Benefit-Cost Analysis of Investing in Data Systems and Processes for Data-Driven Safety Programs: **Decision-Making Guidebook**

FHWA Safety Program

U.S. Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
Investment in roadway safety saves lives

http://safety.fhwa.dot.gov

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16. Abstract 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 Guidebook is intended to assist States in justifying the decision to invest in additional data collection efforts related to safety. 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, this Guidebook provides instructions in how States may assess the potential impact of investment in safety data improvement.		
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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

B/C	Benefit-Cost
BCA	Benefit-Cost Analysis
DOT	Department of Transportation
FARS	Fatality Analysis Reporting System
FDE	Fundamental Data Elements
FHWA	Federal Highway Administration
FTE	Full Time Equivalent
HPMS	Highway Performance Monitoring System
HSIP	Highway Safety Improvement Program
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
NPV	Net Present Value
OMB	Office of Management and Budget
VAC	Value of Avoided Crashes

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION TO THE GUIDEBOOK

Deciding to invest in data is a challenge for many transportation agencies. State transportation agencies frequently 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 safety improvement projects to the infrastructure. Infrastructure improvements are visible to the driving public and typically 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 research to develop guidance on the methodologies that States can use 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 intent of the Guidebook is to assist State and local transportation agencies in justifying the decision to invest in additional data collection efforts related to safety. For example, if a State Department of Transportation (DOT) is having a difficult time justifying the allocation of resources to data collection projects, this Guidebook provides instructions on how agencies may assess the potential impact of investment in safety data improvement. Several sections of this Guidebook discuss and provide examples using segment data, though it should be understood that the methodologies described apply to the collection of ramp and intersection data as well.

This Guidebook is a companion to the FHWA final report *Benefit-Cost Analysis of Investing in Data Systems and Processes for Data-Driven Safety Programs (1)*. The report includes further descriptions of the literature, project purpose, and the methodology that are shared in this Guidebook. Other related publications readers might also find useful include:

1. Lefler, N., et al., *Background Report: Guidance for Roadway Safety Data to Support the Highway Safety Improvement Program,* Federal Highway Administration, FHWA-SA-11-39, Washington, DC, 2011.
2. Lefler, N., et al., *Market Analysis of Collecting Fundamental Roadway Data Elements to Support the Highway Safety Improvement Program*, Federal Highway Administration, FHWA-SA-11-40, Washington, D.C., 2011.
3. Li, Z., et al., *Project-Level Life-Cycle Benefit-Cost Analysis Approach for Evaluating Highway Segment Safety Hardware Improvements,* Transportation Research Record Vol. 2160, Washington, DC, 2010.

A full list of references is provided in the final report referenced above. Additional information can also be found on the FHWA Office of Safety web page at http://safty.fhwa.dot.gov.

The remainder of this Guidebook is organized into the following sections:

- Section 2 details the benefit-cost analysis (BCA) methodology developed for assessing the investments in data collection and discusses the application of the methods for a hypothetical safety analysis example.
- Section 3 addresses the lack of data availability and provides suggestions for States that do not have sufficient levels of data to undertake this analysis.
- Section 4 presents a checklist of the data requirements for each step of the analysis.

2. BENEFIT-COST ANALYSIS (BCA)

BCA is a process used to assess the economic viability of projects. In a 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. FHWA's *Economic Analysis Primer* outlines the basic steps to BCA, which serves as the general framework for this guide *(2)*. Figure 1 shows the five steps that constitute a BCA.

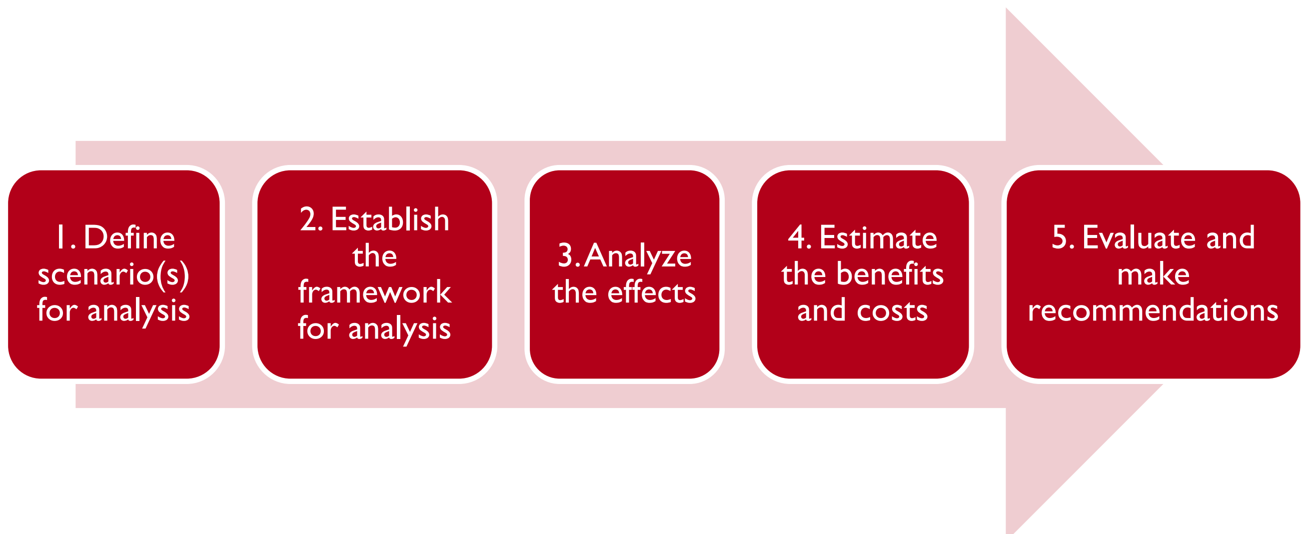

Figure 1. The Five Steps of a BCA.

Agencies can apply this standard approach to almost any significant investment project. The remainder of this Guidebook describes how States can apply this approach specifically to data collection projects associated with roadway safety.

2.1. DEFINE THE PROPOSED INVESTMENT

The analyst will first need to **define the objectives of the project**. Definition of the objective of the data collection project will help determine the scope of activity, and therefore the benefits and costs of the project. For example, one project might have an objective of collecting intersection data, 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 might affect what alternatives could be accepted**. 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 to those of the base case**.

2.2. ESTABLISH FRAMEWORK FOR THE ANALYSIS

Once the analyst defines the investment alternatives and base case and identifies the objectives and constraints on the facility, they will also need to **establish the overall framework for the analysis**. This includes the project life, or the number of years over which the benefits and costs of the project will be evaluated, and the appropriate rate at which to discount future streams of benefits and costs.

Setting these boundaries on the analysis provides a framework for quantifying the benefits and costs for comparable projects and alternatives. **Defining the life of the safety data collection program** allows the analyst to distribute initial investments over the expected life of the investment, and to compare the stream of benefits and costs over the same period. For example, a life-cycle of 20 years may include a 10-year roll out period for data collection and an additional 10 years of implementation. It is important to note that the lifecycle of the data collection effort must include the period of the data collection effort itself (where costs will likely far outweigh any benefits from the effort), as well as the period of implementation of the data (where benefits from having the data will likely far outweigh the costs of any database maintenance). The project life of data collection programs may differ somewhat between individual States, depending on the specifics of the program.

The analyst will need to **discount future costs and future benefit streams within the life of the project to the current year using a common discount rate**. If a State DOT has a specific discount rate that is 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*, which is based on the Office of Management and Budget (OMB) guidance Circular A-94 *(3)*.

2.3. QUANTIFY THE BENEFITS

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. If the benefits and costs are monetary in nature, such as the number of hours spent on the collection at a certain hourly wage, the calculations will be relatively straightforward. If the benefits and costs are not monetary in nature, such as the number of fatal crashes avoided, the analyst will have to make certain assumptions on the calculations to monetize the benefits and costs. The following sections provide a suggested approach for calculating benefits in the following categories:

1. **More efficient project identification.**
2. **Faster project programming.**
3. **Improved project prioritization.**
4. **Streamlined evaluation.**

2.3.1. Reduced Staff Time from More Efficient Project Identification

Without a data collection system in place, State DOT staff may undertake time-consuming, indirect estimation techniques to derive information in lieu of having actual data. Multiple offices within the same agency that use the same, or similar, data elements may be duplicating efforts due to the lack of an officially accepted dataset. One of the potential benefits of data collection during the project identification stage of the safety improvement process is a **reduction in the State DOT staff time needed to identify potential sites due to the existence of the database**.

To determine the amount of State DOT staff time that could potentially be saved, the analyst will **identify and query staff in relevant offices** to determine how many hours are spent in project identification by each department dealing with the lack of sufficient data. The analyst will then **define how many hours of full time equivalent (FTE) labor would be saved annually by each staff member** in the other State DOT offices if the data elements were obtained through the proposed data collection effort. The analyst will then **identify different labor categories and assign an hourly rate by department, or an average hourly rate**, to this saved labor. Different offices might apply a common hourly rate, or may choose different hourly rates. Table 1 provides an example of business process savings from data collection for a fictitious State DOT. Section 2.3.5 will discuss the annualization of these benefits.

Table 1. 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**

2.3.2. 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 will 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. For this analysis, excess crashes are defined as the incidents that may not have occurred if safety projects were programmed more quickly than traditional time horizons, due to the availability of data to expedite decision-making processes.

To develop the excess crash-savings estimate, the analyst must first **identify candidate sites where safety improvements have been implemented**. Candidate sites may include roadway segments, ramps, or intersections. The analyst will **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. 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.

If the State has not collected data at these sites, the analyst will need to 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. The analyst will apply these assumptions 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 c**alculate the excess crash estimates by crash severity, according to the MAIS score**: 0-not injured, 1-minor, 2-moderate, 3-serious, 4-severe, 5-critical, and 6-maximum (fatal).

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 estimate the system-wide 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 *(4)*. The resulting dollar values may then be considered the value of accelerated safety analysis and project programming resulting from data system investments.

2.3.3. Excess Crash Savings from Improved Project Prioritization

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 this additional data.

To do this, the agency will need to collect all data elements 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 are comparable to the total set of roadways for which data will be collected. The agency may 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 seek data collected by another agency to conduct the analysis. The analyst will **then identify the cost of the safety improvements that were undertaken at each of these sites**.

The analyst will then **apply the method for safety improvement candidate prioritization and selection that has been used in the past**, without the assistance of the additional data elements. The ranking of sites should be based on the crash records 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 ranking of sites should be 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.
- Average cost of crashes by type. This report uses national values for cost of crashes; however, if an agency has values specific to their State or jurisdiction, they should use those values.

Using the two rankings, the analyst will **set a fixed budget for safety improvements**, for example $15 million. The budget should be proportional to the size of the sample of roadways used. For example, if the sample would be 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 the budget threshold has been reached**. 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 the budget threshold has been reached**. This will be the bundle of interventions selected using the new data and methods, referred to as the "new bundle". Table 2 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 2. 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 3 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 3. 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 4 aggregates the total crash reduction potential by crash type associated with the new and old bundles of safety improvements. 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 will be referred to as the **marginal**

change in excess crashes. The number of excess crashes is then **multiplied 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 4, the old bundle is associated with total value of avoided crashes (VAC) worth $37,720,318, while the new bundle is associated with avoided crashes worth $56,309,275.

Table 4. Comparison of Crash Reduction Potential of New and Old Bundles.

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

Source: Provided by NHTSA.

The difference between the VAC of the old and new bundles is the value received from the having collected and used the new information for making safety decisions on an annual basis. In this example, the value of data in improving roadway safety via improved decision-making is about $19 million for the sample of roadways. Table 5, on the following page, provides the entire ranking and valuation process in a single table. Note that in this example, because the total amount spent on roadway improvements at candidate locations did not change from the old bundle to the new bundle, no additional costs were incurred. If an agency identifies a bundle of candidate sites that have a higher VAC at either a higher or lower total cost for the bundle, the expenditure by the State DOT to achieve the improvements on these candidate sites may be increased or decreased, respectively. To justify an increased expenditure on the overall bundle, the analyst should ensure that the benefits (total VAC) accrued by the new bundle exceed the additional costs of the new bundle.

Table 5. 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 5:

VAC by Severity		
MAIS 0-1 VAC1	MAIS 2-4 VAC2	MAIS 5-6 VAC3
$12,811	$691,351	$5,283,059

Source: NHTSA (MAIS values not yet published)

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.**

The analyst will also 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. In this example, the sample used in the ranking exercise is ¼ of the size of the list normally examined for roadway safety improvement planning. Therefore, the expansion factor for the benefits is four. Table 6 demonstrates the application of the expansion factor to the annual benefit estimate from the sample.

Table 6. 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	$37,720,318	4	$150,881,270
New	$56,309,275	4	$225,237,100
Difference	**$18,588,958**	**---**	**$74,355,830**

2.3.4. Reduced Staff Hours from Streamlined Evaluation

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

Having spoken to staff in relevant offices to see how they handle the lack of the targeted data elements, the analyst should **define how many yearly hours of full time equivalent labor would be saved in the evaluation of the safety improvement process**, 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 7 shows an example savings from streamlined evaluation for a fictitious State DOT.

Table 7. 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**

2.3.5. Annualize 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, 1/7th of the estimated $278,000 benefit from business process savings in project identification will be recorded, or about $40,000. (Table 1identified a total of $278,000 in savings in reduced staff time in project identification from safety data collection.) For the second year, 2/7 of the estimated $278,000 benefit will be recorded, and so on until the seventh year, when the initial data collection process is complete. From this year onward, the analyst will assume that the annual benefit will 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 8 provides an example of the annualized benefit for efficiency savings in project identification, based on the seven year ramp-up period. Table 9 summarizes the benefits to the Average State from all of the categories identified.

Table 8. 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 9. Overall Benefits to the Average State (Thousands).

Year:	1	2	3	4	5	6	7	8	9	10
Elements	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
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:	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Elements	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
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

2.4. QUANTIFY THE COSTS

The cost estimations developed in this report calculate the additional costs that States would incur in order to gather the data that are not already collected through the Highway Performance Monitoring System (HPMS), or other efforts. This example assumes that all data collection beyond HPMS requirements would be new collection. An individual State's cost estimates will vary by the circumstances in each State. This section guides the analyst in quantifying the following categories of costs:

1. **Investment costs.**
2. **Operations and maintenance costs.**
3. **Cost for locating and coding crashes.**
4. **Data storage and other costs.**

2.4.1. Initial Investment Cost of Data Collection

To establish the initial investment, or base cost, of data collection, the analyst should **collect cost estimates for the collection of roadway, intersection, ramp, and linear referencing system data elements**. These costs should incorporate data collection, data reduction, and integration into a State's existing system.

The Fundamental Data Elements (FDE), a subset of 38 elements from FHWA's Model Inventory or Roadway Elements (MIRE), was released to States in 2011 through an FHWA Office of Safety Guidance Memo and supplemental report, *Background Report: Guidance for Roadway Safety Data to Support the Highway Safety Improvement Program (5)*. This report also provided information on the estimated cost of collecting these elements, for three types of collection efforts:

1. **Condensed FDE List:** Cost of collecting data 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.

2. **Linear Referencing System (LRS):** Cost of collecting data 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. **Full FDE List:** Cost of collecting data 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 data collection of these elements on non-Federal-aid roadways.

In addition to the inventory of FDE that describe the State's roadway infrastructure, **States will wish to collect traffic data**, which is far more time consuming, and therefore costly, on a per mile, intersection, or ramp basis. The average base costs of data collection of the Condensed FDE, LRS, and Full FDE are provided in Table 10. This table identifies the separate costs of collecting the FDE and traffic data for segments, intersections, and ramps. A State may use these estimates as a base for building out the total cost of their program, or may choose to use more specialized estimates of the base costs of establishing, or expanding, their data collection programs.

Table 10. Average Base Cost Estimate *(5)*.

Condensed FDE List	Segments (Per Mile)	Intersections (Each)	Ramps (Each)
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 List - Total	**$530**	**$720**	**$500**

*Assuming one traffic count per mile.
Segments - when the same range in given for the Comprehensive List and the Condensed List, take the high point for Comprehensive and the mid-point for Condensed.
Intersections/Ramps - when the same range in given for the Comprehensive List and the Condensed List - take the mid-point for both, since the midpoints do not change between the two.

In addition to the segment, intersection, ramp, and LRS cost estimates, States may wish to **determine the cost of a data collection effort for an entire State**. Table 11 provides roadway characteristics for three types of States: a **small State** (i.e., Rhode Island), a **large State** (i.e., California), and an **"average" State**.

Table 11. Roadway Characteristics by State Size *(5)*.

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

Using the average base cost estimates and the roadway characteristics, the analyst may **estimate total costs** for the collection of the remaining 22 elements not already collected for HPMS on Federal-aid roadways, as well as the collection of the complete list of 38 FDE elements, and implementation of an LRS on non-Federal-aid roadways. Table 12 provides the base costs estimates for the collection of this data for the small, large, and average State models.

Table 12. 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

2.4.2. Operations and Maintenance Costs

In addition to the costs of initial data collection, the analyst should **calculate the costs to maintain the data**. This includes costs to update the data as conditions change. The frequency of updating this data may differ between States, and between categories of data, based on how quickly and dramatically conditions in the State change. In each calculation, the analyst must first **determine the manner and frequency of data updates**.

For roadway segments, suppose **five percent** of the roadway mileage will be updated annually, and updating the inventory takes **two hours per mile** by an employee earning **$20 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 is:

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

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

For intersection data, suppose the inventory will be updated 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 total number of intersections for the small, large, and average State is known. A split of 20 percent of signalized intersections and 80 percent of unsignalized intersections was used for the calculations in Table 12. The cost of the update of the intersection inventory is assumed to be the same as 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*

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

For ramp data, in this example, suppose ramp inventory will be updated 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 intersection 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*

For the LRS, the analyst will apply a similar approach as used on the other types of infrastructure. In this case, however, as an LRS is required for HPMS on Federal-aid roads, the analyst will **only calculate the cost of the maintenance of the LRS on non-Federal-aid roads**. As with segment data, it is assumed that **five percent** of the roadway mileage would be updated annually, and updating the LRS would take **two hours per mile by an employee earning $20 an hour**. The equation to determine the annual cost of operation and maintenance for the LRS is:

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 10 through Table 12, and the equations and assumptions in this section, the analyst can estimate the annual operations and maintenance costs, as demonstrated in Table 13.

Table 13. 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

2.4.3. Cost for Locating and Coding Crashes on Non-Federal-Aid Roads

The analyst can calculate the costs for locating and coding crashes on non-Federal-aid roads using the costs and roadway characteristics provided in Table 10 and Table 11, and a similar formula to those used in the previous section. For this example, assume that **five crashes can be coded per hour at a labor cost of $20/hour**. These costs only pertain to the costs of coding and locating fatal and injury crashes. The number of property damage-only crashes on non-Federal-aid roads could be not reasonably estimated and are not included here.

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

According to the Fatality Analysis Reporting System (FARS) 2009 crash data, there were 30 crashes not able to be automatically located in Rhode Island, the small State in this Guidebook, 780 in California, the Large State, and a national average of 240 per State *(6)*. Table 14 lists the costs estimates that analysts can use based on the equation above and the available FARS data on the number of crashes that need to be located and coded manually.

Table 14. Average Annual Cost to Locate Crashes.

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**.

2.4.4. Data Storage and Other Costs

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** *(7)*. The price of storage capacity, per gigabyte, will most likely fall over time.

The new methods of data analysis may be more time consuming than old data analysis methods. If this is the case, the analyst should incorporate the costs of these elements 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. For this Guidebook, it is assumed that States have sufficient data storage infrastructure to accommodate additional data collection efforts, so data storage costs are omitted from further calculations.

2.4.5. Annualize Costs

The analyst should **project the total cost estimates over the number of years that it might take to complete the data collection process**. Table 15 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 data collection, maintenance, and location of crashes. The method used in this Guidebook assumes that costs are split evenly over the years of data collection; however, a State DOT may employ a different cost distribution.

Table 15. 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	Location Referencing System, Full FDE	LRS: 7 Segments: 6 Intersections: 8 Ramps: 10

This sample scenario assumes 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. Collection of the Full FDE, versus the Condensed FDE, is expected to encompass an additional year for segments, intersections, and ramps. The installation of the LRS on non-Federal-aid roadways is projected to take 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, separate yearly cost estimates were made, and are reported in Table 16, Table 17, and Table 18. Note that all figures are in thousands of dollars.

Table 16. Yearly Cost Estimates by State Size for Base Data Collection (Thousands).

Year:	1	2	3	4	5	6	7	8	9	10
Elements	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
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 17. Inventory Maintenance Costs (Thousands).

Average State

Year:	1	2	3	4	5	6	7	8	9	10
Elements	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
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:	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Elements	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
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:	1	2	3	4	5	6	7	8	9	10
Elements	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
LRS	-	-	$1.3	$2.60	$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:	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Elements	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
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	$12.7	$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:	1	2	3	4	5	6	7	8	9	10
Elements	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
LRS	-	-	$29.6	$59.1	$88.7	$118.3	$147.8	$177.	$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:	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Elements	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
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 18. Cost to Locate Crashes (Dollars).

States	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
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	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
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

2.5. EVALUATING THE BENEFITS AND COSTS

Once the analyst has completed the calculation of annual benefits and costs, the analyst will **evaluate the benefits and costs**. This involves 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.

2.5.1. Convert into Common Units

To perform the benefit-cost evaluation, **all quantified benefits and costs must be expressed in the same units**. The above methodology was designed to estimate all benefits and costs in dollars. If a State DOT wishes to include any additional benefits and costs that were not covered here, the analyst should **seek out conversion factors** to ensure easy comparison of the benefits and costs.

It is also important to ensure that the same assumptions are made throughout the analysis as to whether or not to **apply an inflation factor to the benefits and costs**. The analyst may choose not to apply an inflation factor to any of the benefits and costs. If an inflation factor is applied, it should be applied to all benefits and costs. For the sake of clarity, no inflation factor has been applied in the examples in this Guidebook.

2.5.2. Calculate Present Values

Once benefits and costs are in dollars, the analyst will then **calculate the present values of these benefits and costs** 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.

To evaluate present values of benefits and costs, the analyst will **discount the future values through the application of a compound interest rate**. OMB guidance suggests a 7.0 percent discount rate *(3)*. 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 four, 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 19 includes all benefits prior to, and after, discounting. The undiscounted benefits were presented in Table 9. 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 20 includes all costs prior to and after discounting. The undiscounted benefits were presented in Table 16, Table 17, and Table 18. 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 19. Total Annual Benefits Prior to and After Discounting for an Average State (Thousands).

Year:	1 2011	2 2012	3 2013	4 2014	5 2015	6 2016	7 2017	8 2018	9 2019	10 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	$39,895.5	$43,499.7	$40,654.0	$37,994.4

Year:	11 2021	12 2022	13 2023	14 2024	15 2025	16 2026	17 2027	18 2028	19 2029	20 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 20. Total Annual Costs Prior to and After Discounting for an Average State (Thousands).

Year:	1 2011	2 2012	3 2013	4 2014	5 2015	6 2016	7 2017	8 2018	9 2019	10 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 2021	12 2022	13 2023	14 2024	15 2025	16 2026	17 2027	18 2028	19 2029	20 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	$15,866.5	$14,828.5	$13,858.4	$12,951.7	$12,104.4	$11,312.6	$10,572.5	$9,880.8

2.5.3. Calculate Net Present Value and Benefit-Cost Ratio

Once the discounting process is complete, the analyst will **calculate the net present value (NPV), or total net benefits, and the benefit-cost (B/C) ratio**. NPV is calculated by subtracting the total present value of costs from the total present value of benefits.

$$NPV = Total\ Present\ Value\ of\ Benefits - Total\ Present\ Value\ of\ Costs$$

The NPV of investments in data collection for the fictional DOT example used in this Guidebook is $546,118,554 minus $299,090,299, or $247,028,255.

The B/C 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 21 summarizes these figures.

Table 21. Net Present Value and Benefit-Cost Ratio.

Net Present Value	$247,028,255
Benefit-Cost Ratio	1.83

2.5.4. Evaluate Risk

If the analyst has any uncertainty in the assumptions made or the estimates obtained, a **sensitivity analysis may be performed** to show how the results are affected by changes in the parameters. For example, if the analyst feels the final costs of the collection of data are too low, or omit unforeseen costs, they may choose to apply a 10-15 percent price escalation factor to the costs used in the base model to see how this changes the final NPV or B/C ratio. The analyst may also take a similar approach might on certain benefits for which there remains uncertainty regarding the true values. As the estimates described in this Guidebook rely on assumptions and, in some cases, on approximations, it may be preferable to the State DOT to have a range of values for the NPV and B/C ratio. One of the advantages of conducting a sensitivity analysis is that the analyst will be able to **prepare a normal estimate and conservative estimate for both benefits and costs**, allowing a range to be presented.

2.5.5. Decision Rules

To **determine whether the implementation of a data collection project is economically justified**, and help an analyst **choose between competing alternatives**, the following decision rules may be applied:

- If NPV ≥ 0, a project is economically justified.
- If B/C ≥ 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 zero, and the benefit cost ratio is 1.83, which is greater than one. 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 benefit cost ratio, such as two, 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 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.

3. 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 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.

Low or medium data collection States 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 for this analysis, an analyst from a low or medium data collection State may construct a sample from a high data collection State. The analyst constructing this sample should, as much as possible, select the road segments and intersections that match the characteristics of the State's own system. For example, the analyst would 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 for individual States. However, a next step may be the development of national multipliers for improvements in roadway safety related to data. These national multipliers could be developed 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 national benefits estimator, States can adjust the national average values according to the particulars of their State. The methods described in this Guidebook can be used 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.

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, it could apply the national averages to its system by multiplying the average per-mile/intersection/ramp benefit with 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 of collecting intersection data for the State.

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 *(8, 9, 10)*. In many practical areas, adequate data do not exist to perform rigorous economic analysis. Instead of abandoning the analysis altogether for lack of data, proxy data is used that is 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. In the future, FHWA, TRB, NHTSA, or others may choose to develop a national benefits estimator. Additional effort is required at the national level to determine the individualized benefits of investment in various safety data from pooled national averages.

Table 22 provides a summary of potential approaches for developing a dataset to undertake analysis. As illustrated in Table 22, all States could benefit from having a national benefits estimator, whether they are currently classified as a having a high, medium, or low level of data collection.

Table 22. Potential Approaches to Developing Datasets 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

4. CHECKLIST

The following is a list of data elements required for an agency to perform the BCA of data collection.

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.
     - Metropolitan Planning Organizations (MPOs) 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.

2. **Faster project programming (this will require the State to choose a project for this example).**
   - 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.

3. **Improved project prioritization (for this calculation, the State needs to collect some data or borrow data from a similar State).**
   - 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 will

use one set of data, such as 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 data has been collected in the State (this will be used as a multiplier to scale up the calculations to the state level).

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.

5. **Data collection costs.**
   - Costs of collecting roadway, ramp, intersection, and LRS data, if other than those provided in the *Market Analysis of Collecting Fundamental Data Elements to Support the Highway Safety Improvement Program (5)*.
   - Roadway characteristics for the State, including number of miles, ramps, and signalized/unsignalized intersections.

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.

7. **Crash location and coding costs.**
   - Total annual injury and fatal crashes not automatically located.

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