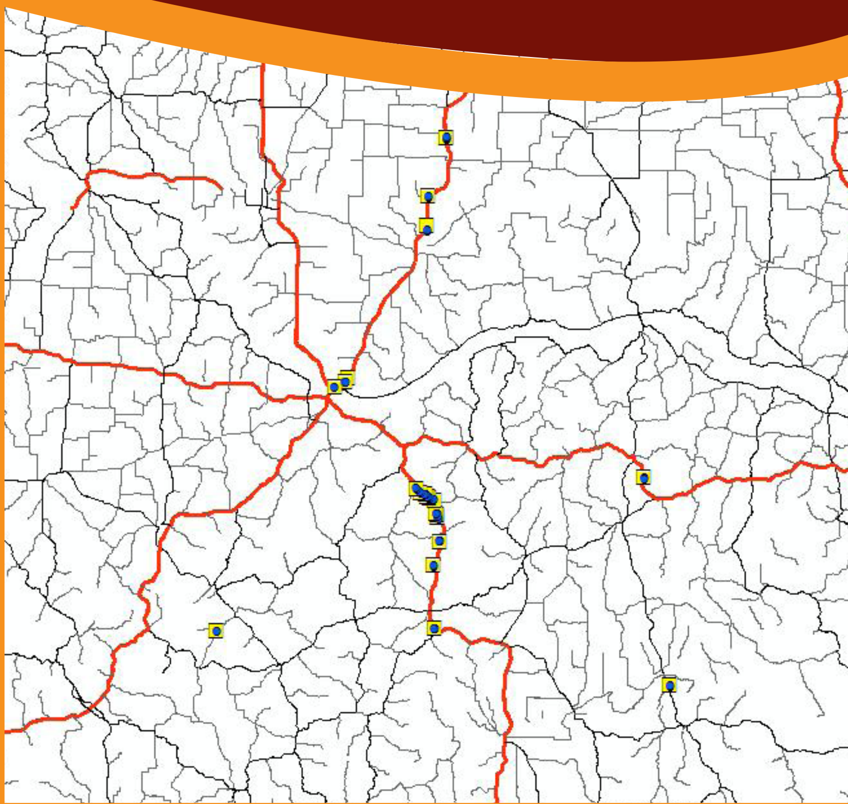
Market Analysis of Collecting Fundamental Roadway Data Elements to Support the Highway Safety Improvement Program



HSIP
Highway Safety Improvement Program
Data Driven Decisions

FHWA-SA-11-40

June 2011

U.S. Department of Transportation
Federal Highway Administration

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Notice

Quality Assurance Statement

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16. Abstract Quality data are the foundation for making important decisions regarding the design, operation, and safety of roadways. Using roadway and traffic data together with crash data can help agencies to make decisions that are fiscally responsible and to improve the safety of the roadways for all users. The Federal Highway Administration (FHWA) Office of Safety has established a fundamental set of roadway and traffic data elements that States should be collecting to support the activities conducted under their Highway Safety Improvement Programs (FDE/HSIP). The objective of this effort was to conduct a market analysis of the potential cost to States in developing a statewide location referencing system and collecting the FDE/HSIP in all public roadways. This effort also investigated potential methodologies that could be applied to estimate the benefits in terms of safety of collecting this additional roadway information. This report provides the results of this effort and provides suggestions for future research.				
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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
CFR	Code of Federal Regulations
DOT	Department of Transportation
EMS	Emergency Medical Services
FARS	Fatality Analysis Reporting System
FDE/HSIP	Fundamental Data Elements for HSIP
FHWA	Federal Highway Administration
GAO	Government Accountability Office
GIS	Geographic Information System
HPMS	Highway Performance Monitoring System
HSIP	Highway Safety Improvement Program
HSM	Highway Safety Manual
MAIS	Maximum Abbreviated Injury Scale
MIRE	Model Inventory of Roadway Elements
NHTSA	National Highway Traffic Safety Administration
OHPI	Office of Highway Policy Information
OMB	Office of Management and Budget
SAFETEA-LU	The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SHSP	Strategic Highway Safety Plan
TRB SHRP 2	Transportation Research Board Strategic Highway Research Program 2
TWG	Technical Working Group
U.S.	United States
USC	United States Code

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Executive Summary

Quality data are the foundation for making important decisions regarding the design, operation, and safety of roadways. By incorporating roadway and traffic data into safety analysis procedures, States can better identify safety problems and prescribe solutions to support their Highway Safety Improvement Programs (HSIP) and implement their Strategic Highway Safety Plans (SHSP). Furthermore, a new generation of safety analysis tools and methods are being developed to help identify safety issues and provide recommendations for improvements. These safety analysis tools, such as the Highway Safety Manual (HSM) and related SafetyAnalyst and Interactive Highway Safety Design Model (IHSDM) software, all require quality roadway, traffic, and crash data to achieve the most accurate results. Using roadway and traffic data together with crash data can help agencies to make decisions that are fiscally responsible and to improve the safety of the roadways for all users.

While HSIP guidance provides information on how safety data should be used, there is no additional detail on the specific data elements that State and local agencies should be collecting, maintaining, and using to support their HSIPs and SHSPs. In response to this gap, the Federal Highway Administration (FHWA) held a series of information gathering sessions in 2009 and 2010 and convened a Technical Working Group (TWG) from 2010 through 2011 to determine a minimum set of roadway and traffic data elements that States should be collecting; what data States are capable of collecting given the current economic environment; and the importance of using roadway and traffic data to support the States' HSIPs.

States should have a common statewide location referencing system, such as a geographic information system (GIS) or a linear referencing system, on all public roads. These systems will enable States to identify high crash locations on all their public roads. As States expand their inventories, these common statewide systems will enable States to link these locations with additional data systems, such as roadway and traffic data.

States should also be collecting a set of minimum roadway and traffic data elements that are fundamental to support their HSIPs. This set of elements is herein referred to as the Fundamental Data Elements for HSIP (FDE/HSIP).

The FDE/HSIP are based on the minimum required elements needed to use enhanced safety analysis tools and methods, including the HSM and related software SafetyAnalyst. They are a subset of the Model Inventory Roadway Elements (MIRE) and duplicate many of the Highway Performance Monitoring System (HPMS) full extent elements that States are already required to collect *(1)*. These FDE/HSIP elements include segment, intersection, and ramp data elements and were determined to be the basic set of data elements an agency would need to conduct enhanced safety analysis to support States' HSIPs.

While the FDE/HSIP were selected in part based on the basic data requirements of existing tools such as such as the HSM and related SafetyAnalyst, they are not exclusive to these tools. The FHWA recognizes that many States are developing analysis tools in-house that will help to support their HSIPs. The FDE/HSIP are a basic set of elements an agency would need to conduct effective, enhanced safety analysis independent of the specific analysis tools used or methods applied. All States should be moving towards using analysis tools and having the FDE/HSIP available to utilize these tools, regardless of whether they are the tools developed through Federal efforts or they are developed in-house.

The objective of this effort was to conduct a market analysis of the potential cost to States in developing a statewide location referencing system and collecting the FDE/HSIP on all public roadways. The primary theory is that collecting additional roadway and traffic data and integrating those data into the safety analysis process will improve an agency's ability to locate problem areas and apply appropriate countermeasures, hence improving safety. This effort also investigated potential methodologies that could be applied to estimate the benefits in terms of safety of collecting this additional roadway information.

A literature review was conducted to identify resources to help develop a methodology for analysis of the cost and benefits of collecting roadway data to improve highway safety. The literature review showed there were no established methodologies to estimate the benefit of collecting roadway data elements for safety. An alternate approach was developed to conduct the market analysis. The costs for data collection were gathered from several vendors and one State department of transportation (DOT) that had been investigating a similar effort. The numbers of fatalities and injuries that would need to be reduced in order to exceed the costs (for a 1:1 and 2:1 ratio) were estimated to determine the benefits. That is, this analysis identified the benefit required to obtain cost effectiveness.

The cost estimations developed for this analysis reflect the additional costs that States would incur based on what is not already being collected through HPMS or not already being collected through other efforts. At the time of this analysis, the FHWA did not know the extent of data collection practices for all States beyond HPMS requirements. In order to accommodate a range of data collection practices among the States, the methodology for the analysis was conservatively based on the assumption that all data collection beyond HPMS requirements would be new collection. Therefore, this analysis of the additional cost to States is most likely greater than the actual cost that would be incurred. Individual cost estimates would vary by the circumstances in each State.

Costs

A summary of the additional costs identified includes the following three sets of data elements:

1. A common relational location referencing system on all public roads.
    - Additional costs would only be incurred on all non-Federal-aid roadways, since HPMS currently requires this for Federal-aid highways.
2. The 22 FDE/HSIP that are not required under HPMS on all public roads.
    - Additional costs would only be incurred on Federal-aid roadways since 16 of the 38 total FDE/HSIP are already required for HPMS on Federal-aid highways.
3. The complete 38 FDE/HSIP on all public roads.
    - Additional costs would be incurred on all non-Federal-aid highways, since HPMS does not require data collection of these elements on non-Federal-aid roadways.

The costs were collected from a variety of vendors and were broken down into a per-mile basis for segments, per intersection, and per ramp. The summary of data collection costs is shown in Table 1.

**Table 1. Summary of Average Data Collection Costs in Addition to HPMS Requirements
(2010 U.S. Dollars)**

Data Collection Elements	Per Mile	Per Intersection	Per Ramp
Location Referencing System on Non-Federal-aid Highways			
Total	***$40***		
22 FDE/HSIP on Federal-aid Roadways (all FDE/HSIP minus HPMS elements)			
Elements	$60	$130	$100
Traffic Data	--	$590	$400
22 FDE/HSIP Total	***$60***	***$720***	***$500***
All FDE/HSIP on Non-Federal-aid Roadways			
Elements	$70	$130	$100
Traffic Data	$460	$590	$400
All Elements – Total	***$530***	***$720***	***$500***

Benefits

There are no established methodologies for estimating the safety benefits of collecting roadway data elements. It was not feasible at the time this analysis was conducted to develop a direct estimate of the safety benefits of collecting roadway inventory data. In lieu of a traditional cost-benefit estimate, a "cost effectiveness" approach was taken.

For the purposes of this analysis, work was conducted to determine what safety benefits would need to be realized from data collection in order to exceed the costs of collection. The needed benefits were calculated by developing an estimate of the number of fatalities and injuries that would need to be reduced in order to exceed a 1:1 ratio and a 2:1 ratio of benefits to costs. These estimates were developed for two scenarios:

Scenario 1:

- Develop a common statewide relational location referencing system on all public roads that is linkable with crash data (i.e., geographic information system, linear referencing system, etc).
    - This would require developing a referencing system on all non-Federal-aid roadways, since HPMS currently requires this for Federal-aid highways.
- Collect the FDE/HSIP on all Federal-aid highways.
    - This would require collecting the 22 FDE/HSIP that are not required under HPMS on roads, since 16 of the 38 total FDE/HSIP are already required for HPMS on Federal-aid highways.

Scenario 2:

- Develop a common statewide relational location referencing system on all public roads that is linkable with crash data (i.e., GIS, linear referencing system, etc).
    - This would require developing a referencing system on all non-Federal-aid roadways, since HPMS currently requires this for Federal-aid highways.
- Collect the FDE/HSIP on all Federal-aid highways.
    - This would require collecting the 22 FDE/HSIP that are not required under HPMS on roads, since 16 of the 38 total FDE/HSIP are already required for HPMS on Federal-aid highways.
- Collect the FDE/HSIP on all non-Federal-aid roads.
    - This would require collecting all 38 FDE/HSIP along all non-Federal-aid highways, since HPMS does not require data collection of these elements on non-Federal-aid roadways.

For both Scenarios, the first two initiatives would involve developing a statewide relational location referencing system on all public roads, and collecting the FDE/HSIP on all Federal-aid highways. Scenario 2 adds a third initiative of collecting the FDE/HSIP in all non-Federal-aid roads.

The analysis period for this effort was established to be 2012 – 2031. The costs were aggregated out to the State level, and then the estimated needed reductions in fatalities and injuries were determined based on the costs for each scenario. Both the costs and benefits were estimated across the analysis period and discounted to reflect 2010 U.S. dollars. The results of the analysis are shown in Table 2.

For Scenario 1, the average annual cost of data collection for an average State (based on HPMS mileage) is $6.3 million for initial collection and $3.4 million for maintenance over the analysis period of 2012 – 2031 (in 2010 U.S. dollars). Using a base of $6,339,701 as the comprehensive cost of a fatality and $516,947 as the comprehensive cost for an injury, a reduction of 0.6 fatalities and 41.0 injuries is required to achieve a greater than 1:1 benefit to cost ratio *(2)*. For Scenario 2, 2.5 fatalities and 163.7 injuries are needed to achieve greater than a 1:1 benefit. Scenario 2 includes collecting the FDE/HSIP on both Federal-aid and non-Federal-aid roads.

Table 2. Summary of Analysis for Average State
Analysis Period 2012 – 2031
Average Annual Costs and Needed Benefits
(Millions of 2010 U.S. Dollars)

Scenario	Cost During Collection	Cost During Maintenance	Estimated Fatalities Needed to Achieve >1:1	Estimated Injuries Needed to Achieve >1:1	Estimated Fatalities Needed to Achieve- >2:1	Estimated Injuries Needed to Achieve >2:1
1	$6.3	$3.4	0.6	41.0	1.2	81.6
2	$23.8	$12.8	2.5	163.7	5.0	325.9

Note - Costs are accumulated throughout the entire analysis period; benefits are realized after the data collection is complete.

Future Research

This effort was a preliminary attempt to quantify the costs and benefits of collecting roadway and traffic data for safety. The primary theory driving the analysis is that collecting additional roadway and traffic data and integrating those data into the safety analysis process will improve an agency's ability to locate problem areas and apply appropriate countermeasures, hence improving safety. Based on the work conducted for this effort, including a thorough literature review, it was determined that there are no established methodologies for quantifying the benefits of investing in safety data improvements. Additional research needs to be conducted to build upon the analysis provided in this report to work towards filling that knowledge gap by developing guidance on the methodologies that can be applied to determine the benefits of investing in data systems and processes for achieving a data-driven safety program. Developing such methodologies would be the crucial next step to help the FHWA Office of Safety achieve its goal to reduce highway fatalities by providing decision makers the tools they need to make informed decisions through an evidenced-based approach to safety implementation.

Introduction

Quality data are the foundation for making important decisions regarding the design, operation, and safety of roadways. By incorporating roadway and traffic data into safety analysis procedures, States can better identify safety problems and prescribe solutions to support their Highway Safety Improvement Programs (HSIPs) and implement their Strategic Highway Safety Plans (SHSPs). Furthermore, a new generation of safety analysis tools and methods are being developed to help identify safety issues and to provide recommendations for improvements. These safety analysis tools, such as the Highway Safety Manual (HSM) and related software SafetyAnalyst and Interactive Highway Safety Design Model (IHSDM), all require quality roadway, traffic, and crash data to achieve the most accurate results. Using roadway and traffic data together with crash data can help agencies to make decisions that are fiscally responsible and to improve the safety of the roadways for all users.

The Federal Highway Administration (FHWA) has developed guidance for States on implementing their HSIPs. While HSIP guidance provides information on how safety data should be used, there is no additional detail on the specific data elements that State and local agencies should be collecting, maintaining, and using to support their HSIPs and SHSPs. The FHWA Model Inventory of Roadway Elements (MIRE) provides a recommended listing of roadway inventory and traffic elements critical to safety management. The MIRE Version 1.0 report includes over 200 roadway and traffic data elements *(3)*. Due to the economic climate, it may not be feasible for States to collect all of the MIRE elements and integrate them into their existing programs. There remains a need for information on the fundamental roadway and traffic elements that departments of transportation (DOTs) should be collecting to support their HSIPs.

In response to this need, the FHWA held a series of information gathering sessions in 2009 and 2010 and convened a Technical Working Group (TWG) from 2010 through 2011. The purpose of the information gathering sessions and TWG was to determine which set of roadway and traffic data elements States should be collecting, what data States are capable of collecting given the current economic environment, and the importance of using roadway and traffic data to support the States' HSIPs.

States should have a common statewide location referencing system, such as a geographic information system (GIS) or a linear referencing system, on all public roads. This will enable States to locate high crash locations on all public roads. As States expand their inventories, these common statewide systems will enable States to link these locations with additional data systems, such as roadway and traffic data.

States should also be collecting a set of minimum roadway and traffic data elements that are fundamental to support a State's HSIP on all public roads. This set of elements is herein referred to as the Fundamental Data Elements for HSIP (FDE/HSIP). The FDE/HSIP include segment, intersection, and ramp data elements and were determined to be the basic set of data elements that an agency would need to conduct enhanced safety analyses to support a State's HSIP.

Objective

The objective of this effort was to conduct a market analysis of the potential cost to States in developing a statewide location referencing system and collecting the FDE/HSIP on all public roadways. The primary theory is that collecting additional roadway and traffic data and integrating those data into the safety analysis process will improve an agency's ability to locate problem areas and apply appropriate countermeasures, hence improving safety.

Background

The following sections provide additional background on the use of safety data in the HSIP, the MIRE elements, and the FDE/HSIP, as each relates to this effort.

Use of Safety Data in the HSIP

In 2009, 33,808 people died in motor vehicle traffic crashes in the U.S. According to the U.S. DOT, the total societal cost of crashes exceeds $230 billion annually *(4).* The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), which was signed into law on August 10, 2005, established the HSIP as a core Federal-aid program. The overall objective of the HSIP is to significantly reduce the occurrence of fatalities and serious injuries resulting from crashes on all public roads. The FHWA established a formalized HSIP process to ensure that the HSIP is carried out in an organized, systematic manner where the greatest benefits are achieved.

The 23 Code of Federal Regulations (CFR) Part 924 states that "*The HSIP shall include a data-driven SHSP and the resulting implementation through highway safety improvement projects."* Further, it defines a SHSP as *"a comprehensive, data-driven safety plan developed, implemented, and evaluated in accordance with 23 U.S.C. 148"(5).*

While the formalized HSIP process detailed in 23 CFR Part 924 addresses the use of safety data in the HSIP, there is no additional detail on the specific data elements that agencies should be collecting, maintaining, and using to support their HSIPs and development and implementation of their SHSPs. This was highlighted by the Government Accountability Office (GAO) Report 09-035 on the HSIP. The report, titled *Highway Safety Improvement Program, Further Efforts*

Needed to Address Data Limitations and Better Align Funding with States' Top Safety Priorities regarding the HSIP, contained recommendations regarding data needs to help fill identified gaps *(6)*. These recommendations, which the FHWA accepted for action, include the following:

1) Define which roadway inventory data elements a State needs to meet Federal requirements for HSIP.

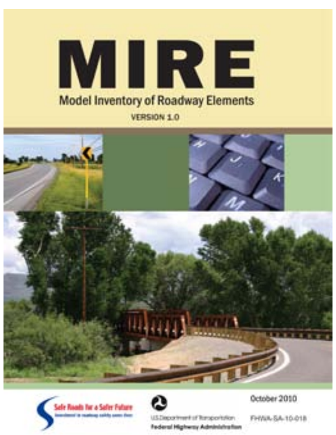
2) Set a deadline for States to finalize development of the required roadway data.

3) Require States to submit schedules to the FHWA for achieving compliance with this requirement *(6)*.

There still remains a need for guidance for the fundamental roadway and traffic data elements that States should be collecting to support their HSIP.

Model Inventory of Roadway Elements

MIRE, the Model Inventory of Roadway Elements, is a recommended listing of roadway inventory and traffic elements critical to safety management *(3)*. MIRE is intended as a guideline to help transportation agencies improve their roadway and traffic data inventories. It provides a basis for what can be considered a good/robust data inventory and helps agencies move towards the use of performance measures.



There are a total of 202 elements that comprise the MIRE listing. These elements are divided among three broad categories: roadway segments, roadway alignment, and roadway junctions. There are many benefits to State and local transportation agencies in expanding their inventories through the collection of MIRE elements. Having these additional data can help better identify where the safety problems are, what those problems are, and how best to treat them. Additional information on MIRE, including the full listing of elements, can be found at http://www.mireinfo.org.

MIRE is intended as guidance and provides a comprehensive listing of the data elements to support the HSIP. However, due to the economic climate, it may not be feasible for States to collect all of the MIRE elements and integrate them into their existing programs.

Fundamental Data Elements for HSIP (FDE/HSIP)

While MIRE provides a comprehensive listing of roadway and traffic data elements, it may not be feasible for States to collect all of the 200+ MIRE elements and integrate them into their existing programs. State departments of transportation (DOTs), particularly highway safety agencies, are facing increasing demands and decreasing resources. Additionally, the 23 CFR 924 provides only general information on how safety data should be used; it does not provide details on specific data elements *(5)*. There remains a need for information on a minimum set of fundamental roadway and traffic elements that DOTs should be collecting to support their HSIPs.

In order to address the States' safety data improvements challenges, the FHWA held a series of information gathering sessions and convened a TWG. The purpose of the TWG was to determine the roadway and traffic data elements that States should be collecting, what States are capable of collecting given the current economic environment, and the importance of using roadway and traffic data in the safety analysis process.

States should have a common statewide location referencing system, such as geographic information system (GIS) or a linear referencing system, on all public roads. This will enable States to locate high crash locations on all public roads in the State. As States expand their inventories, this common system will enable States to link these locations with additional data systems, such as roadway and traffic data.

States should also be collecting a set of minimum roadway and traffic data elements on all public roads that are fundamental to support a State's HSIP - the FDE/HSIP. These are based on the elements needed to apply HSM roadway safety management (Part B) procedures using network screening analytical tools (such as SafetyAnalyst), are a subset of MIRE, and duplicate many of HPMS full extent elements that States are already required to collect on Federal-aid Highways. The FDE/HSIP are comprised of roadway segment, intersection, and ramp elements as shown in Table 3.

The FDE/HSIP are a basic set of elements an agency would need to conduct effective, enhanced safety analysis independent of the specific analysis tools used or methods applied. While the FDE/HSIP were selected in part based on the basic data requirements of existing tools such as the HSM and related SafetyAnalyst, they are not exclusive to these tools. The FHWA recognizes that many States are developing analysis tools in-house that will help to support their HSIPs. All States should be moving towards using analysis tools and having the FDE/HSIP available to utilize these tools, regardless of whether they are the tools developed through Federal efforts or they are developed in-house.

Table 3. FDE/HSIP Elements.

FDE/HSIP Elements	Definition
Roadway Segment	
Segment ID*	Unique segment identifier.
Route Name*	Signed numeric value for the roadway segment.
Alternate 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 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.
Intersection	
Intersection ID	A unique junction identifier.
Location	Location of the center of the junction on the first intersecting route (e.g., route-milepost).

Table 3. FDE/HSIP Elements Continued.

FDE/HSIP Elements	Definition
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 Annual Average Daily Traffic (AADT) on the approach leg of the intersection/junction.
Major Road AADT Year	The year of the Annual Average Daily Traffic (AADT) on the approach leg of the intersection/junction.
Minor Road AADT	The Annual Average Daily Traffic (AADT) on the approach leg of the intersection/junction.
Minor Road AADT Year	The year of the Annual Average Daily Traffic (AADT) on the approach leg of the intersection/junction.
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 identifier 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 that 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 ramp.
Ramp AADT*	AADT on ramp.
Ramp AADT Year	Year of AADT on ramp.

*HPMS full extent elements required on all Federal-aid highways and ramps located within grade-separated interchanges, i.e., NHS and all functional systems excluding rural minor collectors and locals.

In 2011, the FHWA Office of Safety released a guidance memorandum on the fundamental data elements that States should be collecting and incorporating into their safety analyses to support their HSIPs and indicate on what roadways they should be collecting data. In addition to the memorandum, the FHWA Office of Safety has also developed the *Background Report: Guidance for Roadway Safety Data to Support the Highway Safety Improvement Program*, to support the guidance set forth in memorandum and act as a counterpart to this analysis *(7)*. The *Background Report* provides additional detail on FDE/HSIP, existing and emerging data collection methodologies, estimated costs of collection (based on the results of this market analysis), potential funding sources, and model performance measures.

Literature Review

The literature review for this research effort focused on identifying literature pertaining to the costs and benefits of collecting data. This extensive search looked at sources both within the transportation industry and expanded to fields outside of transportation including forestry, medicine and health, ecology, water resources, and mining. Literature from these fields was reviewed for any pertinent methodologies or findings that could be helpful to this research effort. The findings from the review were used to help develop a methodology for conducting a market analysis of the cost and benefits of collecting roadway data to improve highway safety. Most of the literature did not contain information directly relevant to developing a methodology for this type of cost-benefit analysis; however, there were a few resources that provided useful information, and these are summarized in the following paragraphs.

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 were able to quantify 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 *(8)*.

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 *(9)*. 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. Various vendors were used to collect a sampling of pavement, roadside, geotechnical, and bridge elements *(10)*. 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. Information from the vendors who participated in both of these data collection efforts was used to help develop cost estimates for the market analysis *(11)*.

A recent study by Li et al. presents a methodology for a benefit-cost analysis 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. An annual potential for safety improvements associated with improvements to the hardware was calculated and compared 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. This methodology was too specific for the purpose of developing this market analysis but presented a vision on how future data efforts could be quantified, comparing locations without data and locations with data *(12)*.

A full list of all of the literature reviewed for this project, including a brief summary of each resource, can be found in Appendix A.

Methodology

Overview

Based on the results of the literature review, communications with States, discussions with experts, and review of the Office of Management and Budget (OMB) guidance *(13)*, an appropriate methodology was developed to meet the objectives of this effort given the available information.

The literature review showed there were no established methodologies to estimate the benefit of collecting roadway data elements for safety. No one State was identified that has collected the exact list of FDE/HSIP on all public roadways within the State. Therefore, an analysis of collecting all 38 FDE/HSIP to determine the safety benefits was not feasible at the time this investigation was conducted.

An alternate approach was developed to conduct the market analysis. The costs for data collection were provided from several vendors and one State DOT that had been investigating conducting a similar effort. The number of fatalities and injuries that would need to be reduced in order for the monetized benefits to exceed the costs was estimated to determine the benefits. The methodology developed is a hybrid of a benefit-cost analysis and a cost effectiveness analysis.

The cost estimations developed for this analysis reflect the additional costs that States would incur based on what is not already being collected through HPMS or not already being collected through other efforts. At the time of this analysis, the FHWA did not know the extent of data collection practices for all States beyond HPMS requirements. In order to accommodate a range of data collection practices among the States, the methodology for the analysis was conservatively based on the assumption that all data collection beyond HPMS requirements would be new collection. Therefore, this analysis of the additional cost to States is most likely greater than the actual cost that would be incurred. Individual cost estimates would vary by the circumstances in each State.

A location referencing system is already required under HPMS for all Federal-aid highways. In addition, 16 of the 38 FDE/HSIP are also already required for collection under the HPMS for the full extent of Federal-aid highways *(1)*. Full extent accounts for all Federal-aid highways and ramps located within grade-separated interchanges (i.e., NHS and all functional systems excluding rural minor collectors and locals). Table 3 indicates which of the 38 FDE/HSIP are HPMS full extent elements.

Data Collection Costs

The additional costs identified include the following three sets of data elements:

1. A common relational location referencing system.
    - Additional costs would only be incurred on all non-Federal-aid roadways, since HPMS currently requires this for Federal-aid highways.
2. The 22 FDE/HSIP that are not required under HPMS.
    - Additional costs would only be incurred on Federal-aid roadways, since 16 of the 38 total FDE/HSIP are already required for HPMS on Federal-aid highways.
3. The complete 38 FDE/HSIP.
    - Additional costs would be incurred on all non-Federal-aid highways, since HPMS does not require data collection of these elements on non-Federal-aid roadways.

In order to conduct the analysis, costs were obtained from 12 data collection vendors from around the country. Costs were obtained from the vendors on a per-mile basis along segments, a per-intersection basis for intersections, and a per-ramp basis for ramps. The costs for developing a location referencing system were estimated per mile. For the case of traffic counts on segments, an estimate of one count per mile was used to estimate to generate a per mile cost. These costs included data collection and reduction for integration into a State's existing system.

Vendors were identified based on the list of vendors involved in the North Carolina and the Transportation Research Board Strategic Highway Research Program 2 (TRB SHRP2) data collection rodeos which were both conducted in 2008. These rodeos were conducted to test the capabilities of roadway data collection technologies. Many of the rodeo vendors only collected roadway inventory elements and not traffic counts, so the project team also identified several companies that collect traffic counts to obtain cost estimates. The (non-traffic) roadway elements are collected using different methods than the traffic data, and, therefore, the costs for each were calculated separately.

The majority of vendors estimated that they would use digital data collection vans to collect the roadway inventory data. For traffic count data, vendors provided cost estimates based on 48-hour classification counts for segment traffic data, peak hour manual counts for intersections, and technology similar to segment counts to collect ramp data. The costs provided were averaged to develop estimates.

The analysis was based on information provided by vendors and reflects the methods and costs that would be used if the collection was contracted. There are other methods of collecting some of these data elements, including extracting the data from existing plans or visual imagery such as aerials or Google Earth. Some of these methods may be lower in costs, particularly if the cost of agency personnel are not included as part of the costs.

In addition, several State DOTs were contacted to obtain estimates of what the costs would be to collect these "in-house" rather than contract the data collection out to a vendor. Since the data collection was very specific to this list of FDE/HSIP, 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. The analysis was conducted 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).

Benefits

For the purposes of this analysis, the benefits were calculated by developing an estimate of the benefits needed to exceed a 1:1 ratio and a 2:1 ratio of benefits to costs. The first step in the analysis was to calculate the cost of a fatality and the cost of an injury. The 2008 comprehensive cost of a fatality used in the analysis was $6,339,701 and $516,947 for an injury, based on information provided by the National Highway Traffic Safety Administration (NHTSA) *(2)*. The injury costs reflect a Maximum Abbreviated Injury Scale (MAIS) Level 3 injury. MAIS injuries are on a scale of 0-5, with 5 being the most severe non-fatal injury. MAIS Level 3 was chosen as a "mid-point" in this scale.

The future cost of a fatality and injury were forecasted out 20 years to 2031 and then discounted to reflect 2010 dollar values. A discount rate of 7.0 percent was used. The benefit estimation assumed that the benefits would not be realized until the data collection is complete: 2021 for Federal-aid and 2022 for non-Federal-aid roads.

An average of the costs of a fatality and the cost of an injury from 2021 through 2032 was calculated. This calculation provided the cost of a fatality and the cost of an injury, represented in 2010 dollars.

In order to determine the balance of the number of fatalities and injuries that should be used in calculating the benefits, a ratio of the number of fatalities to injuries was calculated using 2009 crash data. In 2009 there were 33,808 total fatalities and 2,217,000 total injuries *(14)*, equating to a fatality to injury ratio of approximately 1:66. Using that ratio, the number fatalities and injuries needed to exceed a 1:1 ratio and a 2:1 ratio of benefits to cost was developed for each State, and for each scenario.

Classification of Roadway Ownership

Costs were aggregated to a State level to estimate the reduction in crashes (fatalities and serious injuries) needed to exceed the costs. The first step in the analysis was to develop a classification of roadway ownership for each State. Three States were analyzed: an "average" State, a small State (information from Rhode Island was used to represent a small State), and a large State (information from California was used to represent a large State). To calculate the costs for each State, the mileage, number of intersections, and number of ramps was determined for the Federal-aid and non-Federal-aid roadways. The mileage was obtained from the FHWA Office of Highway Policy Information (OHPI) *(15).* The mileage for the "average" State was calculated using the U.S total (including Washington, DC) and dividing by 51.

There is not yet an estimate of intersections or ramps available through the OHPI. Therefore, the project team contacted States directly to obtain estimates of the number of intersections and ramps in each State. In addition to a large State and a small State, Missouri and Ohio were contacted to obtain estimates for the "average" State. Missouri and Ohio were chosen to represent the "average" State based on their land mass, roadway mileage, and geographic locations.

All of the States except California were able to provide the total number of intersections and ramps in the State. In California, the total number of intersections was estimated 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 intersections. This assumes there is the same density of intersections per mile on each roadway set.

The number of ramps provided by the States was applied to the Federal-aid roadways with the justification that there would most likely not be ramps on non-Federal-aid roads. The distribution of roadway ownership by State, mileage, intersections, and ramps is shown in Table 4.

Table 4. Breakdown of Roadway Ownership.

State	Mileage Federal-aid	Mileage Non-Federal-aid	Intersections Federal-aid	Intersections Non-Federal-aid	Ramps Federal-aid	Ramps Non-Federal-aid
Average State	19,430	57,390	70,430	208,020	4,450	0
Rhode Island	1,750	4,600	27,560	72,440	380	0
California	55,230	103,490	132,370	248,030	14,660	0

Aggregated Costs

The aggregated costs were developed for two scenarios:

- ***Scenario 1:***
  - Develop a common statewide relational location referencing system on all public roads that is linkable with crash data (i.e., GIS, linear referencing system, etc).
    - Additional costs would be incurred for developing a referencing system on all non-Federal-aid roadways, since HPMS currently requires this for Federal-aid highways.
  - Collect the FDE/HSIP on all Federal-aid highways.
    - Additional costs would be incurred for collecting the 22 FDE/HSIP that are not required under HPMS on roads since 16 of the total FDE/HSIP are already required for HPMS on Federal-aid highways.
- ***Scenario 2:***
  - Develop a common statewide relational location referencing system on all public roads that is linkable with crash data (i.e., GIS, linear referencing system, etc).

    - Additional costs would be incurred for developing a referencing system on all non-Federal-aid roadways, since HPMS currently requires this for Federal-aid highways.
- Collect the FDE/HSIP on all Federal-aid highways.
    - Additional costs would be incurred for collecting the 22 FDE/HSIP that are not required under HPMS on roads since 16 of the total FDE/HSIP are already required for HPMS on Federal-aid highways.
- Collect the FDE/HSIP on all non-Federal-aid roads.
    - Additional costs would be incurred for collecting all 38 FDE/HSIP all non-Federal-aid highways, since HPMS does not require data collection of these elements on non-Federal-aid roadways.

For both Scenarios, the first two initiatives involve developing a statewide relational location referencing system on all public roads, and collecting the FDE/HSIP on all Federal-aid highways. Scenario 2 adds a third initiative of collecting the FDE/HSIP in all non-Federal-aid roads.

The base cost for mileage, intersections, and ramps was then disaggregated annually. The time frames include five years for segments, seven years for intersections, and nine years for ramps on Federal-aid roads; and six, eight, and ten years respectively for non-Federal-aid roadways. These time frames were selected as reasonable intervals for State and local agency collection of the FDE/HSIP data.

For this analysis, data collection was estimated to begin in 2012 and continue for nine years to 2020 for Federal-aid roadways, and continue for ten years to 2021 for non-Federal-aid roadways. The analysis assumes an equal distribution of costs over the data collection period.

In addition to the costs of initial data collection, the costs to maintain the data were also calculated. That is, the costs to update the data as conditions change. For segment data, it was assumed that five percent of the roadway mileage would be updated annually. These updates would not be done by re-collecting the data, but rather based on updates from construction/design plans. It was approximated that updating the inventory would take two hours per mile by an employee earning $20.00 an hour (approximately $40,000 per year).

The intersection inventory would 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. A split of 20 percent of signalized intersections and 80 percent of unsignalized intersections was used to determine the number of signalized and unsignalized intersections. In addition, the cost of inventory updates was also included in the maintenance costs.

The analysis assumes that a ramp inventory would be updated on a six-year cycle, with counts and inventory updates collected on one-sixth of the ramps per year.

The costs for coding and locating crashes on non-Federal-aid roads was also calculated since States would now have the information they need to locate crashes, which they would not have had previously. National statistics were obtained from NHTSA to estimate a ratio of fatal crashes to injury crashes *(14)*. The number of fatal crashes on non-Federal-aid roads was obtained from the NHTSA Fatality Analysis Reporting System (FARS) *(16)*. The ratio of fatal to injury crashes was applied to the number of fatal crashes on non-Federal-aid highways to obtain an estimate of injury crashes on non-Federal-aid highways. Costs for locating and coding these additional crashes were then applied. It was assumed 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 number of property damage only crashes on non-Federal-aid roads could be not reasonably estimated; therefore, they were not included.

These assumptions on data collection cycles, maintenance, and crash coding were based on standard practices obtained through discussions with several States.

Once the costs for collection, maintenance, and coding of the data were determined, they were summed to establish a total cost per year out to 2032. This timeframe would allow for the total 10-year data collection period (for non-Federal-aid roads) and an additional 10 years of implementation. These costs were then discounted using a 7.0 percent discount rate per the OMB guidance to bring the costs back to 2010 values *(13)*. Once the costs were all in the same value year, an annual average cost during the data collection period and an annual average cost during the maintenance period was calculated.

Results

The results of the analysis are shown in the following sections.

Costs

The additional costs identified include the following three sets of data elements:

1. A common relational location referencing system.
    - Additional costs would only be incurred on all non-Federal-aid roadways, since HPMS currently requires this for Federal-aid highways.
2. The 22 FDE/HSIP that are not required under HPMS.
    - Additional costs would only be incurred on Federal-aid roadways, since 16 of the 38 total FDE/HSIP are already required for HPMS on Federal-aid highways.
3. The complete 38 FDE/HSIP.

- Additional costs would be incurred on all non-Federal-aid highways, since HPMS does not require data collection of these elements on non-Federal-aid roadways.

Table 5 provides the calculated average cost per mile, per intersection, and per ramp for each of the sets of elements.

Table 5. Summary of Average Data Collection Costs in Addition to HPMS Requirements. (2010 U.S. Dollars)

Data Collection Elements	Per Mile	Per Intersection	Per Ramp
Location Referencing System on Non-Federal-aid Highways			
Total	***$40***		
22 FDE/HSIP on Federal-aid Roadways (all FDE/HSIP minus HPMS elements)			
Elements	$60	$130	$100
Traffic Data	--	$590	$400
22 FDE/HSIP Total	***$60***	***$720***	***$500***
All FDE/HSIP on Non-Federal-aid Roadways			
Elements	$70	$130	$100
Traffic Data	$460	$590	$400
All Elements – Total	***$530***	***$720***	***$500***

Benefits

The benefits, in terms of the number of fatalities and injuries that would need to be reduced in order to achieve a greater than 1:1 and greater than 2:1 benefit to cost ratio, were determined for each State and for each scenario.

The future cost of a fatality and injury were forecasted out to 2031 and then discounted to reflect 2010 dollar values. The costs were then averaged across the analysis period to provide the cost of a future fatality and the cost of an injury represented in 2010 dollars.

For Scenario 1, this resulted in an average future cost of approximately $2.2 million for a fatality and $0.2 million for an injury in 2010 dollars. Since the benefit estimation assumed that the benefits would not be realized until the data collection is complete (2021 for Federal-aid and 2022 for non-Federal-aid roads), the estimates varied slightly for Scenario 2. For Scenario 2, the average future cost was approximately $2.1 million for a fatality and $0.2 million for an injury in 2010 dollars.

In order to determine the balance of the number of fatalities and injuries that should be used in calculating the benefits, a ratio of the number of fatalities to injuries was calculated using 2009 crash data. In 2009 there were 33,808 total fatalities and 2,217,000 total injuries, equating to a fatality to injury ratio of approximately 1:66 *(14)*. Using that ratio, the number fatalities and injuries needed to exceed a 1:1 ratio and a 2:1 ratio of benefits to costs was developed for each State, and for each scenario.

The results of the analysis are presented in the following sections.

Scenario 1

- Develop a common statewide relational location referencing system on all public roads that is linkable with crash data (i.e., GIS, linear referencing system, etc).
  - This would require developing a referencing system on all non-Federal-aid roadways, since HPMS currently requires this for Federal-aid highways.
- Collect the FDE/HSIP on all Federal-aid highways.
  - This would require collecting the 22 FDE/HSIP that are not required under HPMS on roads since 16 of the total FDE/HSIP are already required for HPMS on Federal-aid highways.

The summary of the average annual costs and required benefits for Scenario 1 are shown in Table 6. For an average State, 0.6 fatalities and 41.0 injuries would need to be reduced per year in order to achieve a greater than 1:1 benefit to cost ratio. This increases to 1.2 fatalities and 81.6 injuries that would need to be reduced per year to achieve a greater than 2:1 benefit to cost ratio for an average State. This ranges from 0.5 fatalities for a small State to 2.5 fatalities for a large State.

Table 6. Summary Average Annual Cost and Needed Benefit for Scenario 1. (Millions of 2010 U.S. Dollars)

State	Cost of Collection	Cost of Maintenance	Cost of a Fatality	Cost of an Injury	Needed Fatalities	Needed Injuries
Benefit > 1:1						
Average State	$6.3	$3.4	$2.2	$0.2	0.6	41.0
Small State	$2.4	$1.3	$2.2	$0.2	0.2	15.5
Large State	$12.6	$6.7	$2.2	$0.2	1.2	80.8
Benefit > 2:1						
Average State	$6.3	$3.4	$2.2	$0.2	1.2	81.6
Small State	$2.4	$1.3	$2.2	$0.2	0.5	30.8
Large State	$12.6	$6.7	$2.2	$0.2	2.5	160.8

Note - Costs are accumulated throughout the entire analysis period; benefits are realized after the data collection is complete.

Scenario 2

- Develop a common statewide relational location referencing system on all public roads that is linkable with crash data (i.e., GIS, linear referencing system, etc).
    - This would require developing a referencing system on all non-Federal-aid roadways, since HPMS currently requires this for Federal-aid highways.
- Collect the FDE/HSIP on all Federal-aid highways.
    - This would require collecting the 22 FDE/HSIP that are not required under HPMS on roads since 16 of the total FDE/HSIP are already required for HPMS on Federal-aid highways.
- Collect the FDE/HSIP on all non-Federal-aid roads.
    - This would require collecting all 38 FDE/HSIP all non-Federal-aid highways, since HPMS does not require data collection of these elements on non-Federal-aid roadways.

The summary of the average annual costs and required benefits for Scenario 2 are shown in Table 7. For an average State, 2.5 fatalities and 163.7 injuries would need to be reduced per year in order to achieve a greater than 1:1 benefit to cost ratio. This increases to 5.0 fatalities and 325.9 injuries that would need to be reduced to achieve a greater than 2:1 benefit to cost ratio for an average State. This ranges from 1.7 fatalities for a small State to 7.3 fatalities for a large State.

Table 7. Summary Average Annual Cost and Needed Benefit for Scenario 2. (Millions of 2010 U.S. Dollars)

State	Cost of Collection	Cost of Maintenance	Cost of a Fatality	Cost of an Injury	Needed Fatalities	Needed Injuries
Benefit > 1:1						
Average State	$23.8	$12.8	$2.1	$0.2	2.5	163.7
Small State	$8.2	$4.5	$2.1	$0.2	0.9	57.3
Large State	$36.0	$17.7	$2.1	$0.2	3.7	241.1
Benefit > 2:1						
Average State	$23.8	$12.8	$2.1	$0.2	5.0	325.9
Small State	$8.2	$4.5	$2.1	$0.2	1.7	114.0
Large State	$36.0	$17.7	$2.1	$0.2	7.3	479.9

Note - Costs are accumulated throughout the entire analysis period; benefits are realized after the data collection is complete.

While this report provides estimates for an the average, small and large State, the FHWA Office of Safety has developed a spreadsheet tool to help States better estimate the cost to collect FDE/HSIP for their specific State. This spreadsheet takes into account collection costs spread over a specified time frame, ongoing costs to maintain the additional data, and other factors involved in the collection and maintenance of data. It also provides States an estimate of how many fatalities and injuries would need to be reduced in order to exceed the data collection costs using the methodology laid out in this report.

Summary

The purpose of this effort was to conduct a market analysis of the development of a statewide common location referencing system and the collection of the FDE/HSIP on all public roads. The primary theory is that collecting additional roadway and traffic data, and integrating those data into the safety analysis process, will improve an agency's ability to locate problem areas and apply appropriate countermeasures, hence improving safety.

A literature review was conducted to identify resources to help develop a methodology for analysis of the cost and benefits of collecting additional roadway data to improve highway safety. The literature review showed there were no established methodologies to estimate the benefit of collecting roadway data elements for safety. An alternate approach was developed to conduct the market analysis. The costs for data collection were gathered from vendors and State DOT. For benefits, an estimate of how many fatalities and injuries would need to be reduced in order exceed the costs (for a 1:1 and 2:1 ratio) were developed. That is, this analysis identified the benefit required to obtain cost effectiveness.

The additional costs identified include the following three sets of data elements:

1. A common relational location referencing system on all public roads.
    - Additional costs would only be incurred on all non-Federal-aid roadways, since HPMS currently requires this for Federal-aid highways.
2. The 22 FDE/HSIP that are not required under HPMS on all public roads.
    - Additional costs would only be incurred on Federal-aid roadways since 16 of the total FDE/HSIP are already required for HPMS on Federal-aid highways.
3. The complete 38 FDE/HSIP on all public roads.
    - Additional costs would be incurred on all non-Federal-aid highways, since HPMS does not require data collection of these elements on non-Federal-aid roadways.

The costs were collected from a variety of vendors and a State DOT, and were broken down into per mile (for segments), per intersection, and per ramp costs.

When the costs were aggregated out to the State level, the estimated reduction in fatalities and injuries were determined based on the costs for each Scenario. Table 8 shows the range of data collection costs and estimated required benefits for the average State for both scenarios. For Scenario 1, the total cost of data collection for an average State (based on HPMS mileage) is $6.3 million for initial collection, and $3.4 million for maintenance over the analysis period of 2012 – 2031 (in 2010 U.S. dollars). A reduction of 0.6 fatalities and 41.0 injuries is required to achieve a greater than 1:1 benefit to cost ratio. This increases in Scenario 2, which also includes collecting the FDE/HSIP on all non-Federal-aid roads. For Scenario 2, 2.5 fatalities and 163.7 injuries are needed to achieve greater than a 1:1 benefit.

Table 8. Summary of Market Analysis for Average State.
Analysis Period 2012–2031
Average Annual Costs and Needed Benefits
(Millions of 2010 U.S. Dollars)

Scenario	Cost During Collection	Cost During Maintenance	Estimated Fatalities Needed to Achieve >1:1	Estimated Injuries Needed to Achieve >1:1	Estimated Fatalities Needed to Achieve- >2:1	Estimated Injuries Needed to Achieve >2:1
1	$6.3	$3.4	0.6	41.0	1.2	81.6
2	$23.8	$12.8	2.5	163.7	5.0	325.9

Note - Costs are accumulated throughout the entire analysis period; benefits are realized after the data collection is complete.

The work conducted for this project was a preliminary attempt to quantify the costs and benefits of collecting roadway and traffic data for safety. The primary theory driving the analysis is that collecting additional roadway and traffic data and integrating those data into the safety analysis process will improve an agency's ability to locate problem areas and apply appropriate countermeasures, hence improving safety. Based on the work conducted for this effort, including a thorough literature review, it was determined that there are no established methodologies for quantifying the benefits of investing in safety data improvements. Additional research needs to be conducted to build upon the analysis provided in this report to work towards filling that knowledge gap by developing guidance on the methodologies that can be applied to determine the benefits of investing in data systems and processes for achieving a data-driven safety program. Developing such methodologies would be the crucial next step to help the FHWA Office of Safety achieve its goal to reduce highway fatalities by providing decision makers the tools they need to make informed decisions through an evidenced-based approach to safety implementation.

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Appendix A: Literature Matrix

Source	Author(s)	Publication	Year	Summary
Transportation Sources				
Colorado DOT	Todd Pickton, Janet Clements, Robert W. Felsburg	*Statewide Economic Benefits of Transportation Investment*	2007	Evaluates statewide economic benefits of future transportation investment in CO using data and benefits studies from other states.
Colorado DOT	Jim Mascolo, Ginger Pelz, Doug Magee	*2008 Safety Engineering Annual Report*	2008	*Report was identified but could not be located.*
County Road Association of Michigan and Michigan DOT	County Road Association of Michigan and Michigan DOT	*PASER Cooperative Road Condition Survey Demonstration Project*	2001	Description of GPS/GIS asset management data collection effort.
FHWA	Ronald C. Pfefer, Richard A. Raub, Roy E. Lucke	*Highway Safety Data: Costs, Quality, and Strategies for Improvement Research Report*	1998	Identifies costs of collecting, reporting, and managing safety data.
Florida DOT	Iskandaria Masduki, Margaret Armstrong, Amy Finley, Rebecca Augustyniak, Kea Herron	*Applying Instructional Design Practices to Evaluate and Improve the Roadway Characteristics Inventory (RCI) Training Curriculum*	2010	Evaluates FDOT's training program for district data collection technicians on the Roadway Characteristics Inventory (RCI) methods. Focuses on an instructional design strategy to improve the training and reduce its cost.
NC Department of Transportation	Y. Richard Kim, Joseph E. Hummer, Mohammed Gabr, David Johnston, B., Shane Underwood, Daniel J. Findley and Christopher M. Cunningham	*Asset Management Inventory and Data Collection*	2009	Results of an effort in NC to collect asset management data on 95 miles on roadway.
NCHRP (Project 8-36, Task 22)	Cambridge Systematics	*Working Paper #1: Economic Benefits of Transportation Investment*	2002	Presents basic information on how safety improvements save lives and the related economic benefit. No discussion on data collection or project selection
NCHRP (Project 8-36, Task 22)	Cambridge Systematics	*Working Paper #3: Community and Social Benefits of Transportation Investment*	2002	Discusses safety improvements of specific treatments. No information presented that adds to current knowledge that would assist in this effort.
NHTSA	L. Blincoe, A. Seay, E. Zaloshnja, T.Miller, E. Romano, S.Luchter, R.Spicer	*The Economic Impact of Motor Vehicle Crashes, 2000*	2002	Report presents analysis results of motor vehicle crash costs in the US in 2000.
SHRP 2	Charles Fay, Sr.	*SHRP 2 Roadway Projects - Safety Symposium 2010 (presentation)*	2010	This presentation reviewed an ongoing SHRP2 projects on roadway data collection. It provided a list of vendors who participated in their data collection rodeo.
TR News, Number 254	Bradley J. Overturf	*A Roadway Photolog Goes High-Definition: Connecticut Expands User Network, Realizes Cost Savings*	2008	The Connecticut Department of Transportation (DOT) has created a high definition image inventory of the State's entire roadway network, accessible for desktop computer viewing by users throughout the agency. The DOT's photolog director traces the development and capabilities of the pioneering system, which has saved the state approximately $2 million.
Transportation Research Record (1719)	James P. Hall, Tschangho John Kim, Michael I. Darter	*Cost-Benefit Analysis of Geographic Information System Implementation: Illinois Department of Transportation*	2000	Paper presents an investigation of the costs and benefits of geographic information system (GIS) implementation in the Illinois DOT. Addresses the need to determine the organizational impact and cost-effectiveness of the technology to achieve the greatest benefit.

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Transportation Research Record (2160)	Zongzhi Li, Samuel Labi, Matthew Karlaftis, Konstantinos Kepaptsoglou, Montasir Abbas, Bei Zhou, Sunil Mandanu	*Project-Level Life-Cycle Benefit-Cost Analysis Approach for Evaluating Highway Segment Safety Hardware Improvements*	2010	Presents a methodology for a benefit-cost analysis of improving highway segment safety hardware over its life cycle. Calculates the annual potential for safety improvements associated with the upgrading of hardware by reductions in fatal, injury, and PDO collisions.
TRB Research E-Circular (E-C077)	James P. Hall	*Enhancing the Value of Data Programs: A Peer Exchange*	2005	Summarizes the proceedings from a peer exchange forum, organized to raise awareness of data programs, share best practices and ideas for addressing data gaps and other emerging problems.
University of Arkansas	Kelvin C.P. Wang, Weiguo Gong, Zhiqiong Hou	*Networked Sensor System for Automated Data Collection and Analysis*	2008	This research describes the development of a real-time multi-functional system for roadway data acquisition and analysis with multiple sensors. This system, Digital Highway Data Vehicle (DHDV), combined the technologies of laser illumination based digital imaging, inertial profiling and GPS mapping into an integrated system to accomplish the multiple tasks of survey and management for roadway data.
University of South Florida	Linjun Lu, Jian John Lu, Pei Sung Lin, Zhenyu Wang, Hongyun Chen	*Developing and Interface Between FDOT's Crash Analysis Reporting System and the Safety Analyst*	2009	This research presents a method to convert information from FDOT's Crash Analysis Reporting (CAR) System to a format that can be used in the SafetyAnalyst software. Other databases were also investigated, such as the Roadway Characteristics Inventory (RCI), for their compatibility with SafetyAnalyst.
Volpe National Transportation Systems Center, FHWA	S.C. Dresley, A. Lacombe	*Value of Information and Information Services*	1998	This report describes and, where possible, quantifies the value of information and information services for transportation agencies. It evaluates the various means of accessing information, and the important role of the information professional.
VTT Tiedotteita--Research Notes	Maila Herrala	*The Value of Transport Information*	2007	The objectives of this research were to identify the attributes affecting the value of transport information, and to specify the valuation methods applied.
Washington State DOT, Transportation Data Office		*Better Decisions Through Better Data*	2007	Discusses how WSDOT collects roadway, traffic, and collision data.
Other Industry Sources				
American Journal of Medicine	S.J. Wang, B. Middleton, L.A. Prosser, et.al	*A Cost-Benefit Analysis of Electronic Medical Records in Primary Care*	2003	The purpose of this study was to estimate the net financial benefit or cost of implementing electronic medical record systems in primary care.
American Society of Mechanical Engineers	Steve Adam, Joseph T. Hlady	*Data is an Asset that Should be Managed*	2007	Illustrates how data can be viewed as an asset rather than an expenditure. The intent of this is not as an accounting strategy, but as a way to illustrate how data shows asset characteristics.
American Statistical Association	C. Sims	*Can we measure the benefits of data programs?*	1984	*Article was identified but could not be located.*
Australia New Zealand Land Information Council	Price Waterhouse Economic Studies & Strategies Unit	*Australian Land and Geographic Data Infrastructure Benefits Study*	1995	Examines the economic gains from developing, maintaining, improving and providing access to land and geographic data infrastructure at a national level. Also determines and prioritizes the steps data supplying organizations in Australia should take to maximize potential infrastructure benefits.

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Canadian Journal of Fisheries and Aquatic Sciences, 67	E.P. Fenichel, G.J.A. Hansen	*The Opportunity Cost of Information: An economic framework for understanding the balance between assessment and control in sea lamprey management*	2010	Research using sea lamprey population management to show how the optimal allocation of resources between assessment and control depends on the total budget, the relative cost of each management activity, the marginal reduction in uncertainty associated with increased assessment, and the marginal effectiveness of increased treatment.
Clinical Trials; London (Periodical)	Reza Rostami, Meredith Nahm, Carl F. Pieper	*What can we learn from a decade of database audits?*	2009	Reviewed a decade of internal data quality audits performed at Duke Clinical Research Institute. Results indicate higher quality data achieved from a series of small audits rather than a single large database audit.
Computer Technology Review	Fred Moore	*The Value of Data*	2002	Focuses on the determination of the monetary value of data.
Decision Sciences Institute	Grant O. Alexander	*Development of an Instrument for Measuring Information and Information Technology's Costs and Economic Value*	1997	Literature review of the measurement of business value of information and information systems, specifically, the issues of information and information technology's costs, benefits, and economic value.
Economics Bulletin	Daniel Sgroi	*Irreversible investment and the value of information gathering*	2003	This report develops a model in which a firm has to decide whether to undertake an irreversible investment.
Fisheries	G.J.A. Hansen, M.L. Jones	*The Value of Information in Fishery Management*	2008	Article illustrates the importance of accounting for all aspects of the value of information using examples drawn from three critical areas of fishery management. Authors discuss how experts have judged the value of assessment programs in the past, and provide suggestions as to how these methods could be expanded to examine the value of information in a more holistic manner.
Institute for Geoinformation, Technical University Vienna	Alenka Krek, Andrew U. Frank	*The Production of Geographic Information - The Value Tree*	2000	Investigates how organizations collect raw geographic data and turn it into usable geographic information. The corresponding economic theory gives guidelines for fixing the transfer prices between the participants, which determines their share of the value produced.
International Journal of Technology, Policy, and Management	Pieter W.G. Bots, Fred A. B. Lohman	*Estimating the Added Value of Data Mining: A Study for the Dutch Internal Revenue Service*	2003	Addresses how the added value of data mining for an organization can be defined and measured before major investments in data warehousing systems are made.
International Pipeline Conference 2004	Bruce Dupuis, Jason Humber	*Pipeline Integrity: Establishing Data Management Value*	2004	Paper addresses the process needed to determine the value of data management to support pipeline integrity.
Journal of AHIMA	M. Mercer	Data warehousing improves care, demonstrates return on investment	2001	*Article was identified but could not be located.*
Journal of Applied Corporate Finance	Margaret Armstrong, William Bailey, Benoit Couet	*The Option Value of Acquiring Information in an Oilfield Production Enhancement Project*	2005	Article presents a case study of an oil production enhancement where Bayesian analysis is used in a real options framework to determine if the cost of collecting additional data is justified.
Journal of Health Services Research & Policy	Susan Griffin, Karl Claxton, Mark Sculpher	*Decision Analysis for Resource Allocation in Health Care*	2008	Addresses the use of economic evaluation to inform resource allocation decisions within health care systems about which interventions to reimburse and whether additional research should be funded.

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Journal of Information Technology	Bert van Wegen, Robert De Hoog	*Measuring the Economic Value of Information Systems*	1996	Paper outlines an approach that combines the information commodity approach, activity-based costing, and graph modeling to determine the value of information systems for information management.
Journal of Mechanical Design Transactions of the ASME	J. M. Ling, J. M. Aughenbaugh, C.J.J Paredis	*Managing the collection of information under uncertainty using information economics*	2006	Introduces the principles of information economics to guide decisions on information collection. Investigates how designers can bound the value of information in the case of distributions with unknown parameters by using imprecise probabilities to characterize the current state of information.
Mining Technology: IMM Transactions Section A	Sean Dessureault	*Justification Techniques for Information Technology Infrastructure in Mining*	2004	The Black-Scholes option pricing method (BSOPM) is used to value the investment in a data warehouse for the mining industry.
NASA Airspace Systems Program	Thomas B. Sheridan	*Strategy for Optimum Acquisition of Information*	2006	Brief tutorial on optimizing acquisition of data (example presented - whether to add an instrument to an aircraft to optimize performance given how much it cost).
Nursing Management; Chicago	Bernadette M. Billinger	*Should your data collection expand or shrink?*	2000	Addresses the issue of expanding data collection and how to evaluate how useful and cost-effective it is in hospital areas. Three guidelines - know what you're collecting, ask the right question, focus your efforts
Pennsylvania State University	Damon Jones, Brian K. Bumbarger, Mark T. Greenberg, et al	*The Economic Return on PCCD's Investment in Research-based Programs: A Cost-Benefit Assessment of Delinquency Prevention in Pennsylvania*	2008	This report considers the cost-effectiveness potential for seven research-based programs funded by the Pennsylvania Commission on Crime and Delinquency (PCCD).
Photogrammetric Engineering and Remote Sensing	S. DeBruin, G.J. Hunter	*Making the Trade-off Between Decision Quality and Information Cost*	2003	Paper discusses how to compare if using additional or different imagery to improve decision quality may be justified by its cost. Compares competing factors using a cost-benefit analysis.
Principles of Microeconomics, 2nd edition (McGraw-Hill)	Robert H. Frank, Ben S. Bernanke	*The Economics of Information*	2003	Chapter on basic economic principles to help identify situations where additional information is most likely to prove helpful.
Resources for the Future	Molly K. Macauley	*The Value of Information: A Background Paper on Measuring the Contribution of Space-Derived Earth Science Data to National Resource Management*	2005	Describes a general framework for conceptualizing the value of information and illustrates how the framework might be used to value information from earth science data collected from space.
Society	Stuart Nagel	*Determining When Data is Worth Gathering*	1978	Brief analysis that investigates how to determine how much data is "excessive" when it comes to gathering data for federal agencies.
STEPHEN (Science & Technology Policy Asian Network)	M.A.T De Silva	*Typology of S&T Statistics and Methods for Data Collection for Output and Input Indicators*		Discusses a few data collection methods, and the development of output indicators (productivity, rate of return).
Studies in Health and Technology Informatics	I. Shabtai, M. Leshno, O. Blondheim, et.al	*The value of information for decision-making in the healthcare environment*	2007	Ealuates the contribution of information technology (IT) to improving the medical decision-making processes at the point of care of internal medicine and surgical departments and to evaluate the degree to which IT investments are worthwhile.
Swedish University of Agriculture Sciences, Dept. of Forest Resource Management	Karl Duvemo	*The Influence of Data Uncertainty on Planning and Decision Processes in Forest Management*	2009	Focuses on how uncertainty in forest data affects the outcome of management planning and decision making.
The Australian Society for Medical Research	Access Economics	*Exceptional Returns: the Value of Investing in Health R&D in Australia*	2003	His research shows that every dollar invested in health R&D in Australia has historically be recouped many times over, and that it makes an exceptional investment with high returns.

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Trends in Ecology and Evolution	R. E. Johannes	*The Case for Data-less Marine Resource Management: Examples from Tropical Nearshore Finfisheries*	1998	Paper discusses the case for data-less management of finfisheries since there are too few researchers to do the work and it is usually not cost-effective.
US Dept. of State	Christopher Dauer	*Insurers uptight about NAIC overhaul of data collection*	1995	Insurance brokers express concern over the NAIC's intention to make data retrieval files more specific. One concern was how much the data files would cost.