-$5,283,059	-$3,221,817	-1.84
18	3	9	$3,000,000	11	5	4	11	4	3	0	-1	-1	$0	-$691,351	-$5,283,059	-$5,974,410	-1.99
19	15	12	$400,000	3	7	0	1	6	0	-2	-1	0	-$25,622	-$691,351	$0	-$716,973	-1.79
20	**10**	**16**	$600,000	7	8	0	5	7	0	-2	-1	0	-$25,622	-$691,351	$0	-$716,973	**-1.19**

Key for VAC on Table 13:

Value of Avoided Crash by Type (VAC)		
MAIS 0-1 VAC1	MAIS 2-4 VAC2	MAIS 5-6 VAC3
$12,811	$691,351	$5,283,059

Source: Values provided by NHTSA.

Sum of total value of crash reductions for Old Rank, Segments 1, 5, 7, 8, 10, 14, 16, 17, 18, 20 = **-$37,720,318** (negative sign indicates savings from crashes avoided, though benefits from this calculation will be incorporated as a positive figure when cumulating overall benefits).

Sum of total value of crash reductions for New Rank, Segments 1, 4, 5, 7, 8, 9, 10, 14, 16, 17, 18 = **-$56,309,275.**

Total Cost of Safety Improvements, Old and New Bundles: **$15,000,000.**

Reduced Staff Hours through Streamlined Evaluation

As with project identification, the absence of comprehensive and reliable data may result in staff conducting time-consuming indirect estimations of the information needed to undertake evaluations of safety improvement projects. These inefficiencies may not only occur within the safety investment planning office of the State DOT, but also in other offices that use the same, or similar, data elements.

As with the project identification benefit, the analyst should speak to staff in relevant offices to see how they are coping with the lack of the targeted data elements. Through these conversations, the staff should define how many yearly hours of FTE labor the agency would save, and assign an average hourly rate to this saved labor. Different offices might apply a common hourly rate, or may choose different hourly rates. Table 14 shows an example savings from streamlined evaluation for a fictitious State DOT.

Table 14. Example of Streamlined Evaluation Benefits from Safety Data Collection.

Department	Number of Annual FTE Staff Hours Saved	Hourly Rate	Total Annual Savings
Safety Investment Planning	160	$95	$15,200
Highway Investment Planning	280	$95	$26,600
Asset Management	80	$95	$7,600
Traffic Engineering	80	$120	$9,600
Pavement Engineering	80	$120	$9,600
MPO and Local Planners	80	$95	$7,600
County Engineers	280	$95	$26,600
Emergency Response	80	$50	$4,000
Total	**1,120**	**---**	**$106,800**

Annualization of Benefits

The analyst will need to apply the estimated annual values for each category of benefits to every year in the project period. In this example, the analyst will assume a ramping-up period of seven years to allow for the gradual implementation of the data collection program. In the first year of data collection, the analyst will record 1/7th of the estimated $278,000 benefit from business process savings, or about $40,000. (Table 8 identified a total of $278,000 in savings in reduced staff time in project identification from safety data collection.) For the second year, the analyst will record 2/7 of the estimated $278,000 benefit, and so on until the seventh year, when the initial data collection process is completed. From the seventh year onward, the annual benefit will be assumed to remain constant at $278,000. An individual agency might choose a different method to phase in benefits, and in some cases may make the assumption that benefits do not accrue for this category until the data collection phase is complete. Table 15 provides an example of the annualized benefit for efficiency savings in project identification, based on the seven year ramp-up period. Table 16 summarizes the benefits to the Average State from all of the categories identified.

Table 15. Example of Annualization of Benefits (Thousands).

Year:	1	2	3	4	5	6	7	8	9	10
More Efficient Project Identification Savings	-	$39.7	$79.4	$119.1	$158.9	$198.6	$238.3	$278.0	$278.0	$278.0

Year:	11	12	13	14	15	16	17	18	19	20
More Efficient Project Identification Savings	$278.0	$278.0	$278.0	$278.0	$278.0	$278.0	$278.0	$278.0	$278.0	$278.0

Table 16. Overall Benefits to the Average State (Thousands).

Year: Elements	1	2	3	4	5	6	7	8	9	10
Annual Business Process Savings	-	$39.7	$79.4	$119.1	$158.9	$198.6	$238.3	$278.0	$278.0	$278.0
Annual Decision-Making Savings	-	$10,622.3	$21,244.5	$31,866.8	$42,489.0	$53,111.3	$63,733.6	$74,355.8	$74,355.8	$74,355.8
Annual Streamlined Evaluation Savings	-	$15.3	$30.5	$45.8	$61.0	$76.3	$91.5	$106.8	$106.8	$106.8
Total Annual Benefits	-	$10,677.2	$21,354.5	$32,031.7	$42,708.9	$53,386.2	$64,063.4	$74,740.6	$74,740.6	$74,740.6
Year: Elements	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Annual Business Process Savings	$278.0	$278.0	$278.0	$278.0	$278.0	$278.0	$278.0	$278.0	$278.0	$278.0
Annual Decision-Making Savings	$74,355.8	$74,355.8	$74,355.8	$74,355.8	$74,355.8	$74,355.8	$74,355.8	$74,355.8	$74,355.8	$74,355.8
Annual Streamlined Evaluation Savings	$106.8	$106.8	$106.8	$106.8	$106.8	$106.8	$106.8	$106.8	$106.8	$106.8
Total Annual Benefits	$74,740.6	$74,740.6	$74,740.6	$74,740.6	$74,740.6	$74,740.6	$74,740.6	$74,740.6	$74,740.6	$74,740.6

3.3.2 Costs

According to the cost framework defined in the previous section, the analyst will quantify the following categories of costs: investment costs, operations and maintenance costs, and data analysis costs.

In June 2011, the FHWA Office of Safety published a *Market Analysis of Collecting Fundamental Data Elements to Support the Highway Safety Improvement Program (11)*. The document provided an estimate of the potential cost to States in developing a Statewide location referencing system and collecting the FDE on all public roadways. This benefit-cost methodology borrows the approach used in this Market Analysis, and will report estimates used as a demonstration of the application of this approach. States undertaking a benefit-cost estimate of their safety data collection program may choose to utilize estimates derived in this study, or may choose to replicate the approach taken using local resources.

The cost estimations developed in this report calculate the additional costs that States would incur in order to gather the data that they are not already collecting through HPMS or other efforts. As FHWA did not have a catalog of data collection practices for all States beyond HPMS requirements when this report was drafted, the methodology is conservatively based on the assumption that all data collection beyond HPMS requirements would be new collection. Individual State's cost estimates would vary by the circumstances in each State.

Approach to Estimating Data Collection Costs

The calculations of the cost of data collection are driven by the nature of the safety data program and depend on how much data were previously collected. To make these calculations, it is necessary to break down costs in three ways: on the basis of Federal-aid and non-Federal-aid roadways, on the basis of type of infrastructure (roadway segment, intersection, ramp, and LRS), and on the basis of the type of activity (data collection, data maintenance, and coding and locating of crashes).

To fully implement the recommended collection of the FDE, the analyst can identify the additional costs on the basis of the classification of roadway ownership. These classifications include the following three sets of data elements:

1. **Costs on Federal-aid roadways for the 22 FDE that are not required under HPMS:** Additional costs would only be incurred on Federal-aid roadways since 16 of the 38 total FDE are already required for HPMS on Federal-aid highways. These data elements will be referred to as the "Condensed FDE."
2. **Costs on non-Federal-aid roadways for a common relational LRS**: Additional costs would only be incurred on all non-Federal-aid roadways since HPMS currently requires this for Federal-aid roadways.
3. **Costs on non-Federal-aid roadways for the complete 38 FDE:** Additional costs would be incurred on all non-Federal-aid roadways since HPMS does not require collection of these data elements on non-Federal-aid roadways. These data elements will be referred to as the "Full FDE."

The analyst will also identify costs on the basis of the type of infrastructure, separated by the types outlined in Table 3, specifically by:

1. Roadway on a per-mile basis.

2. Intersection on a per-intersection basis.
3. Ramp on a per-ramp basis.
4. LRS on a per-mile basis.

On the basis of these infrastructure types, for both Federal-aid and non-Federal-aid roadways, the analyst will need to compute cost estimates for each data collection activity, including:

1. Base cost of initial data collection.
2. Maintenance of the data once the initial collection is complete.
3. Cost of coding and locating crashes.
4. Other potential costs (i.e., data storage).

The following sub-sections outline the methodology and the sample cost estimates used in the *Market Analysis*.

Base Cost of Collection

To establish the base cost of data collection, the *Market Analysis* project team collected cost data from 12 data collection vendors from around the country. The project team obtained separate costs for roadway, intersection, ramp, and LRS elements. For the collection of traffic counts on segments, an estimate of one count per mile was used to estimate a per mile cost. These costs included data collection and reduction for integration into a State's existing system. The project team identified sampled vendors based on the list of vendors involved in the North Carolina and the TRB SHRP2 data collection rodeos conducted in 2008 *(9, 10)*. Since many of the rodeo vendors only collected roadway inventory elements and not traffic counts, the project team also identified several companies that collect traffic counts to obtain cost estimates. Vendors collect the (non-traffic) roadway elements using different methods than the traffic data, and, therefore, the costs for each were calculated separately.

Most vendors anticipated that they would use digital data collection vans to collect the roadway inventory data. For traffic count data, the vendors based their cost estimates on 48-hour classification counts for segment traffic data, peak hour manual counts for intersections, and technology similar to segment counts for ramp data. The project team averaged the individual vendor cost estimates to develop the average estimates used in the *Market Analysis*.

Some of the data elements might be collected through other means, potentially using State DOT resources. Alternative methods of collecting some of these data elements include extracting the data from existing plans or visual imagery, such as aerial photography or Google Earth. These methods may be lower in costs, particularly if the costs of agency personnel are not included. Several State DOTs were contacted to obtain estimates of the costs to collect the data "in-house" rather than contract the data collection out to a vendor. Since the data collection is specific to the list of FDE, the majority of States contacted could not provide an estimate of costs. Only one State that was considering conducting a similar effort provided cost information. However, that State was only considering the collection on intersections. Due to the low response rate, the research team conducted the analysis using the estimates provided by the vendors, acknowledging that these are conservative estimates, and there may be more cost-effective methods available (but information for those methods was not available). The average base costs are provided in Table 17.

Table 17: Average Base Cost Estimate.

	Segments (Per Mile)	Intersections (Each)	Ramps (Each)
Condensed FDE List			
Inventory Elements	$60	$130	$100
Traffic Data	--	$590	$400
Condensed List - Total	**$60**	**$720**	**$500**
Location Referencing System			
Total	**$40**	--	--
Full FDE List			
Inventory Elements	$70	$130	$100
Traffic Data*	$460	$590	$400
Full Set of Elements - Total	**$530**	**$720**	**$500**

*Assuming one traffic count per mile

A State wishing to implement a BCA of their data collection program might choose to use these estimates as a base for building out the total cost of their program. They could also choose to use a similar technique to obtain more specialized estimates of the base costs of establishing, or expanding, their data collection programs.

To estimate the cost of the implementation of a data collection system for an entire State, the *Market Analysis* generated three different models: an "average" State, a small State (on the basis of Rhode Island), and a large State (on the basis of California). To calculate the costs for each State, the *Market Analysis* used data on the roadway mileage, number of intersections, and number of ramps for the Federal-aid and non-Federal-aid roadways. Data on roadway mileage were obtained from the FHWA Office of Highway Policy Information (OHPI) *(28)*. The mileage for the "average" State was calculated using the United States total (including Washington, DC) and dividing by 51. As OHPI does not yet include an estimate of intersections or ramps, the project team contacted States directly to obtain estimates of the number of intersections and ramps in each State. The research team used data from California for the large State, data from Rhode Island for the small State, and data from Missouri and Ohio for the average State. These

States were selected based on their land mass, roadway mileage, and geographic locations. All States, except California, provided the total number of intersections and ramps in the State. The research team estimated the total number of intersections in California based on the total number of miles in the State. The distribution of mileage of Federal-aid and non-Federal-aid roadways was used to estimate the same distribution for ramps. Information on the roadway characteristics of each of these models is provided in Table 18.

Table 18. Roadway Characteristics by State Size.

State	Segments (miles)		Intersections (each)		Ramps (each)	
	Federal-aid	Non-Federal-aid	Federal-aid	Non-Federal-aid	Federal-aid	Non-Federal-aid
Small	1,750	4,600	27,560	72,440	380	0
Large	55,230	103,490	132,370	248,030	14,660	0
Average	19,430	57,390	70,430	208,020	4,450	0

Based on the average base cost estimates and the roadway characteristics, the analyst can estimate the total cost for the collection of the condensed FDE on Federal-aid roads, and the full FDE and LRS on non-Federal-aid roads. Table 19 provides the base costs estimates for the collection of this data for the small, large, and average State models.

Table 19. Cost Estimates for Small, Large, and Average States (Thousands).

State	Federal-aid				Non-Federal-aid				Total Cost
	LRS	Segments	Intersections	Ramps	LRS	Segments	Intersections	Ramps	
Small	N/A	$105.0	$19,843.2	$190.0	$184.0	$2,438.0	$52,156.8	$0	$74,917.0
Large	N/A	$3,313.8	$95,306.4	$7,330.0	$4,139.6	$54,849.7	$178,581.6	$0	$343,521.1
Average	N/A	$582.9	$50,709.6	$2,225.0	$1,147.8	$15,208.4	$149,774.4	$0	$219,648.1

Operations and Maintenance Costs

In addition to the costs of initial data collection, the analyst should also calculate the costs to maintain the data. That is, the costs to update the data as conditions change. The frequency of updating this data may differ across States, and between categories of data, based on how quickly and dramatically conditions in the State are changing.

To estimate the cost of maintenance and operation of the roadway segment data collection system, the analyst must determine the manner and frequency of data updates. For segment data, in this example, it was assumed that five percent of the roadway mileage would be updated annually. The method of update is assumed to be from construction/design plans, rather than from re-collecting the data. The study estimates that updating the inventory would take two hours per mile by an employee earning $20.00 an hour (approximately $40,000 per year). Based on these assumptions, the equation to determine the annual cost of operation and maintenance for roadway segment data would be:

Annual Operation and Maintenance Cost for Roadway Segments =
*Total Miles * 5%*Maintenance Cost per Mile*

*Maintenance Cost per Mile = $20 * 2 hours = $40*

Individual State DOTs may choose to apply a different time or cost estimation, based on their experience.

For intersection data, the analyst must also determine the manner and frequency of data updates. For this example, the analyst assumes that the State would update the inventory on a three-year cycle for signalized intersections, and a five-year cycle for unsignalized intersections. This assumes that traffic volumes will not change dramatically at unsignalized intersections. The project team used a split of 20 percent signalized intersections and 80 percent unsignalized intersections to determine the number of signalized and unsignalized intersections. The cost of the update of the intersection inventory is assumed to be the same as for a one mile roadway segment, $40, or two hours by an employee earning $20 an hour.

Annual Operation and Maintenance Cost for Intersections =
*(Total Signalized Intersections*1/3*Maintenance Cost per Intersection) +*
*(Total Unsignalized Intersections*1/5* Maintenance Cost per Intersection)*

*Maintenance Cost per Intersection = $20 * 2 hours = $40*

To determine the annual operation and maintenance cost for ramps, the analyst assumes that a State would update their ramp inventory on a six-year cycle, with counts and inventory updates collected on one-sixth of the ramps per year. The cost of the update of the ramp inventory is assumed to be the same as for roadway segments and intersections, $40, or two hours by an employee earning $20 an hour.

Annual Operation and Maintenance Cost for Ramps =
Total Ramps(1/6)* Maintenance Cost per Ramp*

*Maintenance Cost per Ramp = $20 * 2 = $40*

To estimate the cost of maintenance and operation of the LRS, the analyst applies a similar approach as used on the other types of infrastructure, but estimates only the cost of the maintenance of the LRS on non-Federal-aid roads, as it is required by HPMS for States to have an LRS for Federal-aid roads. As with segment data, the analyst assumes that the State updates five percent of their roadway mileage annually, and updating the LRS would take two hours per mile by an employee earning $20.00 an hour (approximately $40,000 per year). Based on these assumptions, the equation to determine the annual cost of operation and maintenance for the LRS would be:

Annual Operation and Maintenance Cost for LRS =
*Total Miles of non-Federal-aid roadways * 5%* Maintenance Cost per Mile*

*Maintenance Cost per Mile = $20 * 2 = $40*

These equations provide a guide for analysis. Individual State DOTs may choose to apply a different time or cost estimation based on their experience.

Using the cost figures provided in Table 17 through Table 19, and the equations and assumptions in this section, the analyst can estimate the annual operations and maintenance costs, as demonstrated in Table 20.

Table 20. Average Annual Inventory Maintenance Costs (Thousands).

Elements	Small State	Large State	Average State
LRS	$9.2	$207.0	$57.4
Segments	$12.7	$317.4	$76.8
Intersections	$13,573.3	$51,633.0	$21,782.6
Ramps	$17.6	$677.6	$204.7

Cost for Coding and Locating Crashes

Next, the analyst must calculate the costs for coding and locating crashes on non-Federal-aid roads, since the State now will have the information needed to locate crashes using an LRS and other data elements, both of which they did not have previously. The project team obtained national statistics from NHTSA to estimate a ratio of fatal crashes to injury crashes *(29)*. The project team also obtained the number of fatal crashes on non-Federal-aid roads from the NHTSA Fatality Analysis Reporting System (FARS) *(2)*. The analyst applies the ratio of fatal-to-injury crashes to the number of fatal crashes on non-Federal-aid highways to obtain an estimate of injury crashes on non-Federal-aid highways. They then apply the costs for locating and coding these additional crashes. The project team assumes that five crashes could be coded per hour at a cost of $20/hour. These costs only pertain to the costs of coding and locating fatal and injury crashes. The project team was not able to reasonably estimate the number of PDO crashes on non-Federal-aid roads; therefore, these crashes were not included in the analysis.

Annual Cost for Locating and Coding Crashes = (Total Annual Injury and Fatal Crashes Not Automatically Located / 5) 20*

Table 21 lists the average annual costs to locate crashes based on this equation and the available data on the frequency of injury and fatal crashes.

Table 21. Average Annual Cost to Locate Crashes (Dollars).

States	Crashes Not Automatically Located	Average Annual Cost
Small State	30	$120
Large State	780	$3,120
Average	240	$960

As with maintenance costs, note that the data collection system will not cover the entire roadway for several years. Analysts may choose to apply the cost of coding and locating crashes to a smaller proportion of crashes, corresponding to the proportion of miles of roadway that are already completed. In this example of a hypothetical State, costs to locate crashes are low. This methodology is intended to address all potential costs, even those that are low.

Data Storage and Other Costs

Depending on the use of the data and the infrastructure already in place, individual State DOTs may have other additional costs. For example, the collection of this data may increase data storage costs, and may necessitate an additional investment. Costs of data storage depend on the type of storage used, but generally range from about $0.75-$1.00 per GB per month, or about $90-$120 per GB per year *(30)*.

Other costs would include following the new methods of data analysis, which may be more time consuming than old data analysis methods. If this is the case, the costs of these elements should also be incorporated into the cost tables. The cost would be calculated by multiplying the additional hours of staff time required to undertake analysis with the hourly wage rate of the employees who would be undertaking this work.

Annualization of Costs

The analyst should project these total cost estimates over the number of years that it might take to complete the data collection process. Table 22 provides an example for one potential scenario for the timing of the completion of data collection, and therefore the timing of the payment for the collection, maintenance, and crash location. The method used in this report assumes that costs are split evenly over the years of data collection. If another assumption would be more appropriate, a State DOT could choose to make a different assumption on the distribution of these costs.

Table 22. Assumptions on Timing of Data Collection.

Roadway Type	Data Elements	Time Frame (Years)
Federal-aid	Condensed FDE	Segments: 5 Intersections: 7 Ramps: 9
Non-Federal-aid	LRS Full FDE	LRS: 7 Segments: 6 Intersections: 8 Ramps: 10

As shown in Table 22, the sample scenario shows that the cost of expanding the collection of the condensed FDE on Federal-aid roadway segments will be implemented over the course of five years. Therefore, the total cost of implementing this aspect of the data collection will be distributed over five years. Similarly, the installation of the LRS on non-Federal-aid roadways will be implemented over the course of seven years. Therefore, the cost of installing the LRS will be distributed over seven years. Individual States will need to determine their own timeframe for the installation of their data collection systems.

Based on these assumptions of the allocation of the total costs of the data collection over time, the project team estimated separate yearly costs, as reported in Table 23, Table 24, and Table 25.

Table 23. Yearly Cost Estimates by State Size for Base Data Collection (Thousands).

Year Elements	1	2	3	4	5	6	7	8	9	10
Average State										
LRS	-	$164	$164	$164	$164	$164	$164	$164	-	-
Segments	-	$2,651	$2,651	$2,651	$2,651	$2,651	$2,651	-	-	-
Intersections	-	$25,966	$25,966	$25,966	$25,966	$25,966	$25,966	$25,966	$18,722	-
Ramps	-	$247	$247	$247	$247	$247	$247	$247	$247	$247
Small State										
LRS	-	$26	$26	$26	$26	$26	$26	$26	-	-
Segments	-	$427	$427	$427	$427	$427	$406	-	-	-
Intersections	-	$9,354	$9,354	$9,354	$9,354	$9,354	$9,354	$9,354	$6,520	-
Ramps	-	$21	$21	$21	$21	$21	$21	$21	$21	$21
Large State										
LRS	-	$591	$591	$591	$591	$591	$591	$591	-	-
Segments	-	$9,804	$9,804	$9,804	$9,804	$9,804	$9,142	-	-	-
Intersections	-	$35,938	$35,938	$35,938	$35,938	$35,938	$35,938	$35,938	$22,323	-
Ramps	-	$814	$814	$814	$814	$814	$814	$814	$814	$814

Table 24. Inventory Maintenance Costs (Thousands).

Average State

Year / Elements	1	2	3	4	5	6	7	8	9	10
LRS	-	-	$8.2	$16.4	$24.6	$32.8	$41.0	$49.2	$57.4	$57.4
Segments	-	-	$13.5	$26.9	$40.4	$53.8	$67.3	$76.8	$76.8	$76.8
Intersections	-	-	$327.0	$654.0	$980.9	$1,307.9	$1,634.9	$1,961.9	$2,288.9	$2,524.6
Ramps	-	-	$3.3	$6.6	$9.9	$13.2	$16.5	$19.8	$23.1	$26.4
Year / Elements	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
LRS	$57.4	$57.4	$57.4	$57.4	$57.4	$57.4	$57.4	$57.4	$57.4	$57.4
Segments	$76.8	$76.8	$76.8	$76.8	$76.8	$76.8	$76.8	$76.8	$76.8	$76.8
Intersections	$2,524.6	$2,524.6	$2,524.6	$2,524.6	$2,524.6	$2,524.6	$2,524.6	$2,524.6	$2,524.6	$2,524.6
Ramps	$29.7	$29.7	$29.7	$29.7	$29.7	$29.7	$29.7	$29.7	$29.7	$29.7

Small State

Year / Elements	1	2	3	4	5	6	7	8	9	10
LRS	-	-	$1.3	$2.6	$3.9	$5.3	$6.6	$7.9	$9.2	$9.2
Segments	-	-	$2.2	$4.5	$6.7	$8.9	$11.2	$12.7	$12.7	$12.7
Intersections	-	-	$117.8	$235.6	$353.4	$471.2	$589.0	$706.8	$824.6	$906.7
Ramps	-	-	$0.3	$0.6	$0.8	$1.1	$1.4	$1.7	$2.0	$2.3
Year / Elements	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
LRS	$9.2	$9.2	$9.2	$9.2	$9.2	$9.2	$9.2	$9.2	$9.2	$9.2
Segments	$12.7	$12.7	$12.7	$12.7	$12.7	$12.7	$12.70	$12.7	$12.7	$12.7
Intersections	$906.7	$906.7	$906.7	$906.7	$906.7	$906.7	$906.7	$906.7	$906.7	$906.7
Ramps	$2.5	$2.5	$2.5	$2.5	$2.5	$2.5	$2.5	$2.5	$2.5	$2.5

Large State

Year / Elements	1	2	3	4	5	6	7	8	9	10
LRS	-	-	$29.6	$59.1	$88.7	$118.3	$147.8	$177.4	$207.0	$207.0
Segments	-	-	$56.6	$113.2	$169.8	$226.4	$282.9	$317.4	$317.4	$317.4
Intersections	-	-	$452.6	$905.1	$1,357.7	$1,810.2	$2,262.8	$2,715.3	$3,167.9	$3,449.0
Ramps	-	-	$10.9	$21.7	$32.6	$43.4	$54.3	$65.2	$76.0	$86.9
Year / Elements	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
LRS	$207.0	$207.0	$207.0	$207.0	$207.0	$207.0	$207.0	$207.0	$207.0	$207.0
Segments	$317.4	$317.4	$317.4	$317.4	$317.4	$317.4	$317.4	$317.4	$317.4	$317.4
Intersections	$3,449.0	$3,449.0	$3,449.0	$3,449.0	$3,449.0	$3,449.0	$3,449.0	$3,449.0	$3,449.0	$3,449.0
Ramps	$97.7	$97.7	$97.7	$97.7	$97.7	$97.7	$97.7	$97.7	$97.7	$97.7

Table 25. Cost to Locate Crashes (Dollars).

Year / States	1	2	3	4	5	6	7	8	9	10
Average	-	-	$137	$274	$411	$549	$686	$823	$960	$960
Small State	-	-	$17	$34	$51	$69	$86	$103	$120	$120
Large State	-	-	$446	$891	$1,337	$1,783	$2,229	$2,674	$3,120	$3,120
States	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Average	$960	$960	$960	$960	$960	$960	$960	$960	$960	$960
Small State	$120	$120	$120	$120	$120	$120	$120	$120	$120	$120
Large State	$3,120	$3,120	$3,120	$3,120	$3,120	$3,120	$3,120	$3,120	$3,120	$3,120

Table 26 summarizes the quantifiable benefits and costs related to additional safety-related data collection efforts.

Table 26. Summary of Potential Benefits and Costs from Additional Data Collection.

Type of Benefits	Benefit from Data
Project Identification	• Reduced staff time due to existence of list of potential sites. • More rapid deployment of safety improvement due to quicker identification of potential sites for safety improvement projects.
Countermeasure Selection	• More appropriate and more optimal selection of countermeasures for sites.
Project Prioritization	• Improved ability to target those sites with the highest crash reduction potential.
Evaluation	• Reduced staff time due to more efficient evaluation of efficacy of safety improvements.
Type of Costs	**Unit of Analysis**
Investment Costs	• Roadway. • Intersection. • Ramp. • LRS.
Operations and Maintenance Cost	• Roadway. • Intersection. • Ramp. • LRS.
Costs for Coding and Locating Crashes	• On a per crash basis.
Other Costs (i.e., Data Storage, Cost of Analysis)	• By other unit.

3.4. EVALUATE AND MAKE RECOMMENDATIONS

Once the analyst completes the calculation of annual benefits and costs, the evaluation stage begins. The benefit cost evaluation is implemented in five steps:

1. Ensure that all benefits and costs are in common units.
2. Calculate present values.
3. Calculate total net benefits/net present value.
4. Evaluate risk, if applicable.
5. Apply decision rules.

The following subsections will provide guidance on working through these steps

3.4.1 Convert into Common Units

It is necessary that all quantified benefits and costs be expressed in the same units in order to undertake the benefit cost evaluation. The above methodology was designed to estimate all benefits and costs in units of dollars. In the case that additional costs and benefits have been added to this base methodology, the analyst should seek out conversion factors to ensure easy comparison of the benefits and costs. One example of this is the cost of crash conversion applied to the calculation of improved safety for personal and commercial vehicles.

It is also important to ensure that the analyst applies the same assumptions throughout the analysis as to whether or not to apply an inflation factor to the costs and benefits. If an inflation factor is applied, it should be applied to all costs and benefits. Conversely, the analyst may choose not to apply an inflation factor to any of the costs and benefits. The latter assumption is the one that has been made in this methodology guide.

3.4.2 Calculate Present Values

Once benefits and costs are in dollars, the analyst will need to calculate the present values of these costs and benefits using an appropriate discount rate. Present value is the value of a future cost or benefit discounted to reflect the time value of money and, if applicable, the risk associated with these future streams. This method is commonly used in business and economics to compare cash flows occurring at different times in a meaningful way.

To evaluate present values of benefits and costs, the analyst will need to discount the future values through the application of a compound interest rate. This study has applied a common 7.0 percent discount rate, as per OMB guidance. The equations to apply this discounting principle to costs and benefits are as follows:

$$PV_{cost} = \frac{Cost}{(1+i)^t} \quad and \quad PV_{benefit} = \frac{Benefit}{(1+i)^t}$$

In this equation, *i* represents the discount rate, and *t* represents the number of years into the project cycle. For example, if the year of evaluation were 2010, and the calculation were for benefits and costs in the year 2014, 2010 would be year 0, 2014 would be year 4, and *t* would equal four. The analyst would apply this equation to the costs and benefits for every year of the project life. By using a compound interest rate, costs in later years in the project life are discounted to a greater extent than those early in the project cycle.

The following tables identify the total discounted and undiscounted benefits and costs for the average State. Table 27 includes all benefits prior to, and after, discounting. The undiscounted benefits were presented in Table 16. The total present value of benefits is the sum of the present value of benefits for each year in the project life. In this example the total discounted annual benefits (in present value using constant $2010) is $546,118,554.

Table 27. Total Annual Benefits Prior to and After Discounting for Average State (Thousands).

Year:	1	2	3	4	5	6	7	8	9	10
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Undiscounted Annual Benefits (Current $)	---	$10,677.2	$21,354.5	$32,031.7	$42,708.9	$53,386.2	$64,063.4	$74,740.6	$74,740.6	$74,740.6
Discounted Annual Benefits (Constant $2010)	---	$9,325.9	$17,431.6	$24,436.8	$30,450.9	$35,573.5	$39,895.4	$43,499.7	$40,653.9	$37,994.3

Year:	11	12	13	14	15	16	17	18	19	20
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Undiscounted Annual Benefits (Current $)	$74,740.6	$74,740.6	$74,740.6	$74,740.6	$74,740.6	$74,740.6	$74,740.6	$74,740.6	$74,740.6	$74,740.6
Discounted Annual Benefits (Constant $2010)	$35,508.7	$33,185.7	$31,014.7	$28,985.7	$27,089.4	$25,317.2	$23,661.0	$22,113.1	$20,666.4	$19,314.4

Table 28 includes all costs prior to, and after, discounting. The undiscounted benefits were presented in Table 23, Table 24, and Table 25. The total present value of costs is the sum of the present value of costs for each year in the project life. In this example, the total discounted annual cost (in present value) is $299,090,299.

Table 28. Total Annual Costs Prior to and After Discounting for Average State (Thousands).

Year:	1	2	3	4	5	6	7	8	9	10
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Undiscounted Annual Cost (Current $)	---	$29,028.5	$29,380.6	$29,732.7	$30,084.7	$30,436.8	$30,672.3	$28,485.7	$21,416.1	$2,933.4
Discounted Annual Cost (Constant $2010)	---	$25,354.6	$23,983.3	$22,682.9	$21,450.0	$20,281.3	$19,101.1	$16,578.9	$11,649.0	$1,491.2

Year:	11	12	13	14	15	16	17	18	19	20
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Undiscounted Annual Cost (Current $)	$38,235.7	$38,235.7	$38,235.7	$38,235.7	$38,235.7	$38,235.7	$38,235.7	$38,235.7	$38,235.7	$38,235.7
Discounted Annual Cost (Constant $2010)	$18,165.5	$16,977.1	$15,866.4	$14,828.5	$13,858.4	$12,951.7	$12,104.4	$11,312.6	$10,572.5	$9,880.8

3.4.3 Calculate Net Present Value and Benefit Cost Ratio

Once the discounting process is complete, the calculation of net present value (NPV), or total net benefits, is fairly straightforward. NPV is calculated by subtracting the total present value of costs from the total present value of benefit.

NPV = Total Present Value of Benefits – Total Present Value of Costs

In this example, the NPV is equal to $546,118,554 minus $299,090,299, or $247,028,255.

The B/C ratio is also a straightforward calculation. This ratio is calculated through the following equation:

$$B/C\ ratio = \frac{Total\ Present\ Value\ of\ Benefits}{Total\ Present\ Value\ of\ Costs}$$

In this example, the B/C ratio equals 1.83. Table 29 summarizes these figures.

Table 29. Net Present Value and Benefit-Cost Ratio.

NPV	$247,028,255
B/C Ratio	1.83

With this information in hand, the analyst can then move to evaluate risk and make a decision as to whether the project is economically justified.

3.4.4 Evaluate Risk

If some of the figures are uncertain, the analyst may choose to conduct a sensitivity analysis to show how the results are affected by changes in the parameters. For example, if the analyst is uncertain about the final costs of the collection of the data, they might apply a 10-15 percent price escalation factor to the costs used in the base model to see how this would change the final net present value of the project. A similar approach might also be taken on certain benefits for which there remains some uncertainty regarding the true values.

3.4.5 Decision Rules

The NPV and the B/C ratio help the analyst when deciding if the implementation of a data collection project is economically justified, and choosing between completing alternatives. To undertake this analysis, the following decision rules may be applied:

- If NPV $\geq$ 0, a project is economically justified.
- If B/C $\geq$ 1, a project is economically justified.
- NPV and the B/C ratio can also be compared with the NPV or B/C ratios of alternative projects in order to select the most beneficial option. The highest NPV or B/C ratio for a given level of constraint will be the best alternative.

In the sample case, the NPV is $247,028,255, which is greater than 0, and the benefit cost ratio is 1.83, which is greater than 1. This indicates that this data collection project is economically justified. It is possible that in some cases the project may be economically justifiable in the base case, and not in the sensitivity or risk analysis scenarios, or vice versa. In these cases, the analyst will need to assess the likelihood of the risk coming to pass when making a judgment.

For some projects where there are many alternatives, the State may require a higher B/C ratio, such as 2, in order for an alternative to be considered for implementation. In this case, our project would fail in its current formulation. This might lead to the overall rejection of the proposal, or may lead to attempts to reduce the cost of implementation, or find new ways to benefit from the data. If there are two or more different options for data collection, the analyst may compare the B/C ratio of the two projects to assess which project is more advantageous. In addition to the B/C ratio, agencies often need to account for other factors in decision-making, such as priority and policy.

CHAPTER 4—SUMMARY OF INPUTS AND OUTPUTS

This section provides an overview of the inputs required to perform the BCA described in this report. In addition, the outputs from each of the benefit and cost sections are provided in a summary.

4.1 INPUTS

The following section outlines the data elements required by an agency to perform the BCA of data collection.

4.1.1 Saved Staff Hours in Project Identification (Safety Office and Others)

- Number of hours spent on project identification through estimation techniques used in the absence of existing data and wage rate of staff employed to perform the estimation.
- Estimated number of hours required to collect real data (instead of relying on estimates) and associated wage rate.
- Departments that would benefit from data collection. A sample list may include:
    - Safety Investment Planning.
    - Highway Investment Planning.
    - Asset Management.
    - Traffic Engineering.
    - Pavement Engineering.
    - MPO and Local Planners.
    - County Engineers.
    - Emergency Response.
- Number of estimated annual FTE staff hours, for other departments, spent in performing estimates in lieu of relying on existing data, and associated hourly rate.

4.1.2 Faster Project Programming

This benefit category will require the State to choose a project for this example. It requires the following inputs:

- Total amount of time (in months) from the identification of a safety problem location to the completion of countermeasure implementation.
- Average monthly crashes, by MAIS 0-1, MAIS 2-4, and MAIS 5-6 crash types, that occurred prior to countermeasure implementation.
- Average monthly crashes, by MAIS 0-1, MAIS 2-4, and MAIS 5-6 crash types, that occurred after countermeasure implementation.

- Estimated amount of time (in months) that programming decisions could have been made earlier if the data elements were available.

4.1.3 Improved Project Prioritization

For this calculation, the State needs to collect some data or borrow data from a similar State. It requires the following inputs:

- Total cost of the bundle of safety interventions for an improvement project (budget for safety improvements).
- List of 20-50 candidate sites from a previous safety improvement project (suggest at least two to three years ago) for ramps, segments, or intersections. The example uses one set of data (e.g., segments), though the approach would be the same for the other types.
- The cost of the safety improvements required for each of the candidate sites.
- A ranking of the sites based on crash records and road characteristics, prior to the safety improvement, using the identification and prioritization methods preferred by the State in the absence of data. For example, if segment data is collected but ramps are not, use the method or prioritization for ramps on the candidate sites, such as total number of crashes versus total cost of crashes, weighted by crash severity.
- A ranking of the sites based on existing data (the assumption is that existing data provides more information that can be used to rank and prioritize candidate sites, and that the resultant ranking would be different based on improved data collection).
- Average annual crashes, by MAIS type, two to three years before improvement, for each site.
- Average annual crashes, by MAIS type, two to three years after improvement, for each site.
- Locally accepted average cost of crashes by type.
- Percentage of total segments/intersections/ramps for which the State has collected data (this will be used as a multiplier to scale up the calculations to the state level).

4.1.4 Saved Staff Hours in Streamlined Evaluation (Safety Office and Others)

- Number of hours and wage rates saved through streamlined evaluation due to the availability of data, across all departments, identified in item 1 of this checklist.

4.1.5 Data Collection Costs

- Costs of collecting roadway, ramp, intersection, and LRS data, if other than those provided in FHWA's *Market Analysis of Collecting Fundamental Data Elements to Support the Highway Safety Improvement Program (11)*.
- Roadway characteristics for the State, including number of miles, ramps, and signalized/unsignalized intersections.

4.1.6 Operations and Maintenance Costs

- Roadway characteristics for the State, including number of miles, ramps, and signalized/unsignalized intersections from the previous list item.
- The estimated amount of staff time and hour wages required to update and maintain the inventory of roadway elements.

4.1.7 Crash Location and Coding Costs

- Total annual injury and fatal crashes not automatically located.

4.2 OUTPUTS

The following section summarizes the outputs from each of the benefit and cost sections identified in the report.

4.2.1 Saved Staff Hours in Project Identification (Safety Office and Others)

- Total dollars saved, per department, through more efficient project identification.

4.2.2 Faster Project Programming

- Total dollars saved from avoided crashes through faster project programming.

4.2.3 Improved Project Prioritization

- New ranking of candidate improvement locations, as well as the calculated total amount of dollars in crashes avoided through the expenditure on safety improvement countermeasures at these locations.

- The difference between the total value of avoided crashes from this new ranking system, compared to the old ranking system (ranked before the State could use the information gained from data collection).

4.2.4 Saved Staff Hours in Streamlined Evaluation

- Total dollars saved, per department, through more streamlined evaluation from having collected data available.

All of the above benefits will be annualized, discounted, and converted to constant dollars. This is considered to be converting the benefit streams to a present value.

4.2.5 Data Collection Costs

- Annual costs of collecting roadway, ramp, intersection, and LRS data, for Federal-aid and Non-Federal-aid roads.

4.2.6 Operations and Maintenance Costs

- Annual costs of maintaining inventory of roadway elements, including LRS, segments, intersections, and ramps.

4.2.7 Crash Location and Coding Costs

- Annual estimated cost to locate and code crashes on non-Federal-aid roads.

All of the above costs will be annualized, discounted, and converted to constant dollars (this is considered to be converting the cost streams to a present value). Present value benefits and costs will be compared either through an NPV calculation or a B/C ratio. If the NPV is positive or the B/C ratio is larger than one, the project is economically justified.

CHAPTER 5—CONCLUSIONS & RECOMMENDATIONS

The FHWA Office of Safety's mission is *to reduce highway fatalities by making our roads safer through a data-driven, systematic approach.* Safety analyses have expanded beyond just crash data with the development of sophisticated analysis tools and methods. The need for improved crash, roadway, and traffic data is vital. Using these data together can help agencies make decisions that are fiscally responsible, and improve the safety of the roadways for all users. States must judiciously allocate the scarce public resources available for roadway safety improvements to those projects that have the highest payout in terms of reduced fatalities and injuries per dollar spent.

The methodology established in this report is the first of many steps that will ultimately provide States with the best information and knowledge available to facilitate safety data investment decision-making. It quantifies the economic returns from investing in data improvements. This report and the associated guidebook will serve to guide analysts seeking to explore and understand the costs and benefits of roadway safety data investments. The methodology is a solid foundation for future research and tool development, and will continue to evolve as it is applied to the unique circumstances of each State. However, this is an initial step at the national level to assist States in their efforts to justify expenditure on data collection.

Some States already collect the data elements needed to undertake some, or all, of the analyses identified in this report. However, many more States do not yet have sufficient data or resources to acquire all of the necessary data for their State. Even constructing a sample data set, or collecting data on a sample of roadways, is expensive and time consuming. To assist States that do not yet have the resources in place to conduct the analysis prescribed in this report, FHWA, TRB, NHTSA, or others may seek to construct national multipliers for improvements in roadway safety related to data. These national multipliers could be constructed on a per-mile, intersection, and ramp basis, to allow the benefits to be scaled up or down to any State size. Separate multipliers might be obtained for roadways and intersections of different types. Additionally, adjustment factors could be proposed for States with certain distinctive attributes (e.g., mountainous, extreme weather conditions, etc.).

In addition, FHWA may also seek to create a table of national average benefits to improve the ease and cost-effectiveness of this type of analysis. With a table of national average benefits estimates, States can adjust the national average values according to the particulars of their State. FHWA can use the methods described in this report on pooled national data to derive national averages for benefits from specific types of data. With a generic national estimate on the benefits of data collection on a per-mile, per-ramp, or per-intersection basis, States could then have a benchmark upon which to base their own investments in segment, intersection, and ramp data. Further, a national benefits estimator can also allow States that do not have extensive data to perform a BCA on the value of data collection prior to expending resources on direct data collection efforts.

Additional effort is required at the national level to assist States that do not yet have a data collection system in place. States would also benefit from having a spreadsheet tool that can perform these benefits and costs calculations accurately and uniformly. This tool can be based on the sample data used in this report, an average state (not yet defined by FHWA), or incorporate national average benefits. This tool would allow analysts at the State DOTs to customize the BCA methodology described in this report to their State, using an easy-to-use interface that produces clear, and easy-to-interpret benefit and cost estimates, as well as the relevant NPV and B/C ratios. FHWA could provide this tool to all State DOTs to assist the safety departments in justifying the allocation of transportation resources to the collection of additional roadway data on Federal-aid and non-Federal-aid roads.

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APPENDIX A — SUMMARY OF PROBLEM IDENTIFICATION METHODOLOGIES FROM HIGHWAY SAFETY IMPROVEMENT PROGRAM MANUAL.

	Problem Identification Method	Data Inputs and Needs	Strengths	Weaknesses
1	Average Crash Frequency	• Crashes by type and/or severity and location.	• Simple; • May be applied to crashes by type and severity.	• Does not account for RTM bias; • Does not account for exposure; • May overlook low-volume sites and overemphasize high-volume sites; • Does not identify a performance threshold.
2	Crash Rate	• Crash counts and location; • Average Daily Traffic Volumes (ADT), Total Entering Volume (TEV), or Annual Average Daily Traffic Volumes (AADT).	• Simple; • Can modify to account for severity if EPDO or RSI based crash count is used.	• Does not account for RTM bias; • Does not identify a performance threshold; • May overemphasize sites with low volumes; • Comparisons cannot be made across sites with significantly different volumes.
3	Equivalent Property Damage Only (EPDO) Average Crash Frequency	• Crashes by severity and location; • Fatal, injury, and PDO crash weighting factors.	• Simple; • Considers crash severity.	• Does not account for RTM bias; • May overemphasize locations with a small number of severe crashes; • Does not identify a performance threshold; • Does not account for traffic volume.
4	Relative Severity Index (RSI)	• Crashes by type and location; • Crash costs by type.	• Simple; • Considers crash type and crash severity.	• Does not account for RTM bias; • May overemphasize locations with small number of severe crashes; • Does not account for traffic volumes.

	Problem Identification Method	Data Inputs and Needs	Strengths	Weaknesses
5	Critical Crash Rate	• Crash counts and location; • Annual Average Daily Traffic Volumes (AADT).	• Reduces exaggerated effect of sites with low volumes; • Considers variance in crash data; • Establishes a threshold for comparison; • Can be applied to specific crash type or severity.	• Does not account for RTM bias.
6	Excess Predicted Average Crash Frequency Using Method of Moments	• Crashes by type and location; • Traffic volume (AADT or ADT).	• Establishes a threshold of expected performance for a site; • Considers variance in crash data; • Allows sites of all types to be ranked in one list.	• Does not account for RTM bias; • Does not account for traffic volumes; • Ranking results are influenced by reference populations.
7	Level of Service of Safety	• A minimum of three years crash data; • Crashes by location; • SPF, overdispersion parameter, and all variable required for SPF.	• Considers variance in crash data; • Accounts for volume; • Establishes a threshold for comparison.	• Effects of RTM bias may still be present.
8	Excess Predicted Average Crash Frequency Using SPFs	• A minimum of three years crash data • Crashes by type, severity, • location; • Calibrated SPF.	• Accounts for volume; • Establishes a threshold for comparison.	• Requires calibrated SPF; • Effects of RTM may still be present in the results.
9	Probability of Specific Crash Types Exceeding Threshold Proportion	• Crashes by type, severity, and location.	• Also can be used as a diagnostic tool; • Not affected by RTM bias; • Considers variance in crash data.	• Does not account for traffic volumes; • Some sites may be identified for unusually low numbers of non-target crash types.

	Problem Identification Method	Data Inputs and Needs	Strengths	Weaknesses
10	Excess Proportion of Specific Crash Types	• Crashes by type, severity, and location.	• Also can be used as a diagnostic tool; • Not affected by RTM bias; • Considers variance in crash data.	• Does not account for traffic volumes; • Some sites may be identified for unusually low numbers of non-target crash types.
11	Expected Average Crash Frequency with EB Adjustment	• A minimum of three years crash data; • Crashes by type, severity, and location; • Calibrated SPFs and overdispersion parameters.	• Accounts for RTM.	• Requires locally calibrated SPF; • Requires rigorous analysis; • Data intensive.
12	EPDO Average Crash Frequency with EB Adjustment	• A minimum of three years crash data; • Crashes by type, severity, and location; • Calibrated SPFs and overdispersion parameter; • Fatal, injury, and PDO crash weighting factors.	• Accounts for RTM; • Considers crash severity.	• May overemphasize locations with a small number of severe crashes depending on weighting factors used. • Requires rigorous analysis; • Data intensive.
13	Excess Expected Average Crash Frequency with EB Adjustment	• A minimum of three years crash data; • Crashes by type, severity, and location; • Calibrated SPF and overdispersion parameter.	• Accounts for RTM; • Establishes a threshold for comparison.	• Requires locally calibrated SPF; • Requires rigorous analysis; • Data intensive.
	Source: Highway Safety Improvement Program Manual, First Edition, Draft 3.1, April 2009.			

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