Pilot FHWA In-Service Performance Evaluation of Guardrail End Terminals, Volume I: Data Analysis, Project Summary, and Report Development

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FOREWORD

The roadside safety community has long recognized the importance of monitoring the in-service performance of roadside hardware. The emerging importance of asset management for highway agencies coupled with recent attention on guardrail terminal crashes has motivated many highway agencies to improve their capabilities for performing in-service performance evaluations (ISPEs) of roadside hardware. The Federal Highway Administration (FHWA) initiated the Pilot In-Service Performance Evaluation of Guardrail End Terminals (ISPE of GETs) project to investigate the practicality of highway agencies performing routine in-service evaluation of end treatments. The pilot study did not evaluate nor did it compare the performance of specific devices.

The final report is published in three volumes: Volume I is the main text of the final report, Volume II is the Practice-Ready Guide, and Volume III is the Data Dictionary and Forms. This document, *Pilot FHWA In-Service Performance Evaluation of Guardrail End Terminals, Volume I: Data Analysis, Project Summary, and Report Development,* summarizes the procedures and activities of the five highway agencies that participated in the FHWA Pilot ISPE of GETs. The report provides a methodology for State highway agencies to conduct in-service performance evaluations. Highway agencies can collect routine, useful ISPE data that have the potential for making significant improvements to roadside safety while also maximizing the utility of scarce highway agency resources. The findings in this report will be useful for roadside safety professionals as they determine how to monitor and assess the condition of roadside safety assets.

Brian P. Cronin, P.E.
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From September 2015 to the end of January 2019, the Federal Highway Administration partnered with departments of transportation in California, Massachusetts, Missouri, and Pennsylvania, as well as the Pennsylvania Turnpike Commission, to perform a proof of concept for a methodology for data collection of w-beam guardrail end terminals. Data collectors took photographs and recorded observations at crash scenes in which passenger vehicles experienced a head-on crash with the impact heads of common guardrail terminals, including the ET 2000, ET Plus® with both 4- and 5-inch guide channels, Sequential Kinking Terminal (i.e., SKT), MASH-compliant Sequential Kinking Terminal (i.e., MSKT), FLared Energy Absorbing Terminal (i.e., FLEAT), X-Lite, X-Tension®, and MAX-Tension™. The pilot study demonstrated that highway agencies can collect performance data of guardrail terminals by integrating in-service performance data-collection procedures into their normal crash-response activities.</td></tr>
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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 1,000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 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 (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

PILOT FHWA IN-SERVICE PERFORMANCE EVALUATION OF GUARDRAIL END TERMINALS REPORT SERIES

This volume is the first of three volumes in this research report series. *Pilot FHWA In-Service Performance Evaluation of Guardrail End Terminals, Volume I: Data Analysis, Project Summary, and Report Development* is the final report. Volume II and Volume III are forthcoming publications. Volume II consists of Appendix A, and Volume III consists of Appendix B. Any reference to a volume in this series will be referenced in the text as "Volume II: Appendix A" or "Volume III: Appendix B." The following list contains the three volumes of this series:

Volume	Title
I	Pilot FHWA In-Service Performance Evaluation of Guardrail End Terminals, Volume I: Data Analysis, Project Summary, and Report Development
II	Pilot FHWA In-Service Performance Evaluation of Guardrail End Terminals, Volume II: Appendix A, Practice Ready Guide
III	Pilot FHWA In-Service Performance Evaluation of Guardrail End Terminals, Volume III: Appendix B, Data Dictionary and Forms

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LIST OF ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
ADC	agency data collector
APL	approved products list
APOC	agency point of contact
Caltrans	California Department of Transportation
CHP	California Highway Patrol
DOT	department of transportation
FHWA	Federal Highway Administration
FLEAT	FLared Energy Absorbing Terminal
GET	guardrail end terminal
ISPE	in-service performance evaluations
KABCO	five-level injury scale used for police reports where K is fatal injury, A is suspected serious injury, B is suspected minor injury, C is possible injury, and O is no apparent injury
KC	Kansas City
MASH	Manual for Assessing Safety Hardware
MassDOT	Massachusetts Department of Transportation
MoDOT	Missouri Department of Transportation
MOU	memorandum of understanding
MSHP	Missouri State Highway Patrol
MSKT	MASH-compliant Sequential Kinking Terminal
MSP	Massachusetts State Police
NCHRP	National Cooperative Highway Research Program
NHS	National Highway System
NHTSA	National Highway Traffic Safety Administration
PennDOT	Pennsylvania Department of Transportation
PII	personally identifiable information
POC	point of contact
PSP	Pennsylvania State Police
PTC	Pennsylvania Turnpike Commission
QPL	qualified products list
R&D POC	research and development point of contact
SCI	Special Crash Investigations
SD	Secure Digital
SKT	Sequential Kinking Terminal
SME	subject-matter expert
SW	southwest
TIM	traffic incident management
TRB	Transportation Research Board

EXECUTIVE SUMMARY

The roadside safety community has long recognized the importance of monitoring the in-service performance of roadside hardware. While procedures for collecting and analyzing in-service performance data have been available for years, highway agencies have limited experience in conducting in-service performance evaluations. The emerging importance of asset management for highway agencies coupled with recent attention on guardrail terminal crashes has contributed to many highway agencies improving their capabilities for performing in-service performance evaluations of roadside hardware.

The Federal Highway Administration (FHWA) conducted a pilot study from September 2015 through January 2019 to encourage highway agencies to improve their ability to conduct in-service performance evaluations. FHWA partnered with the departments of transportation in California, Massachusetts, Missouri, and Pennsylvania, and the Pennsylvania Turnpike Commission to perform a proof of concept for a methodology for collecting data on guardrail end terminal crashes. Data collectors took photographs and recorded observations at crash scenes involving passenger vehicles and the impact heads of common guardrail terminals including the ET 2000, ET Plus® with both 4- and 5-inch guide channels, Sequential Kinking Terminal (i.e., SKT), MASH-compliant Sequential Kinking Terminal (i.e., MSKT), FLared Energy Absorbing Terminal (i.e., FLEAT), X-Lite, X-Tension®, and MAX-Tension™.

The FHWA pilot study resulted in the collection of data from 567 crashes with W-beam guardrail end terminals and demonstrated that highway agencies can collect guardrail terminal performance data by integrating in-service performance data-collection procedures into their normal crash-response activities.

This report summarizes the procedures and activities of the five highway agencies that participated in the FHWA Pilot Guardrail End Terminal In-Service Performance Evaluation. After data collection had concluded, the report authors interviewed the following participants to determine what procedures worked most effectively in the context of each highway agency's crash response practices:

- Highway agency data collectors.
- Highway agency points of contact (POC).
- National Highway Transportation Safety Administration (NHTSA) Special Crash Investigation (SCI) data-collection team manager.
- FHWA subject matter experts.
- FHWA Research and Development (R&D) POC.
- NHTSA SCI POC.

This report examines the procedures used by each of the data-collection teams to identify lessons learned that will help highway agencies to plan and execute future data-collection efforts. Lessons learned provide highway agencies with suggestions for next steps to start, continue, or expand future in-service performance evaluations in their jurisdictions. The report summarizes data for the 567 individual crashes. The FHWA pilot study did not evaluate or compare the performance of specific devices.

CHAPTER 1. INTRODUCTION

A reoccurring theme in roadside hardware crash test and evaluation procedures over the last 40 yr is the recommendation to conduct in-service performance evaluations (ISPEs) of roadside hardware. Michie et al. recommended ISPEs in *National Cooperative Highway Research Program (NCHRP) Report 230*, the crash test and evaluation procedures published in 1981 (Michie 1981). Ross et al. reiterated the need for ISPEs in *NCHRP Report 350*, as did the American Association of State Highway and Transportation Officials (AASHTO) in both editions of the *Manual for Assessing Safety Hardware* (MASH) (AASHTO 2009, 2016; Ross et al. 1993). More than a decade ago, Baxter, in *Memorandum: In-Service Performance Evaluation and Continuous Monitoring of Roadside Safety Features*, noted the following:

> Ideally, all highway agencies should know precisely what has been incorporated into its roadway/roadside infrastructure and be able to monitor the performance of individual components of its highway system. Asset management has become a primary means of accomplishing this goal in many States. However, there remains one area where in-service evaluation or performance monitoring seems to be minimal at best, and that is the area of roadside safety features. (Baxter 2005)

Roadside hardware, such as W-beam guardrail end terminals (GETs), should demonstrate successful performance according to the currently adopted crash-test and evaluation criteria in the AASHTO MASH. To be eligible for Federal-aid funding on the National Highway System (NHS), roadside safety hardware should be compliant with the AASHTO MASH, or in some cases, with *NCHRP Report 350*. Satisfying these same procedures is also usually necessary to be accepted on most States' qualified products list (QPL) or approved product lists (APL). Laboratory crash-test performance evaluations of guardrail terminals during the development phases of those terminal designs provide the first benchmarks for device performance. Laboratory crash tests are carefully monitored and conducted at specific impact speeds, angles, and with specific vehicle types. In a crash test, hardware installers are not subjected to live traffic during installation and the installations are checked by the designers. The approach and run-out areas in a crash test are flat and clear of obstacles, and the impact conditions are carefully controlled and monitored. These specific test conditions are designed not only to evaluate hardware performance but also to achieve repeatability among crash-test laboratories. Laboratory crash tests are an important evaluation step, but they test under narrow conditions, which are not representative of all field conditions. Laboratory crash tests are not a guarantee of consistent performance under the numerous field conditions that exist and the many ways vehicles strike roadside safety hardware.

After demonstrating successful performance in laboratory crash tests, highway agencies install roadside hardware, such as GETs, in the field according to the guidelines of the AASHTO *Roadside Design Guide* (RDG) and the appropriate highway agency design standards (AASHTO 2011). The RDG provides guidance on how to select, locate, and place roadside hardware that has been successfully crash tested.

While some ISPEs were performed in the 1970s, the first formal comprehensive guide to performing ISPEs of roadside hardware was published as *NCHRP Report 490*, *In-Service Performance of Traffic Barriers* in 2003 (Agent 1975; Ray, Weir, and Hopp 2003). *NCHRP Report 490* defined two approaches to conducting ISPEs of roadside hardware: a retrospective ISPE and a prospective ISPE. Carrigan et al. (2017) recently harmonized the *NCHRP Report 490* method with more recent developments in statistics and epidemiology for the study of rare events like roadside crashes with hardware. Carrigan et al. explored modern statistical techniques for modeling the conditional probability question that underlies all ISPEs of roadside hardware: What is the crash outcome and performance of the roadside hardware when a crash has occurred (Carrigan et al. 2017; Persaud 2016)? There are several potential performance measures and outcomes, including the proportion of vehicle-occupant fatalities or serious injuries, the cost of repairing the terminal, and the effect of environmental conditions on the hardware. Of these, the proportion of vehicle-occupant fatalities or serious injuries is the most important and basic measure of roadside-hardware performance. Methods for performing ISPEs of roadside hardware have been available for several decades. What remains is to institutionalize ISPEs into the regular and routine operations of highway agencies as suggested by Baxter 15 yr ago (Baxter 2005).

After a highly publicized question arose concerning a widely used GET, Federal Highway Administration (FHWA) and AASHTO commissioned a Task Force on Guardrail Terminal Performance "comprised of Federal and State safety experts, [who] analyzed the data collected by FHWA to determine whether there is any evidence of unique performance limitations of the 4-inch ET Plus system and the degree to which any such performance limitations extend to other extruding W-beam guardrail terminals" (FHWA 2016). Six FHWA engineers, three AASHTO staff engineers, and nine engineers from highway agencies made up the Task Force. This Task Force reviewed crash information supplied by the States and the public through a Federal Register website and examined several nationwide, federally maintained databases. The Task Force performed a variety of reviews and analyses and found that while there were performance limitations for all W-beam guardrail terminals, none were unique to the ET Plus®. The Task Force also noted the following:

> Within the roadside safety community, it is recognized that even with the "best" practice of terminal design, with the wide variety of traffic and field conditions and applications, there will be crashes that exceed the performance expectations for the terminals. In addition, roadside features such as ditches, curbing, uneven terrain, and steep slopes in the vicinity of the terminal factor into the ability to mitigate the severity of the outcome of a guardrail terminal crash event. (AASHTO-FHWA 2015, p. 117)

The Task Force on Guardrail Terminal Performance found that all GET systems have similar performance limitations. Despite the roadside-safety community's decades-long suggestions encouraging ISPEs, highway agencies have performed relatively few. When questions arise regarding roadside safety hardware, highway agencies have limited data about whether installed roadside hardware performs as intended.

The Transportation Research Board (TRB) initiated a policy review of ISPEs of GET systems. The TRB policy-review team reviewed literature, interviewed experts, assessed the feasibility of highway agencies performing ISPEs of GET systems, and identified appropriate next steps.

The results, published in *TRB Special Report 323*, concluded the following:

> State highway agencies will require more information about the benefits, costs, and practicality of routine in-service evaluation of end treatments in general before deciding to undertake new data collection and analysis programs necessary to carry out more challenging analyses. The committee recommends research to advance practice and test the feasibility of and costs associated with more complex evaluations. It also recommends research to examine whether procedures for testing the performance of devices should be altered. (NASEM 2018)

CHAPTER 2. OBJECTIVES OF THE FHWA PILOT ISPE OF GETS

FHWA initiated the pilot study to investigate the "practicality of routine in-service evaluation of end treatments" being performed by highway agencies. *TRB Special Report 323* recommended studies like the FHWA Pilot ISPE of GETs investigation, and the 2005 Baxter memorandum showed that FHWA has long promoted the use of ISPEs (McGee et al. 2017; Baxter 2005). FHWA's objective for the Pilot ISPE of GETs was to see if routine data collection for ISPEs is feasible using resources, procedures, and personnel typically available to highway agencies.

The purpose of the FHWA pilot study was neither to produce definitive answers about the performance of specific GET systems nor to determine which GET systems performed better than others. The purpose of the pilot study was to investigate the feasibility of using existing State resources to develop a data-collection methodology suited to ISPEs. This was an untested activity; therefore, State POCs designated trial areas in which to collect data.

The design of the FHWA pilot study focused on the implementation of ISPE data-collection procedures and the evaluation of the effectiveness of those procedures for wider routine adoption by highway agencies. Results of the FHWA pilot study are reflected in the lessons learned and recommendations for future ISPE data collection discussed in chapter 6 and chapter 7 of this report. The available data summarized in chapter 5 are a byproduct of the pilot study and not the main result.

FHWA initiated the data collection for the FHWA pilot study in 2015 by developing collaborative relationships with departments of transportation in California, Massachusetts, Missouri, and Pennsylvania, as well as the Pennsylvania Turnpike Commission (PTC). The intent was to collect data on crashes that involved any of the following hardware evaluated using the procedures in *NCHRP Report 350*: ET 2000, ET Plus with both 4- and 5-inch guide channels, FLared Energy Absorbing Terminal (i.e., FLEAT), Sequential Kinking Terminal (i.e., SKT), X-Lite, and X-Tension®. Later, some of the participating highway agencies added then-emerging MASH GET systems like the SoftStop®, MAX-Tension™, and MASH-compliant Sequential Kinking Terminal (i.e., MSKT).

The National Highway Traffic Safety Administration (NHTSA), FHWA Resource Center's Safety Technical Services Team, FHWA's Office of Safety, and FHWA division offices in each of the States collecting data provided support and assistance in planning, preparing, and conducting the data collection for the FHWA pilot study. Highway-agency personnel collected photographs and completed forms based on onsite observations. For crashes that did not require an ambulance, highway-agency personnel collected data for the FHWA pilot study. For crashes that required an ambulance, NHTSA SCI teams investigated the crashes for most of the partner highway agencies (NHTSA 2019a). The protocol objective was for an SCI team to deploy to a crash site within 24 hours of receiving notification of the crash. There were variations for how the process evolved in each data-collection area, which is described in more detail in chapter 4.

The first data-collection effort started in Missouri in November 2015. Data collection for all highway-agency partners was completed by the end of January 2019. The FHWA pilot study sought to identify challenges for collecting data for effective ISPEs and recommend best practices for the following:

- Data collection on crashes involving roadside safety hardware.
- Interagency communication at the State level regarding crash reporting.
- Data management regarding hardware maintenance and inventory.

The primary objective of the FHWA pilot study was to be a proof of concept for a methodology to collect highway agency-level data for use in ISPEs of GETs. Results of the pilot study's data-collection efforts are meant to provide a template (i.e., data-collection forms, photographic guidelines, and lessons learned) for highway agencies and other agencies that may facilitate routine ISPEs of roadside hardware.

This report documents the pilot study and assesses the alternatives for data-collection procedures used in each data-collection area. This report is based solely on information provided to the authors by FHWA and pilot study participants after the conclusion of the data-collection activity. This report describes data-collection efforts, summarizes the data collected, and synthesizes the lessons learned in the pilot study. Based on the experiences of the participants, this report also presents recommendations on how highway agencies can undertake ISPE data-collection activities in the future.

CHAPTER 3. STUDIED HARDWARE

Roadside safety hardware developed between 1993 and 2011 had to demonstrate acceptable crashworthy performance based on test and evaluation procedures in *NCHRP Report 350* for State DOTs to receive Federal-aid highway reimbursement on the NHS (FHWA 1997; Ross et al. 1993). FHWA reviewed crash-test reports as a service to highway agencies and issued eligibility letters to developers of roadside hardware, including GET systems. FHWA eligibility letters were not an endorsement or approval of the tested hardware. Rather, eligibility letters indicated that the hardware was eligible for reimbursement under the Federal-aid highway program. Individual highway agencies determine what roadside hardware will be installed on roadways. Most highway agencies require some evidence of successful crash-test evaluations according to *NCHRP Report 350* or MASH to include a product on the highway agency's QPL or APL. An FHWA eligibility letter often was considered sufficient documentation by many highway agencies.

Initially, the FHWA pilot study focused on GET systems tested and evaluated using *NCHRP Report 350*. As the pilot study progressed, new GET systems emerged that were tested and reviewed by the participating highway agencies and FHWA according to the new MASH crash-test and evaluation procedures (AASHTO 2009, 2016). Some agencies added these new MASH GET systems to their ongoing ISPE data-collection efforts. Table 1 shows the GET systems included in the pilot study, the manufacturer of the system, the test procedure used to evaluate the system (i.e., *NCHRP Report 350* or MASH), and the FHWA eligibility letter series that addresses the system.

There were 8 *NCHRP Report 350* GET systems plus a category for the ET Plus with an unknown guide channel width and 3 MASH GET systems, creating a total of 11 GET systems. Two types of energy-absorption strategies characterize these GET systems: extruding and telescoping. Extruding impact heads use the kinetic energy of the impacting vehicle to push the guardrail through an impact head. The extruding impact head changes the shape of the guardrail as it passes through the impact head, thereby converting kinetic energy into strain energy. Telescoping GET systems, on the other hand, dissipate the kinetic energy of the impacting vehicle through friction generated by sliding guardrail and cable components along the length of the GET. All Lindsay GET systems are the telescoping variety (e.g., X-Tension, MAX-Tension, and X-Lite), whereas all Road Systems and Trinity Highway Products GET systems are of the extruding variety. Figure 1 through figure 9 show photographs of the impact head or face of the 10 GET systems studied. More information on each GET system is available on the manufacturer's website or in the eligibility letters listed in table 1.

Table 1. GET systems evaluated in the FHWA pilot study.

Manufacturer	GET System	Test Procedure	Eligibility Letter Series (FHWA 2020a)
Trinity Highway Products (Trinity 2020)	ET 2000	*Report 350*	cc-12 to cc-12t
	ET Plus with 5-inch guide channels	*Report 350*	cc-12i to cc-12t
	ET Plus with 4-inch guide channels	*Report 350*	cc-12 to cc-12t cc-94 to cc-94a
	ET Plus with unknown guide-channel width	*Report 350*	cc-12 to cc-12t cc-94 to cc-94a
	SoftStop	MASH	cc-115 to cc-115i
Road Systems Inc. (RSI 2020)	FLEAT	*Report 350*	cc-46 to cc-46d cc-61 to cc-61c cc-88 to cc-88e cc-129
	SKT	*Report 350*	cc-40 to cc-40b cc-61 to cc-61c cc-88 to cc-88d cc-130
	MSKT	MASH	cc-126 to cc-126g
Barrier Systems by Lindsay (Lindsay 2020)	X-Lite	*Report 350*	cc-120 to cc-120b
	X-Tension	*Report 350*	cc-102 to cc-102a
	MAX-Tension	MASH	cc-133 to cc-133a cc-134 to cc-134a cc-141 to cc-141a

Source: FHWA.

Figure 1. Photograph. ET 2000 extruding end treatment impact head.

Source: FHWA.

Figure 2. Photograph. ET Plus extruding end treatment impact head (4- and 5-inch guide channels).

Source: FHWA.

Figure 3. Photograph. SoftStop extruding end treatment impact head.

Source: FHWA.

Figure 4. Photograph. SKT extruding end treatment impact head.

Source: FHWA.

Figure 5. Photograph. MSKT extruding end treatment impact head.

Source: FHWA.

Figure 6. Photograph. FLEAT extruding end treatment impact head.

Source: FHWA.

Figure 7. Photograph. X-LITE telescoping end treatment impact head.

Source: FHWA.

Figure 8. Photograph. X-Tension telescoping end treatment impact head.

Source: FHWA.

Figure 9. Photograph. MAX-Tension telescoping end treatment impact head.

Devices listed in table 1 and shown in figure 1 through figure 9 have multiple design variations. Several of these devices can be installed in dozens of design variations. The X-Lite may be installed, for example, in a tangent or flared configuration. The ET Plus, ET 2000, SKT, and FLEAT are all available in wood- and steel-post configurations. The SKT is sometimes installed using a slotted rail and other times with a combination rail for the first guardrail element.

Some SKT and FLEAT configurations are installed with groundline struts; others are installed without them. Many systems have different arrangements and options for the breakaway posts used at post locations 1 and 2, and some can be used with or without breakaway line posts. Data-collection procedures accounted for some of these variations by using the data-collection forms discussed in chapter 4, which captured information on the type and size of each post and blockout in each system. Data collectors did not determine exactly which variation was in use at a specific crash scene. GET systems were categorized by participants in the FHWA pilot study by the impact head alone; therefore, it is important to recognize that the results shown in chapter 5 group all variations of a particular GET system together. In other words, the results for the SKT or ET Plus include steel- and wood-post variations as well as multiple variations of the breakaway posts. The field data collectors did not assess whether the GET systems included all appropriate parts or were assembled correctly. Their identification was made based solely on the impact head.

CHAPTER 4. DATA COLLECTION

BACKGROUND

Participating agencies collected information for 567 crashes. The first data collection began in Missouri in November 2015, and the data collection was complete in all areas by January 31, 2019. A crash with any 1 of the 10 GET systems triggered data collection for a new case.

This study was focused on terminal performance assuming a crash occurred, not on crash causation. To be included in the FHWA pilot study, a crash had to meet the case inclusion criteria listed in the Case Inclusion Criteria section of this chapter.

Except for Massachusetts, which will be discussed later in this chapter, data collection was a joint effort between the participating State agencies, NHTSA, and FHWA. This effort was a two-tier data-collection effort: highway agency personnel collected lower-severity cases and NHTSA's SCI teams collected higher-severity cases. Higher-severity cases were those resulting in at least one ambulance transport from the crash scene. Lower-severity crashes involved property damage only (PDO) and minor injuries, requiring no ambulance transport from the crash scene. This distinction is a NHTSA-observed practice to capture all relevant crashes.

The NHTSA SCI teams arrived at the crash scene generally within 2 or 3 d to conduct their data collection and investigation, and the teams investigated a total of 58 cases throughout the study. Data were not collected statewide except for ambulance-transported cases in Missouri. Generally, eligible cases were collected in predefined regions of each State over a specified period. In California, however, the predefined region changed during the FHWA pilot study. Table 2 shows the number of cases collected in each area, dates the preliminary data collection and full data collection started, and dates when data collection ceased. California performed a pilot data collection to test whether procedures worked as expected before starting full data collection.

Table 2. GET crashes by highway agency.

State	Agency	Cases Collected	Start of Preliminary Data Collection	Start of Full Data Collection	End of Data Collection
California	Caltrans	136	7/1/2016	1/25/2017	1/25/2019
Massachusetts	MassDOT	122	—	5/24/2016	11/26/2018
Missouri	MoDOT	142	—	11/13/2015	11/26/2018
Pennsylvania	PennDOT	137	—	2/15/2016	11/26/2018
Pennsylvania	PTC	30	—	5/1/2016	11/26/2018
Total	**—**	**567**	**—**	**—**	**—**

—Not applicable.

Participating Highway Agencies and Personnel

Conducting this study involved a variety of personnel serving in various roles in several cooperating agencies. Law-enforcement agencies were essential to the study, but table 3 focuses on the typical roles of highway-agency personnel involved in each ISPE.

Table 3. FHWA pilot study roles.

Role	Description
ADC	Agency data collectors were generally among the first personnel to arrive at the scene and were responsible for taking photographs, making observations, and filling out forms as appropriate. The ADC was most often a highway agency maintenance employee. ADC personnel also notified the APOC in most data-collection areas if the crash involved ambulance transport.
APOC	The ADC generally transmitted collected data to the APOC, who was usually a highway agency R&D staff member. The APOC collected all case materials and transmitted the data to FHWA's R&D POC. For crashes involving ambulance transport in all data-collection areas except Massachusetts, the APOC contacted the FHWA R&D POC about deploying a NHTSA SCI team to investigate a crash. The APOC was also usually the primary contact between the highway agency and law-enforcement agencies.
SCI DC	The SCI DC refers to data collectors from the NHTSA SCI teams. In addition to collecting data and taking photographs, SCI teams collected more extensive data and wrote a report on each investigated crash.
SME	SME personnel helped plan the ISPE, developed training materials and example forms, conducted training, and provided on-call assistance to the FHWA R&D POC when making case-inclusion decisions. SMEs in the pilot study were all FHWA employees.
FHWA R&D POC	The FHWA R&D POC periodically received the data collected by the APOC and managed FHWA's data repository. The FHWA R&D POC also served as the POC for making positive GET identifications and initial decisions for SCI team deployment. The FHWA R&D POC consulted with an FHWA SME to determine eligibility of cases. The FHWA R&D POC contacted the NHTSA SCI POC to deploy a NHTSA SCI team to investigate ambulance-transport crashes.
NHTSA SCI POC	If a crash was determined by the FHWA R&D POC and SME to meet the sampling criteria, the FHWA R&D POC contacted the NHTSA SCI POC and the team coordinator, who deployed an available NHTSA SCI team to the crash site.

ADC = agency data collector; APOC = agency point of contact; SCI DC = special crash investigation data collector; FHWA R&D POC = Federal Highway Administration research and development point of contact; SME = subject-matter expert; NHTSA SCI POC = National Highway Safety Transportation Administration special crash investigation point of contact.

Data-collection activity in each area involved the participation and cooperation of several agencies. The following agencies were involved in the FHWA pilot study in the five data-collection regions:

- FHWA Research and Development (R&D) and local division offices.
- Highway agency maintenance district in which the GET ISPE data were collected.
- Highway agency R&D.
- State police and sometimes local law-enforcement agencies.
- NHTSA special crash investigation (SCI).

FHWA provided coordination and SMEs to the pilot study highway-agency participants. The FHWA developed training materials and trained agency data collector (ADC) and agency point of contact (APOC) personnel in each of the participating highway agencies. FHWA division office personnel in each local area also assisted in setting up and maintaining the needed local agency contacts.

Local highway-agency personnel collected much of the data and coordinated with law-enforcement agencies and FHWA. Law-enforcement agencies detected most of the crashes, notified the traffic operations center, and maintained control of the crash scene until crash victims and the damaged vehicle were removed.

The NHTSA SCI team provided a reconstructionist who collected data on crashes where an ambulance transported a minimum of one vehicle occupant from the scene. Each SCI team consisted of two highly experienced crash reconstructionists who collected scene and vehicle data in accordance with standard NHTSA data-collection protocols. The SCI teams also made observations of each impacted GET system and recorded them on a form designed by FHWA subject-matter experts (SMEs). A SCI team was generally able to arrive on scene within 1 to 3 d of the crash. There are three SCI teams, one each for the western, central, and eastern portions of the United States.

Case Inclusion Criteria

Cases had to meet the following criteria to be included in the study:

- Crash occurred between the start and end date of data collection.
- Crash occurred on a roadway owned by the highway agency in a specific geographical area.
- Crash involved a single passenger vehicle.
- Crash involved a head-on frontal collision with the impact head of one of the GET systems listed in table 1.
- Crash with the GET system was the first harmful event.
- *NCHRP Report 350* or MASH generally anticipated the impact scenario (e.g., exclude unanticipated scenarios like side impacts or rearward impacts).

Data were collected for 61 crashes later determined not to meet the sampling criteria previously listed. Table 4 lists reasons for excluding a case and the number of cases excluded for each reason. A case may have been excluded for multiple reasons; however, at least one reason is listed for each case.

Table 4. Reasons for case exclusion in the Pilot ISPE of GETs.

Reason Case Excluded	Number of Cases
Impact was not on impact head	6
Multiple vehicles involved	5
Non-passenger* vehicle involved	18
Impact did not occur on front of vehicle	6
Terminal was not in study group	3
Terminal type could not be determined	22
Terminal impact was not first harmful event	1
Total	**61**

*NHTSA defines passenger vehicles as passenger cars, sport utility vehicles, minivans, and pickup trucks. Nonpassenger vehicles constitute any vehicle not included in the passenger vehicle definition.

Crash Severity

If a crash met the inclusion criteria listed in the previous section, the next step was to determine the crash severity and deploy appropriate personnel. Except for Massachusetts, the FHWA pilot study was a two-tier data-collection effort. The intent was for NHTSA SCI teams to investigate cases involving ambulance transport of a crash victim and highway agency personal to collect data for nonambulance-transported crashes. MassDOT personnel collected data in Massachusetts regardless of ambulance-transport status.

The SCI recommended that ambulance transport and nonambulance transport serve as surrogates for crash severity. FHWA adopted the crash-severity surrogate proposed by SCI for the FHWA pilot study because there were no other consistent and timely means of distinguishing crash severity. The protocol objective was to identify a uniform pool of SCI cases and increase the likelihood of investigators reaching crash scenes with the damaged infrastructure still present for inspection. Crash outcome was, therefore, classified into four discreet categories shown in table 5.

Table 5. Definition of crash outcome for data-collector deployment.

Case Responder	Transport Status	Injuries	Description
SCI	Transported by ambulance	Fatal	A vehicle occupant transported by ambulance died within 30 d of the crash.
		Injuries indicated (serious)	A vehicle occupant transported by ambulance did not die within 30 d of the crash.
Agency	Not transported by ambulance	Injuries indicated (minor)	Some indication that a vehicle occupant was injured based on a police report, administrative summary, or some other source of information.
		Injuries not indicated (PDO)	No indication of injury to vehicle occupant.

The APOC determined from the traffic operations center, law enforcement, or the ADC if there was ambulance transport. The APOC then communicated to the FHWA R&D point of contact (POC) that there was ambulance transport as part of the SCI deployment decision. Final data did not normally document the source of the ambulance-transport information.

FHWA's In-Service Performance Evaluation Resources web page includes three summary tables, two of which include crash-outcome information (FHWA 2020b). "Crash type" on the web page refers to the four dichotomized crash-outcome categories: fatal, serious, minor, and PDO. The "Injuries" column of table 5 shows the crash outcome category corresponding to the FHWA web page. This report will use the ambulance transport status rather than "injury" because it is more accurate and transparent. It is not unusual, for example, for an ambulance to transport a crash victim to a hospital as a precaution even though there are no apparent injuries. "Ambulance transported" better describes this situation than "serious injury." The "crash type" categories on the FHWA web page should not be confused with the similarly worded KABCO police-reported injury scale. KABCO is the five-level injury scale used on police reports, where K indicates fatal injuries, A indicates suspected serious injuries, B indicates suspected minor injuries, C indicates possible injuries, and O indicates no apparent injuries.

Documentary evidence was necessary to classify a case as fatal. SCI teams, for example, performed additional investigations that allowed for a more detailed description of injuries based on hospital records and police reports. The SCI usually involved obtaining police reports and sometimes hospital records to document vehicle-occupant injuries. The Massachusetts data relied on administrative summaries of police crash reports, which documented the extent of occupant injuries.

FHWA Pilot Study Process

Details of notification and data collection varied among agencies depending on the logistic, administrative, and procedural policies of the different participating agencies. Most highway agencies used the general process illustrated in figure 10. Starting at the top-left side of figure 10, eligible cases were detected as a routine part of the crash-response process, which usually involved a traffic operations center. Traffic operations centers receive notification of crashes from law-enforcement agencies, public, and highway agencies. After receiving notification of a crash, the traffic operation center dispatches law enforcement, highway agency cleanup crews, emergency services, and other appropriate first responders according to local policy and the specifics of the crash.

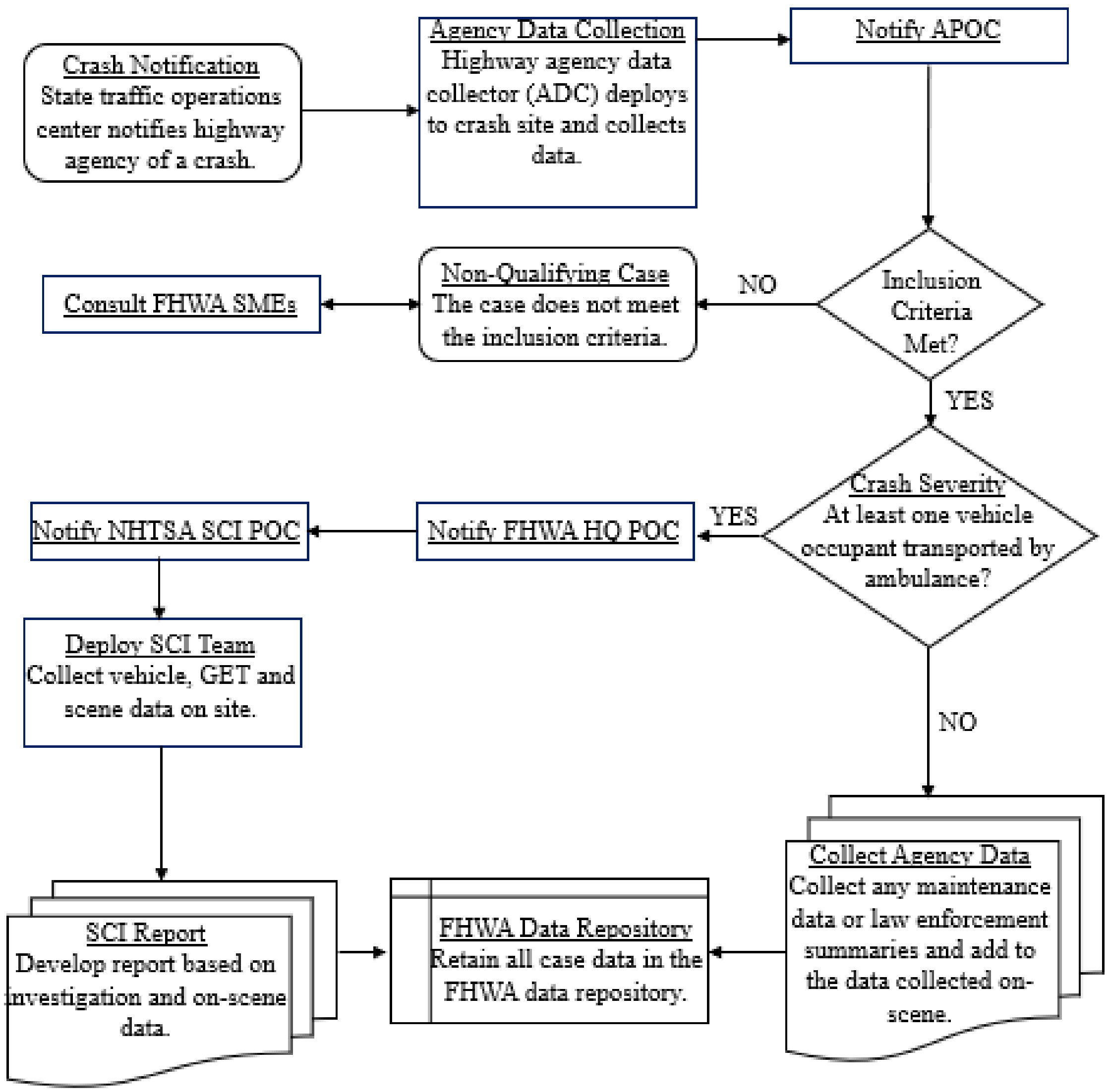


Figure 10. Flowchart. Data-collection process.

The appropriate highway agency maintenance district responds to these notifications using their State agency standard operating procedures. When the highway agency maintenance staff arrived on scene, they were the first to evaluate if the crash was eligible for inclusion in the data collection. The maintenance staff (e.g., ADC) took photographs and, in some areas, made observations and completed data-collection forms. The ADC then transmitted these data to the APOC.

If the agency personnel and APOC determined there was no ambulance transport, the ADC took the recommended photographs and, in some areas, completed the data-collection form. The ADC forwarded the case materials to the APOC. In some cases, the APOC collected and added additional information to each case file, such as maintenance records, law enforcement administrative summaries, and supplementary materials. The APOC collected relevant case materials into a locally stored case folder.

The APOC periodically transmitted case folders to the FHWA R&D POC for inclusion in the FHWA data repository. There were also cases where the State ADC sent pictures and data directly to the FHWA R&D POC.

If the APOC determined that an ambulance transported a vehicle occupant, the crash could be eligible for investigation by the NHTSA SCI. In such cases, the APOC notified the FHWA R&D POC for a deployment evaluation. The FHWA R&D POC consulted with the APOC and FHWA SME personnel to determine if the crash met all the criteria listed in the Case Inclusion Criteria section of chapter 4 and involved ambulance transport of at least one vehicle occupant. If the crash met all these criteria, the FHWA R&D POC notified the NHTSA SCI POC, who deployed an available team to the crash scene to collect scene, vehicle, and GET information. The SCI teams were usually able to arrive at the crash scene between 1 to 3 d of the crash event.

SCI teams produced reports summarizing the findings of their investigations. The reports included the GET ISPE form as supplementary material. After standard NHTSA reviews, the report was posted on the NHTSA website and the case materials were made available on the NHTSA case viewer website (NHTSA 2019b). To find all the Pilot ISPE of GETs case reports developed by SCI teams, users of the NHTSA case viewer website can select "Guardrail End Treatment" in the "Type" selection box under the "Search by SCI Case Type and Case Year" heading. SCI investigative reports are available on the NHTSA website (NHTSA 2019b).

The FHWA SME developed a seven-page Pilot ISPE of GETs data-collection form. SCI teams used the FHWA form whereas other agency teams modified the form for their own needs and several agency teams did not use a form at all. The information captured on the form is generally not available on a typical police crash report. All highway agency data-collection teams took photographs. The following sections describe the data-collection effort in each area.

CALIFORNIA DEPARTMENT OF TRANSPORTATION

Agency Objectives

The California Department of Transportation's (Caltrans's) stated objective for participating in the FHWA pilot study was to collect data regarding the infield performance of its GETs. The factors of interest included the following:

- Crash performance in terms of occupant risk.
- Sensitivity of the system to environmental conditions, site characteristics, and impact conditions.
- Degree of sensitivity to improper installation, maintenance, and repair.

Caltrans personnel indicated that while the FHWA pilot study was interesting and informative anecdotally, it did not completely meet their original expectations.

Involved Agencies

Agencies involved in the FHWA pilot study in California included the following:

- FHWA R&D and California division office.
- Caltrans headquarters and District 8 and District 12 (figure 11).
- California Highway Patrol (CHP) and its Multidisciplinary Accident Investigation Team (MAIT).
- NHTSA SCI team.

Caltrans is responsible for the construction, operation, and maintenance of all State-owned roads in California. CHP is responsible for law enforcement on State-owned roadways. During usual patrol duties, CHP detected cases in the data-collection area. CHP has a special MAIT composed of trained crash reconstructionists working out of eight different MAIT offices located throughout California. A CHP sergeant leads each team, which includes at least two CHP officers, one Motor Carrier Specialist, and one Caltrans engineer. MAITs respond to collisions that meet certain criteria, and the team's primary responsibility is to support law enforcement's collection of evidence. The CHP MAIT unit detected one ambulance-transport crash that occurred outside the data-collection area and added it to the Caltrans data. The FHWA pilot study benefitted from the support of law-enforcement personnel in California and Missouri. CHP participation was essential to the success of the effort in California.

Caltrans was the only highway agency in the FHWA pilot study that developed a formal written agreement for the agencies involved. Participating agencies thought a written agreement was necessary to clarify the interactions between agencies to ensure separation of the evidence-collecting role of law-enforcement personnel and highway safety data collected by Caltrans. FHWA, Caltrans, and CHP developed a memorandum of understanding (MOU) that established the responsibilities of each party and cited appropriate Federal law. All parties signed the agreement on January 25, 2017. CHP committed to making a rapid determination (i.e., 15–20 minutes) about whether the scene was a crime scene because Caltrans personnel are not able to collect data on active crime scenes.

The features of the Caltrans ISPE data collection are summarized in the following list.

- Preliminary data-collection start date—July 1, 2016.
- Preliminary data-collection end date—January 25, 2017.
- Full data-collection start date in District 12—January 25, 2017.
- Full data-collection start date in District 8—December 13, 2017.
- Data-collection end date—January 25, 2019.

Data-collection areas included all Caltrans-owned roads in Caltrans District 12, and I–15 and all Caltrans-owned roadways south of I–15 in San Bernardino and Riverside Counties in Caltrans District 8. Other Caltrans districts contributed ad hoc cases.

Study Design

Data-Collection Area

Figure 11 shows a map of Caltrans districts, and table 6 summarizes data-collection activity in California. Initially, the intent was to collect GET system data only in District 12 as part of a 2-mo-long preliminary data collection starting on July 1, 2016. However, the preliminary data collection continued until January 25, 2017, as the MOU and photographic guidelines were being finalized. During the preliminary data-collection period, there were relatively few cases observed. Caltrans determined based on a one-time spot inventory that the GET systems, which were the focus of the data collection in California, comprised only about 30 percent of the end treatment hardware in District 12. Caltrans, in consultation with FHWA, decided to add all Caltrans-owned highways in Riverside County and southern San Bernardino County, south of and including I–15 in District 8. District 8 borders District 12, as shown in figure 11. Highways in much of District 12 were often congested, resulting in slower speed and presumably less-severe crashes. Selected areas of District 8 included I–15 between Anaheim, CA, and Las Vegas, NV. This stretch of I–15 is a higher speed, free-flowing roadway with more inventory of the studied GET hardware. The location of the NHTSA SCI team in Anaheim and interest from local Caltrans leadership contributed to the initial selection of District 12 for the ISPE project.

Figure 11. Graphic. Caltrans districts (Caltrans 2019).

Notification Process

Upon responding to a crash scene, Caltrans maintenance staff took the GET ISPE photographs and reported the specific location and time of repair to the Caltrans District Transportation Management Center (TMC). Caltrans kept as much of the damaged GET as possible intact (i.e., large pieces) at one of its maintenance facilities and preserved and numbered damaged posts to facilitate later examination by the SCI team. If the case did not involve ambulance transport of at least one crash victim, then there was no further data collection (i.e., there was no GET ISPE form used in California). If the crash involved ambulance transport in District 12, then Caltrans maintenance personnel contacted the TMC, which contacted the FHWA R&D POC. District 8 personnel contacted the FHWA R&D POC directly without going through the TMC. The FHWA R&D POC reviewed the photographs to determine if the GET impact head was one of those in the study group. If necessary, the FHWA R&D POC consulted one of the internal FHWA SMEs for confirmation. When it was confirmed that the impact head was from one of the FHWA pilot study systems shown in table 1, the FHWA R&D POC notified the NHTSA SCI POC, who deployed a team to the site.

As shown in table 6, Caltrans maintenance personnel collected photographs for 132 cases, the SCI team collected 3 cases, and CHP MAIT collected 1 case for a total of 136 cases in California.

Table 6. Summary of data collected by Caltrans.

	Trinity Highway Products					Road Systems			Lindsay			
Agency	**ET 2000**	**ET PLUS (Unknown 4- or 5-Inch)**	**ET PLUS (4-Inch)**	**ET PLUS (5-Inch)**	**SoftStop**	**FLEAT**	**SKT**	**MSKT**	**X-LITE**	**X-TENSION**	**Not Selected for Study**	**Total**
Caltrans/MAIT	0	0	1	0	0	0	0	0	0	0	0	1
Caltrans/SCI	0	1	0	0	0	1	0	0	1	0	0	3
Caltrans	2	1	28	8	3	9	43	0	32	1	5	132
Total	**2**	**2**	**29**	**8**	**3**	**10**	**43**	**0**	**33**	**1**	**5**	**136**

Depending on its status as a potential crime scene and the need for immediate cleanup or repair by Caltrans, the following scene data-collection parameters were set:

- If CHP determined the crash scene was a potential crime scene and the scene required rapid cleanup by Caltrans, then the NHTSA SCI team relied on Caltrans maintenance personnel's photographs and requested vehicle and scene photographs through normal CHP channels. CHP did not allow SCI personnel on active crime scenes.
- If the scene did not require rapid cleanup by Caltrans, then the NHTSA SCI team returned to the scene with Caltrans staff after CHP departed the scene.
- If CHP determined that the crash scene was not a crime scene, then SCI worked with Caltrans maintenance staff during the typical 6-hour maintenance window at the scene.
- For repairs scheduled between 6 hours and 1 week after the crash, SCI scheduled work on the scene with Caltrans maintenance staff.

The intent of these procedures was to ensure separation between any CHP criminal investigation and the SCI GET ISPE. The MOU specified that SCI personnel use appropriate safety gear, such as hard hats and retroreflective vests. Caltrans was responsible for arranging traffic control through CHP when SCI investigators were on site. Law-enforcement crash reports were generally not available to the ISPE team.

The flowchart shown in figure 10 illustrates the process used in California. CHP troopers generally detected eligible crashes when they arrived at crash scenes, although in one case, Caltrans maintenance personnel detected an eligible crash independently of CHP. CHP and Caltrans areas of responsibility do not exactly coincide. Specific routes in District 8 were chosen in part to coordinate with CHP patrol boundaries. If Caltrans property was involved, CHP routinely notified Caltrans maintenance staff immediately and they deployed to the scene to assess the need for cleanup and repair.

Data Collection

Caltrans personnel did not use ISPE data-collection forms. The only data collected were the photographs taken by Caltrans personnel unless NHTSA SCI investigated the crash. Figure 12 shows a typical case photograph taken by Caltrans. Caltrans personnel took photographs using the FHWA GET ISPE photographic protocol, described in Volume II: Appendix A of this report, and used smartphone cameras for photography, although they experimented with higher-resolution cameras and videography. The FHWA pilot study objective was to design a data-collection effort that required minimal time onscene and had the least impact on other Caltrans or CHP responsibilities. All 132 cases documented by Caltrans maintenance personnel included photographs. On average, Caltrans personnel took 9 photographs per case and sometimes documented the crash with as many as 25 photographs. Caltrans and FHWA originally thought that a SME would review the information after the completion of data collection to extract similar data to those collected using data-collection forms by other agencies. To date, a lack of SME availability and resources has prevented such review.

Source: FHWA.

Figure 12. Photograph. California case CA-ET4_3.

No police reports or administrative summaries were available in California, although CHP MAIT submitted one case.

The NHTSA SCI team investigated three cases in California: an ET Plus with unknown guide-channel width, a FLEAT, and an X-Lite. All three cases involved ambulance transport and none involved a fatality. NHTSA published two of the SCI reports, which are available on the NHTSA Crash Viewer website. In addition to the three SCI cases, CHP MAIT investigated one ambulance-transported case, an ET Plus with 4-inch guide channels, which did not result in a fatal injury. Caltrans personnel documented 132 nonambulance-transported cases (table 6). Five Caltrans cases did not meet the inclusion criteria and were excluded. The SKT was the most frequently collected GET in California followed by the X-Lite, then followed by ET Plus with 4-inch guide channels, as shown in table 6.

MASSACHUSETTS DEPARTMENT OF TRANSPORTATION

Agency Objectives

The Massachusetts Department of Transportation's (MassDOT's) stated objective for participating in the FHWA pilot study was to gain a better understanding of crashes involving GETs and to receive specialized training in data collection. MassDOT participated to support FHWA's effort and to improve MassDOT's own capabilities.

MassDOT had been informally collecting information on ET Plus guardrail terminals since the fall of 2014 to enable MassDOT to respond accurately to internal and external requests for information about GETs. MassDOT wanted to obtain information that helped determine the relative safety performance of GET hardware in relation to other GET hardware. MassDOT noted that the FHWA pilot study was helpful in assessing ISPE data-collection requirements and that GETs require constant monitoring.

Involved Agencies

Agencies involved in the pilot study in Massachusetts included the following:

- FHWA R&D, Resource Center, and Massachusetts Division Office.
- MassDOT.
- Massachusetts State Police (MSP).
- MSP Collision Analysis Reconstruction Section (CARS).

MassDOT is responsible for the construction, operation, and maintenance of all MassDOT-owned roads. MassDOT personnel collected data in Massachusetts and coordinated with FHWA and MSP. The MSP is the State police force that detected crashes. MSP CARS unit consists of 7 sergeants and 17 troopers who are trained crash reconstructionists. CARS officers are accredited or in the process of being accredited by the Accreditation Commission for Traffic Accident Reconstruction (MSP 2019a). MSP routinely deploys the CARS team whenever the onsite trooper determines that the subject crash is or could become a fatal crash. Data collection started May 24, 2016, and ended November 26, 2018. The data-collection area included all MassDOT-owned roads in MassDOT District 4 with several ad hoc cases collected in District 3.

Study Design

Data-Collection Area

Data collection occurred in MassDOT District 3 and District 4, though most cases came from District 4. Figure 13 shows MassDOT maintenance districts and figure 14 shows MSP troop boundaries.

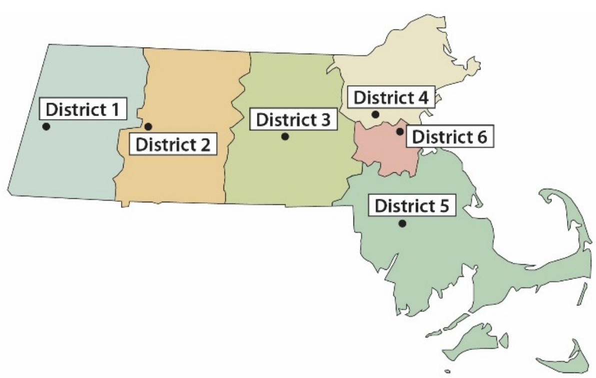
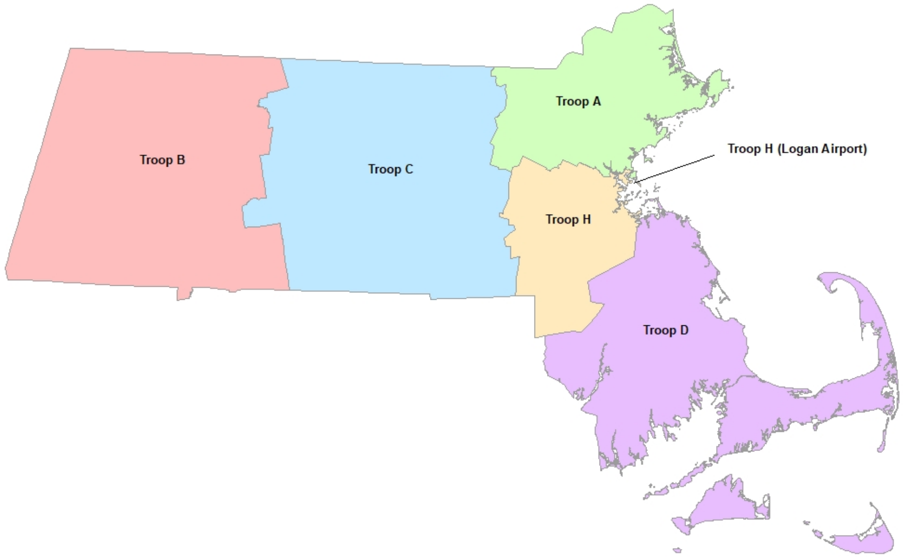


Figure 13. Graphic. MassDOT maintenance districts (MassGIS 2019).



Source: FHWA; data from the Commonwealth of Massachusetts.

Figure 14. Graphic. MSP patrol boundaries.

MassDOT District 4 and MSP Troop A cover similar territory. MSP was the only law-enforcement agency involved in the study. The MassDOT quick response policy requires repair of damaged hardware within 24 hours of notification. MassDOT personnel identified as accident recovery chasers coordinate the quick repair policy. Recovery chasers arrange cleanup, obtain towing contractors, and deploy repair contractors to the site. A single individual was the accident recovery chaser in all of District 4 and acted as the ADC. Crash recovery contractors (i.e., repair contractors) sometimes provided photographs, especially if they arrived at the scene before the ADC. Taking before-and-after repair photographs of damaged Commonwealth property for the MassDOT insurance recovery unit has been routine in Massachusetts for some time. Taking the GET ISPE photographs became an extension of this established procedure. Figure 15 and figure 16 are examples of a typical Massachusetts before-and-after repair sequence.

Source: FHWA.

Figure 15. Photograph. Massachusetts case MA-MSKT_10 before repairs.

Source: FHWA.

Figure 16. Photograph. Massachusetts case MA-MSKT_10 after repairs.

The data-collection process was different in Massachusetts than the usual process shown in figure 10 because NHTSA SCI teams were not deployed in Massachusetts. MSP, motorists, or MassDOT maintenance personnel notify the District Highway Operations Center whenever any type of crash occurs. The Highway Operations Center routinely deploys the MassDOT accident recovery chaser, who also serves as the ISPE GET ADC. The ADC determined if the crash met the case inclusion criteria and collected data simultaneous to performing other crash-recovery duties. The ADC in Massachusetts took photographs and completed the ISPE GET data-collection form. The ADC assembled all data into a case folder and sent it to the APOC, who operated out of MassDOT headquarters. The original protocol was for the APOC to obtain fatal and serious injury crashes from the CARS team reports. This administrative process, however, was not entirely successful but the APOC was able to get law-enforcement administrative summaries of most cases. The administrative summary includes the police-reported crash severity and was added to the case file by the APOC, who periodically transmitted case files to the FHWA R&D POC for inclusion in the ISPE GET data repository.

Notification Process

The ISPE crash-notification process in Massachusetts aligned closely with normal operating procedures of both MassDOT and MSP. MSP routinely dispatches troopers to the scene of highway crashes involving property damage or injury on roads owned by MassDOT. Part of the normal MSP procedure is to immediately notify oncall MassDOT maintenance personnel in the appropriate district office if any MassDOT property was damaged or involved in the crash. The MassDOT accident recovery chaser is routinely responsible for arranging repairs, vehicle towing, and cleanup because of MassDOT's quick repair policy. The accident recovery chaser, therefore, performed the ADC duties simultaneously with their normal duties. The process differed from the flowchart shown in figure 10 because the NHTSA SCI team was never deployed and all case-inclusion decisions were made by the ADC and APOC.

FHWA provided a 2-d training session to crash recovery chasers from all MassDOT maintenance districts prior to the start of data collection, but only District 4 participated in the GET ISPE to a significant extent. MassDOT indicated that it is considering expanding the data-collection effort statewide.

Data Collection

Data collected in Massachusetts included a GET data-collection form, photographs, and law-enforcement administrative summaries. MassDOT redesigned the form used for the GET ISPE.

MassDOT ADC intended to take the FHWA-recommended photographs for the GET ISPE as part of the initial response to the crash. Many Massachusetts cases contain only two photographs: one of the damaged GET (figure 15) and another of the repaired or replaced GET (figure 16). Most cases did not include the eight photographs suggested by FHWA, as described in Volume II: Appendix A.

The original protocol also envisioned using the CARS team reports and data instead of the NHTSA SCI teams data used in other data-collection areas; however, it was not possible to obtain CARS reports from MSP because of a personnel change. Instead, the APOC obtained MSP administrative journal summaries as a short-term substitute for the CARS reports. Crash severity in Massachusetts was based on information in administrative summaries, which were extracted from the police report. MSP provided administrative summaries for 101 of the 122 crashes documented in Massachusetts. MassDOT accident recovery chasers took photographs and filled out data-collection forms for 122 crashes in Massachusetts. Five Massachusetts cases were later excluded because they did not satisfy inclusion criteria.

MassDOT provided the photographs and forms for the 122 cases collected in Massachusetts, as shown in table 7. The GET hardware collected most frequently was the X-Lite, followed by the 4-inch guide channel ET Plus. A few SRT cases were collected even though not officially part of the study. The MSKT was added to the ISPE when MassDOT started to install the GET.

Table 7. Summary of data collected by MassDOT.

Agency	Trinity Highway Products				Road Systems			Lindsay			Not Selected for Study	Total
	ET 2000	ET PLUS (4-Inch)	ET PLUS (5-Inch)	SoftStop	FLEAT	SKT	MSKT	X-LITE	X-TENSION	MAX-Tension		
MassDOT Total	1	32	1	0	0	9	12	61	0	1	5	122

MISSOURI DEPARTMENT OF TRANSPORTATION

Agency Objectives

The Missouri Department of Transportation's (MoDOT's) stated objective for participating in the FHWA pilot study was to gain a better understanding of crashes involving GETs. MoDOT has been studying the performance of GETs for several years; therefore, supporting FHWA's effort provided an opportunity to enhance its research. In 2014, MoDOT became interested in the performance of the ET Plus. MoDOT was one of the highway agencies that responded to FHWA's request for guardrail terminal information that resulted in the AASHTO-FHWA report on guardrail terminal performance (AASHTO-FHWA 2015). When FHWA approached MoDOT about participating in the pilot study, the agency considered participation to be the next logical step for evaluating in-service performance of GETs used in Missouri.

MoDOT transitioned to using MASH guardrail terminals in July 2016. Participation in the FHWA GET ISPE allowed MoDOT to collect ISPE data on the new MASH devices (i.e., the MSKT and SoftStop) and on the existing *NCHRP Report 350* devices already in service. MoDOT expected that the new MASH terminals would provide improved crash performance when compared to previous design devices. MoDOT found participation in the GET ISPE pilot study to be a useful proof-of-concept activity and thought it worked well in Missouri.

Involved Agencies

Agencies involved in the FHWA pilot study in Missouri included the following:

- FHWA R&D and Missouri Division Office.
- MoDOT.
- Missouri State Highway Patrol (MSHP).
- NHTSA SCI team.

MoDOT is responsible for the construction, operation, and maintenance of all MoDOT-owned roads in Missouri. MSHP detected most of the crashes, but local law enforcement also detected cases in select areas of the State as discussed in the Data Collection section. The FHWA pilot study benefitted from the support of Missouri law-enforcement personnel, whose participation was essential to the success of the effort. MoDOT was the first highway agency to begin data collection; therefore, many lessons learned emerged in Missouri. Each of the three NHTSA SCI teams participated in at least one crash event in Missouri. The data-collection start date was November 13, 2015, and the end date was November 26, 2018. The data-collection area included GET crashes involving ambulance transport on all MoDOT-owned roadways and nonambulance transport GET crashes in the Kansas City (KC) and Southwest (SW) districts only.

Study Design

Data-Collection Area

MoDOT used the two-tier data-collection method, shown in figure 10. A NHTSA SCI team investigated any crash with an eligible GET and an ambulance-transported occupant occurring anywhere in the State. The KC and SW MoDOT maintenance districts were the only districts in which MoDOT personnel investigated crashes that did not involve ambulance transport in Missouri.

Notification Process

The crash-notification and data-collection process in Missouri aligned with normal operating procedures of both MoDOT and MSHP. MSHP routinely dispatches troopers to the scene of highway crashes involving property damage or injury. Part of the normal MSHP procedure is to notify on-call MoDOT maintenance personnel in the appropriate district office if any MoDOT property was damaged or involved in the crash. MoDOT maintenance staff is routinely responsible for determining the need for repairs and cleanup and making the appropriate arrangements.

As shown in figure 17 and figure 18, MoDOT maintenance districts and MSHP patrol divisions are similar though not identical. As previously described, there were two somewhat different notification and data-collection protocols used in Missouri: one that was used in the KC and SW MoDOT maintenance districts and the other used in all other MoDOT maintenance districts.

Source: FHWA.

Figure 17. Graphic. MoDOT maintenance districts.

© 2019 MSHP.

Figure 18. Graphic. MSHP boundaries (MSHP 2019).

One innovation in Missouri was the development and distribution of the dash card shown in figure 19 and figure 20. MoDOT provided these dash cards to maintenance and law-enforcement personnel to assist them in identifying GET impact heads included in the study. The KC and SW MoDOT maintenance districts used the procedure shown in figure 10 for crash events that did not involve ambulance transport.

If an ambulance transported any of the crash victims, then the onscene maintenance personnel contacted the MoDOT APOC and transmitted the identification photographs. The MoDOT APOC then contacted the FHWA R&D POC and transmitted the identification photographs and requested SCI participation in the crash investigation.

Figure 19. Graphic. Front of MoDOT guardrail terminal identification dash card.

MoDOT

U.S. Department of Transportation
Federal Highway Administration

Fatal or Serious Injury Guard Rail End Terminal Crash Reporting

Initial contact about a crash event:
MoDOT Transportation Management Center (TMC) in St Louis
Call (314) 275-1522

Please provide the following information about the crash:

Date: ______________________ Time: ______________________
County: ______________ Route: ________ Direction of Travel: ________
Vehicle Year: ____________ Make: ________ Model: ____________
Towed to: ____
Driver (1) information: ______________________________
Transported to: ___________________________________
Driver (2) information: ______________________________
Transported to: ___________________________________

Figure 20. Graphic. Back of MoDOT guardrail terminal identification dash card.

In all other maintenance districts besides KC and SW, MoDOT maintenance personnel would only contact the MoDOT APOC when an ambulance transported a vehicle occupant to a hospital. The MoDOT APOC would then contact the FHWA R&D POC with preliminary photographs and information. The FHWA R&D POC would notify the NHTSA SCI POC if the case met the inclusion criteria, and an SCI team would deploy to the scene.

Data Collection

Data collected by MoDOT generally included the GET data-collection form, photographs, and a maintenance report. Figure 21 shows a typical photograph from MoDOT. The GET data-collection form, as redesigned by MoDOT and included in Volume III: Appendix B of this report, was usually but not always completed and included. MoDOT intended to use the FHWA GET ISPE photography protocols but, on average, the ADC took only four of the eight FHWA-recommended photographs.

Most Missouri cases include a standard MoDOT maintenance and repair report, which provides details about the cost and parts needed to repair or replace the installation, the date of repair, and the contractor responsible for the repairs. Missouri was the only highway agency that provided maintenance information in the FHWA pilot study. Generally, Missouri PDO and minor-injury cases do not include a police report or police reconstruction. In the pilot study, most PDO and minor injury crashes occurring in Missouri did not reach the threshold for police investigation or were hit-and-run crashes.

Source: FHWA.

Figure 21. Photograph. Missouri case MO-XLT_1.

Table 8 shows that a total of 142 cases were collected in Missouri. NHTSA SCI teams collected data for 44 crashes and MoDOT maintenance personnel collected 98 cases. All three SCI teams collected cases in Missouri. Eight cases investigated by the SCI teams were fatal crashes. The SCI-collected cases were collected statewide and the MoDOT-collected cases were collected only in the KC and SW MoDOT maintenance districts. The ET Plus with 4-inch guide channels was the GET system most often collected, followed by the SKT, then the SoftStop. Six cases were collected but later excluded because they did not meet all case-inclusion criteria.

Table 8. Summary of data collected by MoDOT.

	Trinity Highway Products					Road Systems			Lindsay			
Agency	**ET 2000**	**ET PLUS (Unknown 4- or 5-Inch)**	**ET PLUS (4-Inch)**	**ET PLUS (5-Inch)**	**SoftStop**	**FLEAT**	**SKT**	**MSKT**	**X-LITE**	**X-TENSION**	**Not Selected for Study**	**Total**
MoDOT/SCI	6	0	11	1	10	0	10	2	4	0	0	44
MoDOT	8	2	39	11	9	0	17	0	6	0	6	98
Total	**14**	**2**	**50**	**12**	**19**	**0**	**27**	**2**	**10**	**0**	**6**	**142**

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION

Agency Objectives

The Pennsylvania Department of Transportation's (PennDOT's) stated objective for participating in the FHWA pilot study was to collect data for performance of GETs in the field. PennDOT expressed interest in comparing its experience with that of other highway agencies.

Involved Agencies

Agencies involved in the FHWA pilot study in Pennsylvania included the following:

- FHWA R&D and Pennsylvania Division Office.
- PennDOT.
- Pennsylvania State Police (PSP).
- NHTSA SCI teams.

PennDOT is responsible for the construction, operation, and maintenance of all PennDOT-owned roads. PSP is the State police force that initially detected most of the crashes. Data collection started February 15, 2016, and ended November 26, 2018.

Table 9 shows the maintenance districts and routes for data collection.

Table 9. PennDOT data-collection area.

Maintenance Districts	Routes
1	US 6, I–79, I–80, and I–90
2	US 22, US 220, and I–80
3	No routes in this district
4	US 6
5	PA 61, PA 248, PA 724, and I–81
6	No routes in this district
8	PA 272, US 15, US 22, US 30, US 222, I–81, and I–83
9	No routes in this district.
10	I–79 and I–80
11	I–79, I–279, and I–376
12	US 119, US 30, and I–79

Study Design

Data-Collection Area

Figure 22 shows PennDOT maintenance-district boundaries. Figure 23 shows PSP patrol boundaries. The GET ISPE data-collection areas in Pennsylvania were not whole maintenance districts, which was typical for other highway agencies. Instead, the PennDOT APOC selected the specific routes in various maintenance districts shown in table 9. Examining the crash history of each route was the first step in the selection process to identify routes with higher numbers of guardrail terminal crashes. Some districts (e.g., District 3 and District 9) were excluded because of a small number of GET system crashes in the historic crash data. Heavily urbanized areas (e.g., Philadelphia in District 6) were excluded because of the increased risk to data collectors and the need to close already congested lanes.

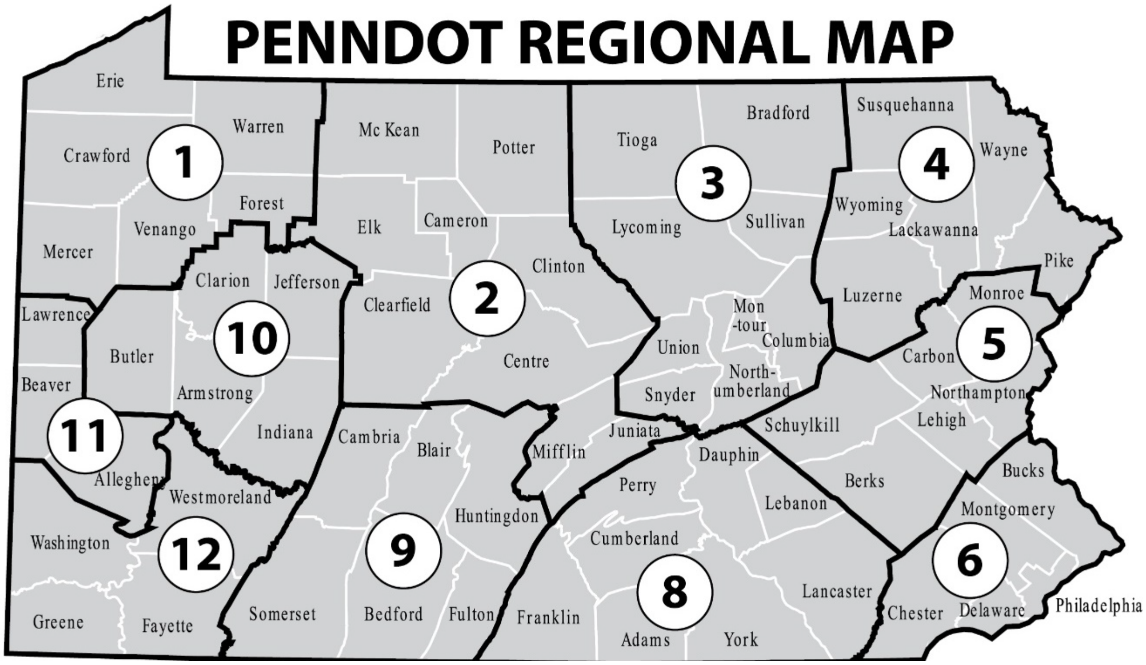


Figure 22. Graphic. PennDOT maintenance districts.

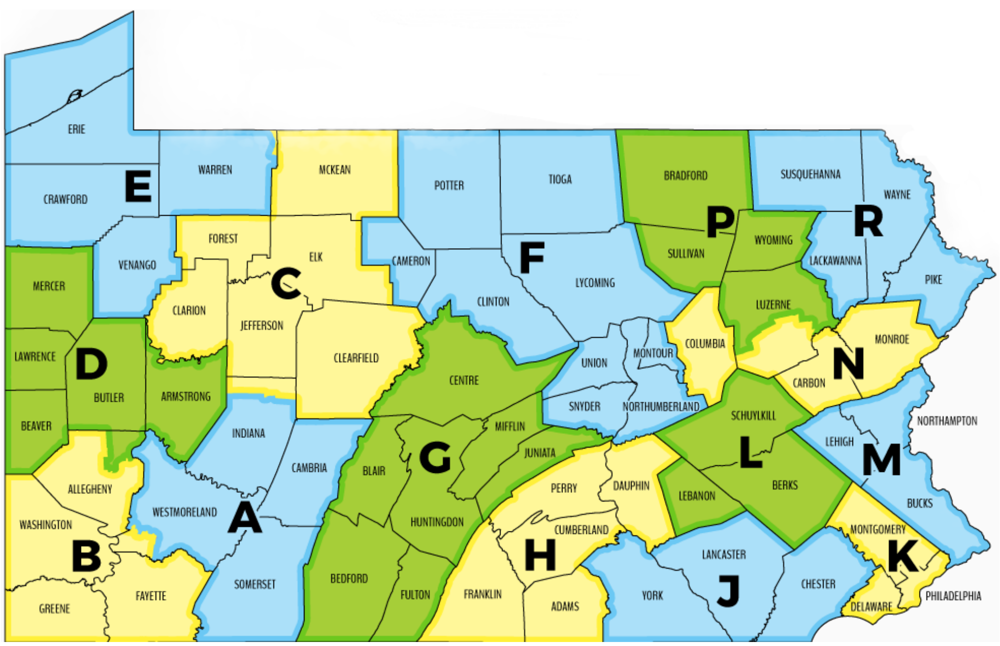


Figure 23. Graphic. PSP patrol districts (PSP 2020).

Notification Process

The crash-notification process in Pennsylvania followed the protocol shown in the flowchart in figure 10. The PSP was routinely dispatched to the scene of highway crashes on PennDOT-owned roads. As part of its normal operating procedure, PSP notified PennDOT electronically of any fatal crashes within a few days and any ambulance-transported crashes within several weeks of the crash. Upon notification of the crash, PennDOT maintenance personnel visited the crash site to determine the need for repair and, while doing so, took GET photographs if maintenance personnel concluded a qualifying GET was involved in the crash. The PennDOT APOC supplemented the photographic information with a law-enforcement administrative summary gleaned from the police report.

If the case involved an ambulance-transported crash victim, the PennDOT APOC contacted the FHWA R&D POC and transmitted identification photographs. If the FHWA R&D POC, with the assistance of FHWA SME personnel, determined the subject end treatment was one of the GET systems included in the study, the FHWA R&D POC contacted the NHTSA SCI POC, who deployed an SCI team to the site. Generally, SCI teams arrived onsite within 1 to 3 d of PennDOT notification of the crash.

Data Collection

Data collected by PennDOT personnel for cases not transported by ambulance consisted of photographs taken by the ADC and an administrative summary provided to the APOC by the PSP.

The intent was for PennDOT maintenance personnel to use the GET ISPE photography protocol developed by FHWA. Most cases, however, only included four or five photographs instead of the recommended minimum of eight. Figure 24 shows a typical photograph from a PennDOT case.

Source: FHWA.

Figure 24. Photograph. Guardrail in PennDOT case PA-SKT_36.

The NHTSA SCI teams collected five cases and PennDOT maintenance personnel collected 132 cases for a total of 137 cases in Pennsylvania, as shown in table 10. NHTSA published all five SCI investigative reports from the PennDOT data-collection area on the NHTSA website.

PennDOT data contain three fatal GET cases collected by SCI. There were 45 “not selected for study” cases in the PennDOT data-collection area, leaving 92 eligible cases. The terminal type could not be determined in most of the cases not selected for study because the repair occurred before data collectors visited the site. The most frequently collected GET system was the SKT followed by the ET Plus with a 4-inch-wide guide channel width.

Table 10. Summary of data collected by PennDOT.

	Trinity Highway Products					Road Systems			Lindsay			
Agency	**ET 2000**	**ET PLUS (Unknown 4- or 5-Inch)**	**ET PLUS (4-Inch)**	**ET PLUS (5-Inch)**	**SoftStop**	**FLEAT**	**SKT**	**MSKT**	**X-LITE**	**X-TENSION**	**Not Selected for Study**	**Total**
PennDOT/SCI	0	0	1	1	0	0	2	0	1	0	0	5
PennDOT	10	14	16	6	0	3	33	0	4	0	45	132
Total	**10**	**14**	**17**	**7**	**0**	**3**	**35**	**0**	**5**	**0**	**45**	**137**

PENNSYLVANIA TURNPIKE COMMISSION

Agency Objectives

The PTC’s stated objective for participating in the FHWA pilot study was to gain a better understanding of the performance of GET hardware. The PTC was willing to support the FHWA effort and enhance its own capabilities for performing ISPEs.

Involved Agencies

Agencies involved in the FHWA pilot study on the Pennsylvania Turnpike included the following:

- FHWA R&D and Pennsylvania Division Office.
- PTC.
- PSP Troop T.
- NHTSA SCI teams.

The PSP Troop T is the State police troop responsible for patrols on the entire turnpike, including extensions. Data collection started on May 1, 2016, and ended on November 28, 2018.

Study Design

Data-Collection Area

The Pennsylvania Turnpike is a controlled-access highway system that spans 522 mi and consists primarily of I–76 spanning the Commonwealth from east to west and the I–476 north–south spur connecting the Philadelphia suburbs and Scranton. Figure 25 shows the Pennsylvania Turnpike system map. PSP Troop T is responsible for law enforcement on the entire turnpike system, which is divided into western and eastern patrol sectors.

© 2019 PTC.

Figure 25. Map. Pennsylvania turnpike system (PTC 2019).

Notification Process

The ISPE crash-notification process on the Pennsylvania Turnpike corresponded with the normal operating procedures of both PTC and Troop T. The flowchart shown in figure 10 illustrates the ISPE process used on the Pennsylvania Turnpike. Troop T routinely dispatches troopers to the scene of highway crashes. If turnpike property is damaged or cleanup is required after the crash, the normal Troop T procedure is to immediately notify oncall PTC maintenance personnel, who deploy to the crash scene for an assessment. If the case involved ambulance transport, the onscene maintenance personnel (i.e., ADC) contact the PTC POC and transmit identification photographs. The PTC POC contacts the FHWA R&D POC to make SCI-deployment decisions.

Data Collection

Data collected on the Pennsylvania Turnpike generally consisted of photographs and the GET data-collection form. The PTC ADC took the photographs needed for the FHWA pilot study while onsite using the FHWA ISPE GET photography protocol.

Figure 26 shows a photograph from PTC data. PTC cases generally do not include a police report or crash reconstruction.

Source: FHWA.

Figure 26. Photograph. Guardrail in Pennsylvania Turnpike case PA-SKT_514.

The NHTSA SCI collected 6 cases and PTC maintenance personnel collected 24 cases for a total of 30 cases on the Pennsylvania Turnpike system as shown in table 11. None of the cases on the Pennsylvania Turnpike investigated by the NHTSA SCI involved fatalities. The SKT was the most collected GET system on the Pennsylvania Turnpike, followed by the FLEAT.

Table 11. Summary of data collected by PTC.

	Trinity Highway Products					Road Systems			Lindsay			
Agency	**ET 2000**	**ET PLUS (Unknown 4- or 5-Inch)**	**ET PLUS (4 Inch)**	**ET PLUS (5 Inch)**	**SoftStop**	**FLEAT**	**SKT**	**MSKT**	**X-LITE**	**X-TENSION**	**Not Selected for Study**	**Total**
PTC/SCI	0	0	2	0	0	0	4	0	0	0	0	6
PTC	0	0	1	0	0	7	16	0	0	0	0	24
Total	**0**	**0**	**3**	**0**	**0**	**7**	**20**	**0**	**0**	**0**	**0**	**30**

CHAPTER 5. RESULTS

DATA SOURCES

This chapter provides a summary of the data collected in the FHWA pilot study. Data are available on FHWA's ISPE website. After the FHWA pilot study's data collection was complete, personally identifiable information (PII) was redacted from the source material. Some PII was redacted by the highway agency POC and other PII was redacted by FHWA when assembling and reviewing data. A single PDF file contains all available materials for a single case except the SCI report when SCI investigated the case. This PDF file contains photographs, data-collection forms, and depending on the highway agency, maintenance forms, police reports, administrative summaries, and other supplemental materials. The case number is also the name of the PDF file. Figure 27 shows the naming convention for PDF files. For example, a PDF file with the name RDT-HRDS-Projects-ISPE-PA-FLEAT_4 indicates the fourth FLEAT case collected by PennDOT.

$$\text{PDF File Name} = \text{RDT} - \text{HRDS} - \text{Projects} - \text{ISPE}\begin{bmatrix}\text{CA}\\ \text{MA}\\ \text{MO}\\ \text{PA}\end{bmatrix} - \begin{bmatrix}\text{ET4}\\ \text{ET5}\\ \text{ET2000}\\ \text{ETUnknown}\\ \text{FLEAT}\\ \text{MaxTension}\\ \text{MSKT}\\ \text{NS}\\ \text{SKT}\\ \text{Softstop}\\ \text{XLT}\\ \text{XTension}\end{bmatrix}\_[\text{Integer}]$$

Source: FHWA.

Figure 27. Graphic. Pilot ISPE of GETs case file-naming convention.

There were two data-collection areas in Pennsylvania; therefore, cases collected in the PennDOT area described in the Pennsylvania Department of Transportation section of chapter 4 are designated with an integer less than 500. Cases collected on the Pennsylvania Turnpike described in the Pennsylvania Turnpike Commission section of chapter 4 are designated with an integer of 500 or greater. Cases for which the GET system type (i.e., selections in the second bracket) is labeled "NS" indicate cases that did not meet inclusion criteria. NS case information was collected and submitted, but the case was separated from GET data tabulations because the case did not satisfy all inclusion criteria listed in the Case Inclusion Criteria section of chapter 4 (e.g., the vehicle was not a passenger vehicle, the GET system was unknown, or the GET system was not one of those listed in table 1).

Case Counts

Table 12 provides a summary of crash cases collected in each highway agency data-collection area with the bilevel notification criteria (i.e., ambulance transported or not ambulance transported). Table 13 is a summary of ambulance-transport status by GET system and a GET system total for all areas. Table 14 is a summary of crash counts by collecting agency and GET system.

Table 12. Summary of crashes collected by highway agency and crash outcome.

State	Agency	Transported by Ambulance	Not Transported by Ambulance	Total
California	Caltrans	4	128	132
Massachusetts	MassDOT	29	88	117
Missouri	MoDOT	47	89	136
Pennsylvania	PennDOT	7	85	92
Pennsylvania	PTC	5	25	30
Selected for study total		92	415	507
Not selected for study		—	—	60
Total Collected		—	—	**567**

—Not applicable.

Table 13. Summary of crashes by GET system and crash outcome.

	Trinity Highway Products				Road Systems				Lindsay				
Crash Severity	**ET 2000**	**ET Plus (Unknown 4- or 5-Inch)**	**ET Plus (4 Inch)**	**ET Plus (5 Inch)**	**SoftStop**	**FLEAT**	**SKT**	**MSKT**	**X-LITE**	**X-Tension**	**MAX-Tension**	**Not Selected for Study**	**Total**
Not transported by ambulance	20	17	107	27	12	18	116	8	88	1	0	59	473
Transported by ambulance	7	1	24	2	10	2	18	6	21	0	1	2	94
Total	**27**	**18**	**131**	**29**	**22**	**20**	**134**	**14**	**109**	**1**	**1**	**61**	**567**

Table 14. Summary of crashes by GET system and collecting agency.

Data-Collection Agency	Trinity Highway Products					Road Systems			Lindsay			Not Selected for Study	Total
	ET 2000	ET Plus (Unknown 4- or 5-Inch)	ET Plus (4 Inch)	ET Plus (5 Inch)	SoftStop	FLEAT	SKT	MSKT	X-LITE	X-Tension	MAX-Tension		
Caltrans/SCI	0	0	1	0	0	1	0	0	1	0	0	0	3
Caltrans	2	2	28	9	3	9	43	0	32	1	0	4	133
MassDOT/SCI	0	0	0	0	0	0	0	0	0	0	0	0	0
MassDOT	1	0	32	1	0	0	9	12	61	0	1	5	122
MoDOT/SCI	6	0	11	1	10	0	10	2	4	0	0	0	44
MoDOT	8	2	39	11	9	0	17	0	6	0	0	6	98
PennDOT/SCI	0	0	1	1	0	0	2	0	1	0	0	0	5
PennDOT	10	14	16	6	0	3	33	0	4	0	0	45	132
PTC/SCI	0	0	2	0	0	0	4	0	0	0	0	0	6
PTC	0	0	1	0	0	7	16	0	0	0	0	0	24
Total	**27**	**18**	**131**	**29**	**22**	**20**	**134**	**14**	**109**	**1**	**1**	**60**	**567**

Crash severities reported by police were not available in most States' data-collection sites for this study because of local law, policy, and procedures. As discussed in the MassDOT section of chapter 4, Massachusetts was the only data-collection area to collect crash severities reported by police by using administrative summaries. For consistency, these data are not presented in this report, but are available on the Research Projects page of the FHWA website.

DISCUSSION

The information in table 11 through table 14 is limited to counts and should not be used to compare GET-system performance for several statistical reasons. The cases from each agency are neither a census nor a random sample. A census is obtained if all cases meeting the inclusion criteria in the Case Inclusion Criteria section of chapter 4 are collected during a specified period in a specified data-collection area. A random sample is obtained if every case meeting the inclusion criteria in the Case Inclusion Criteria section of chapter 4 has an equal chance of being selected for data collection. GET crashes are rare events; therefore, a probability sampling approach is not appropriate because there are already few cases. The Pilot ISPE GET sample is neither random nor a census, so it is misleading to form conclusions from the data (e.g., it is misleading to calculate a percentage of fatal crashes involving a specific GET system).

As noted in chapter 2, FHWA's primary objective in performing the pilot study was to determine if the procedures and methods that could be implemented by highway agencies were sufficient to collect data to perform ISPEs. FHWA's objective was not to evaluate the performance of specific GET systems. Another reason for not evaluating GET-system performance from these data is that there are not enough data to make statistically meaningful conclusions, even if samples were unbiased. Using ambulance transport is another limitation in these data because ambulance transport is not a definitive indicator of occupant outcome. Ambulance transport was used as a crash-severity surrogate as a method for deploying SCI teams expeditiously, but it is not a measure of crash-victim injury.

CHAPTER 6. LESSONS LEARNED

INTRODUCTION

This report examined the procedures used by data-collection teams to identify lessons learned that will help highway agencies in planning and executing future data-collection efforts. The authors assessed the effectiveness of the procedures by interviewing highway agency team members, reviewing training materials, and reviewing written procedures. Researchers focused attention on how data-collection teams obtained notification of a crash, the timing of response to the crash, data-collection field procedures (e.g., measurement techniques, photograph specifications), training, training materials, communication between agencies (e.g., the NHTSA SCI team, agency maintenance personnel, law enforcement, FHWA division offices), and potential for future analysis of newly collected data.

Highway agencies integrated ISPE data collection into their normal procedures with little difficulty. The experiences of these five agencies illustrated the importance of planning, training, and communication between involved parties. The challenges were rigorously following a case-selection protocol, finding a documentable source for crash severity, and using bilevel data collection. Additional attention to planning and execution of ISPE data-collection activities can overcome these challenges in the future.

Interviews with key FHWA pilot study personnel involved with the data-collection effort were the primary source material for identifying lessons learned. Along with the interviews, the authors of this report obtained training materials and any written field data-collection procedures. The interviewed data collection personnel included the following:

- ISPE planners (e.g., FHWA and participating agencies).
- Case inclusion decisionmakers (e.g., FHWA R&D POC, APOCs).
- Data collectors for non-ambulance transport cases (e.g., crash-recovery specialists, maintenance staff, ADCs).
- NHTSA SCI team manager for ambulance transport cases (e.g., NHTSA SCI teams).
- FHWA SME personnel.
- Data managers (e.g., FHWA R&D POC and APOCs).

Some individuals filled several roles while others filled one role. The report authors categorized each lesson learned into one of the following categories:

- Planning.
- Training.
- Crash detection and notification.
- Data-collector safety.
- Observations, measurements, and photographs.
- Data management and integrity.
- Data verification and analysis.

Once the authors categorized each lesson learned, similar or identical lessons from different agencies were combined and sometimes further refined. The authors then examined each lesson learned regarding the following assessment criteria:

- The procedure **worked well**, and nothing needs to be changed.
- The procedure presented **manageable challenges** that could be mitigated with some effort.
- The procedure presented **insurmountable challenges** that are difficult to change.
- The participants did **not attempt** to use the procedure in the FHWA pilot study but thought it should be considered in future studies.

The following sections describe the lessons learned from the participants in the FHWA pilot study. The assessment category for each lesson learned is shown in parenthesis.

PLANNING THE ISPE

Carefully and thoroughly planning the ISPE is the first critical step to obtaining useful data that can answer questions from the highway agency about what the agency wants to measure. Clearly identifying the objective of the ISPE, identifying sources of data, and investigating legal, logistic, and policy impediments to data collection should all be done at the outset of the project. Good planning will ensure that the data-collection effort goes smoothly and captures information that will be useful for analyzing the results of the ISPE. The lessons learned for planning an ISPE are as follows:

- Identify the desired performance measure.
- Define specific geographical and temporal data-collection boundaries.
- Define specific case inclusion criteria.
- Estimate expected number of cases based on past data.
- Do not use special law enforcement crash investigation teams.
- Use uniform data collection for all severity levels.
- Determine what sources of information are available.
- Identify SMEs.
- Find motivated team members.
- Develop strong team relationships.
- Develop and use appropriate data-collector safety procedures.

Each lesson learned is discussed in the following sections.

Identify the Desired Performance Measure

Clearly identify the measure of performance for the ISPE and be sure there is a source for that data. For example, the most basic measure of roadside-hardware performance is occupant risk, assessed using the crash severity (e.g., fatal, injury, PDO) reported by police. If the police report is not available, where will the information originate? Is there an alternate way to determine and record crash-severity information (e.g., law enforcement administrative summaries)? Another performance outcome example might be determining the proportion of incorrectly installed GET systems. Where will this information originate? Are there inventory or maintenance inspection records available? Can onscene investigators determine if the system is correctly installed after it is damaged in a crash? Establishing a clear objective measure of the performance and the source for collecting the measure is essential to the success of an ISPE. (Manageable Challenge)

Define Specific Geographical and Temporal Data-Collection Boundaries

Be specific about the boundaries of the data-collection area and when data collection begins and ends. Adding some cases outside the data-collection area or outside the date range will compromise the statistical integrity of the sample. Do not add cases from outside the data-collection area or time no matter how interesting the crash might be. (Manageable Challenge)

Define Specific Case Inclusion Criteria

Develop a specific protocol for case inclusion and apply it rigorously. Case-inclusion criteria for the FHWA pilot study were presented earlier in the Case Inclusion Criteria section of chapter 4. While onsite, the ADC should be able to determine if the case fits the inclusion criteria quickly. If there is doubt, collect the case data and the APOC will decide on including the case later. (Manageable Challenge)

Estimate Expected Number of Cases Based on Past Data

Try to determine or estimate how many crashes involving the investigated hardware have happened in the proposed data-collection area in previous years by reviewing crash or maintenance records. Before committing to a specific data-collection area, confirm that there likely will be enough of the investigated devices to be useful. This can be determined from an inventory of hardware or a spot-check of inventory on selected routes. If there are not many devices in the area, then there will be few eligible cases to collect. Similarly, if devices are located on congested, busy, or high-speed facilities, it may be difficult and potentially dangerous for data collectors to be onsite. The data-collection area and time should be chosen such that at least 110 cases are expected for each of the most commonly installed GET systems, as will be described later in the Estimate the Number of Cases Needed for Statistical Analysis section of chapter 7. (Manageable Challenge)

Do Not Use Special Law Enforcement Crash Investigation Teams

Special law enforcement investigation units, although capable of collecting the necessary data, might not be able to participate in an ISPE data-collection activity. The primary mission of law enforcement investigative units is to collect and preserve evidence for possible criminal or civil litigation; consequently, they may not be able to share information with the highway agency. Formal agreements may be difficult to obtain and may require lengthy negotiations. Similarly, informal agreements can disappear with personnel changes. (Insurmountable Challenge)

Use Uniform Data Collection for All Severity Levels

As previously discussed, having different data collectors and procedures for ambulance-transported and nonambulance-transported crashes complicates the data-collection process and increases the chances of missing or mischaracterizing a case. While special investigators collecting more information at higher severity crashes appears to be a good way to focus limited resources, statistical conclusions are limited to data commonly collected across all cases. If the results of a routine ISPE indicate a certain type of impact should be further evaluated for updates to the hardware-assessment procedures, focusing on special investigations of higher severity crashes might be more appropriate rather than a routine ISPE. (Manageable Challenge)

Determine What Sources of Information Are Available

There are several potential data sources for an ISPE, as illustrated in figure 28. Find out what sources of information are already routinely collected and determine if they can be obtained and used in the ISPE. For example, all law-enforcement agencies complete crash reports, but the availability of those reports to the highway agency varies depending on local laws and policies. Some States will allow law-enforcement agencies to share the report with the highway agency, but others will not. Some law enforcement agencies will share summaries with the highway agency. In some States, the police reports will be available to the highway agency eventually but not in time for inclusion in the ISPE. Some States make police reports publicly accessible over the Internet, however, personal information regarding the crash victims that may not be available to highway agency must be known to look up the report. Determine the needed information, where the information originates, and what the limitations are on obtaining, sharing, and using the information. (Manageable Challenge)

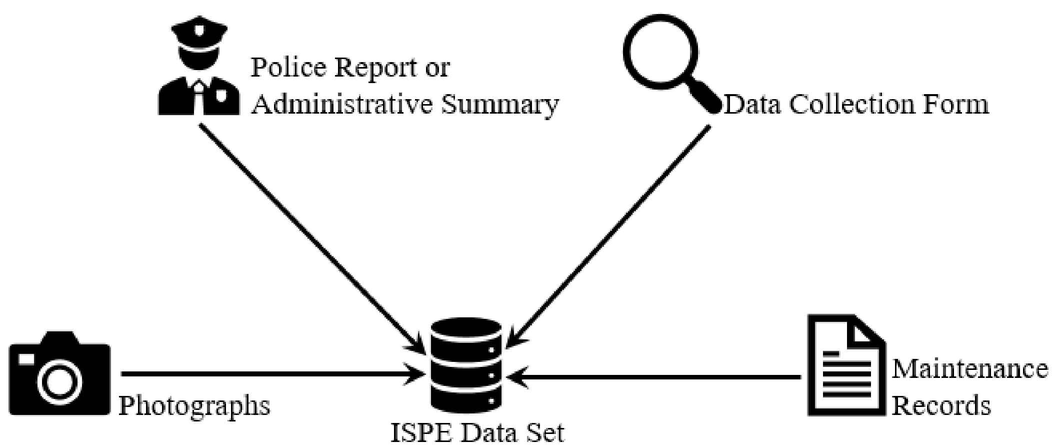


Figure 28. Flowchart. Potential ISPE data sources.

Identify SMEs

Identifying and coordinating with SMEs provides an important resource for planning and executing the ISPE. The SME can help answer questions about how the devices are supposed to work, identifying devices in the field, and installing devices in the field. The SME can be particularly valuable in training field personnel and helping with the planning of the ISPE. The SME may be an employee of the highway agency performing the ISPE, the local FHWA division office, FHWA R&D, or even a consultant or academic. (Worked Well)

Find Motivated Team Members

The success of an ISPE often hinges on the commitment, cooperation, and dedication of participants. ADCs, APOCs, and SMEs that are motivated and engaged in finding out how roadside hardware functions in the field will have a positive impact on data quality. For example, one person can focus on data collection, which can aid in data consistency and give the person a sense of ownership of a unique and important task. (Worked Well)

Develop Strong Team Relationships

Developing strong relationships between team members is very important. Data collectors must know and have confidence in their APOC, and the APOC needs to have good relationships with law enforcement and the traffic operations center. Getting buy-in from each team member is important for the smooth functioning of the team. In some cases, having a short pilot test of the procedures can help find communication challenges before starting full data collection. Another aspect of developing strong team relationships is to plan for and expect staffing changes. (Worked Well)

Develop and Use Appropriate Data Collector Safety Procedures

The safety of data collectors is of paramount importance beginning with the planning stages of the project through the completion of the field data-collection effort. Having appropriate traffic control while data collectors are on-site and wearing appropriate field gear for visibility and safety (e.g., reflective vests, hard hats, steel-toed boots), as shown in figure 29, leads to improved onsite safety. Data-collector safety is also a consideration in choosing a data-collection area. Highly congested areas may be difficult regions in which to work, or they might require extensive and expensive traffic control. For cases in which data collection is deemed too dangerous for the data collectors, the case should still be included in the database (i.e., a case number and date assigned) but with an indication that data were not collected because of the difficulty of safely working on the site. (Worked Well)

Figure 29. Photograph. Data collector wearing appropriate safety gear at a crash site.

TRAINING

Training data-collection and crash-notification team members is vital. Participants must know how to identify the subject hardware correctly and apply case-inclusion criteria. Missed or delayed notifications can result in missed opportunities to document the rest position of damaged vehicles or the condition of the damaged guardrail. Knowledge about how roadside hardware is supposed to function is also useful to help the data collector know what to document with photographs. Training should be provided before data-collection begins.

In some instances, FHWA SMEs provided refresher training to highway agencies after the initial training and after performing some early data collection. These followup training sessions were particularly effective because the team had a chance to reflect on their recent experiences and better appreciate how procedures worked in the field.

The lessons learned regarding training personnel for an ISPE include the following:

- Provide hands-on training for data collectors.
- Develop and disseminate training aids.
- Participate in traffic incident management (TIM) training.

Each of these lessons is discussed in the following sections.

Provide Hands-On Training for Data Collectors

Hands-on training where data collectors can see and inspect roadside hardware included in the ISPE is helpful. The training is especially helpful if the SME can participate and show data collectors specific features and characteristics of each type of hardware to aid in identification and inspection if necessary. (Worked Well)

Develop and Disseminate Training Aids

It is useful to develop and disseminate training aids for identifying roadside hardware of interest, especially for law-enforcement personnel who do not have experience with roadside hardware. Dash cards with pictures of the devices to be investigated and contact information are a good tool for spreading information about the ISPE to maintenance workers, contractors, and law-enforcement personnel. Dash cards worked well in Missouri and were later adapted in California as well. (Worked Well)

Participate in TIM Training

Most law-enforcement agencies periodically train their patrol personnel in TIM procedures. If a highway agency plans an ISPE in a specific region, it may be beneficial to contact the law-enforcement agency and request time to inform law-enforcement personnel about the prospective ISPE data collection in the next TIM session. (Manageable Challenge)

CRASH DETECTION AND NOTIFICATION

Developing effective methods to detect all eligible crashes and notify the appropriate personnel are key ingredients to developing a statistically sound dataset. Missed cases put the reliability of the data and the conclusions drawn from an analysis of the data into question. The more robust the detection and notification procedures are, the more confident stakeholders can be regarding the validity of the analysis and results. Lessons learned pertaining to crash detection and crash notification are as follows:

- Use normal operating procedures as much as possible.
- Include local law enforcement where needed.
- Investigate crash-notification processes.

Each of these lessons is discussed in the following sections.

Use Normal Operating Procedures as Much as Possible

Many highway agencies routinely receive crash notifications through a traffic operations center. The traffic operations center receives notices of crashes from a variety of law enforcement agencies, the public, and the highway agency. The traffic operations center links the highway agency maintenance personnel and law enforcement and is an excellent resource for notifying the data collector, who may be the highway agency's crash-recovery specialist or the traffic control specialist. If notification will come from a traffic operations center, it is important for ISPE personnel to understand how the operations center notification process works so that all eligible cases result in a notification. It is critical to account for staffing changes. (Worked Well)

Include Local Law Enforcement Agencies Where Needed

Before starting the ISPE, it is important to determine exactly how the highway agency interacts with different law-enforcement agencies and the traffic operations center. For example, State Police might be responsible for all routes owned by the highway agency, so the highway agency need only work with one law enforcement agency. In other areas, State Police might only be responsible for the Interstate and U.S. highway system while local law-enforcement agencies are responsible for primary and secondary systems in the State. In this case, the ISPE team might need to establish relationships and procedures with local law-enforcement agencies as well as State Police. Working out how to coordinate with law enforcement can also help plan inclusion criteria. For example, if the State Police are responsible for certain routes or roadway types, conforming the data-collection area to those same types of roadways will be helpful. (Manageable Challenge)

Investigate Crash-Notification Processes

The data collector should ideally be onscene before the cleanup and recovery personnel move the vehicle or damaged safety hardware. While this was sometimes the case for the systems in the FHWA pilot study, the data collector usually did not arrive until after a towing contractor removed the vehicle from the scene. It is best to arrive onscene before the vehicle is removed so the data collector can document in the photographs the vehicle's rest position, damage to the vehicle, and the position of GET system elements before they are moved or removed for salvage.

Some highway agencies used accident recovery chasers or crash recovery specialists as the ADC in agencies with quick response policies for repair and cleanup. These personnel were ideal data collectors because their normal duties already deployed them to the site quickly to arrange for vehicle removal, highway cleanup, and hardware repair. Quick-response personnel also know where the vehicle and damaged materials were taken so they could be examined later if necessary.

A plan should be developed for what to do if the ADC does not arrive while the vehicle and damaged hardware are in their rest positions. For example, it may be possible to take photographs of the damaged vehicle or hardware in a salvage yard if the storage location can be determined. Alternatively, similar photographs may be available from other first responders (e.g., vehicle-removal contractor, fire, law enforcement, insurance). Agencies should explore these backup sources of information in planning the data-collection effort.
(Manageable Challenge)

OBSERVATIONS, MEASUREMENTS, AND PHOTOGRAPHS

Observations, measurement records, and photographs are the core source data collected for each case. Conclusions about the performance of the GET systems are based on direct observations (i.e., data collected) of the highway agency data collector, law-enforcement officers, and in some cases special investigators like the NHTSA SCI team members or SMEs. Photographs and observations noted on forms allow for the proper identification of the GET system, documentation of GET-system damage, and identification of possible failure mechanisms. Lessons learned pertaining to observations and measurements and taking photographs include the following:

- Consider crash-recovery specialists as data collectors.
- Consider alternatives to paper forms.
- Determine data-collection needs.
- Establish detailed photographic guidelines.

Each of these lessons is discussed in the following sections.

Consider Crash-Recovery Specialists as Data Collectors

Many highway agencies use a crash-recovery specialist who is often an agency maintenance employee to coordinate crash cleanup, vehicle towing, guardrail terminal repair, documentation of damage for insurance recovery, and communication with law enforcement. Crash-recovery specialists are an excellent choice for data collectors because most of the data needed are already part of the crash-recovery specialist's current role at the crash site. Using a crash-recovery specialist also minimizes the additional time required for ISPE data collection because the crash-recovery specialist is already performing many of the required functions. Crash-recovery specialists are usually maintenance personnel; therefore, they are generally familiar with the types of roadside hardware used by the highway agency. (Worked Well)

Consider Alternatives to Paper Forms

Paper forms are easy to develop and use but present some logistical challenges. Paper forms can be lost, become illegible, must be scanned to email, and can be subject to inconsistent information entry. For example, a paper form might have a field labeled, "vehicle type." A data collector might write, "small car," "2016 Nissan Sentra," or "passenger vehicle," which will require someone to interpret the entry and translate it into a standardized response for analysis. It is relatively easy to develop smartphone apps or data-collection web pages that automatically add the data to an electronic dataset. Radio buttons and dropdown menus used in these types of data-collection tools limit the responses to a consistent set of appropriate responses. When cellular service is unreliable or unavailable, the transmission of the collected data can be delayed until cellular service is available. (Not Attempted)

Determine Data-Collection Needs

If the primary data are photographs, the photographic coverage must be extensive and should occur before removing the vehicle and damaged hardware components so that a SME can have the maximum amount of information. The agency conducting the ISPE needs to commit and reserve funding to allow a SME to complete the data extraction from the photographs; otherwise, the effort to obtain the photographs might be wasted. Also, the agency should be mindful of the elements that cannot be collected using photographs and must be supplemented through other sources (e.g., crash severity, ambulance transport). (Manageable Challenge)

Establish Detailed Photographic Guidelines

While relying on photographs exclusively does not provide all the necessary information of a crash, photographs are a valuable means of documentation. Training data collectors to recognize what photographs are needed, the angles and orientations that should be emphasized, and the information that should be visible in the photographs is important. Providing example photographs during training is an effective training approach. It is also useful for a SME to critique a few sets of photograph submissions early in the data-collection effort to confirm that data collectors are taking the right type and number of photographs. Written photographic guidelines helped tremendously in the FHWA pilot study. Volume II: Appendix A provides a recommended procedure based on the experience of the teams in the pilot study.

While some teams in the FHWA pilot study used higher resolution hand-held cameras, photographs taken with cell phones are usually adequate. Many photographs taken in the pilot study used smartphones with resolution of 12 megapixels or higher. Usual image sizes are approximately 3 MB for smartphone cameras and 15 MB for hand-held digital cameras. An ISO setting of 100 is ideal but can only be achieved using hand-held digital cameras; therefore, a minimum ISO setting of 50 is recommended. Regardless of the camera device, strive for the highest quality image possible.

Sometimes crashes occur at night or under poor lighting conditions. If the vehicle and damaged hardware are still in their rest positions, the ADC should take photographs regardless of the lighting conditions. If the lighting is poor, the ADC should return to the site when there are better lighting conditions to take additional photographs even though the vehicle will have been removed.

It is sometimes useful to take before (i.e., damaged) and after (i.e., repaired) photographs of the crash locations. These are often already taken for insurance-recovery purposes. Similarly, the highway agency's photologs or even Google Earth™ can provide suitable before photographs. (Manageable Challenge)

DATA MANAGEMENT AND INTEGRITY

Source data for all collected cases must be assembled and preserved to document the ISPE properly. Data should be preserved for situations where questions arise about a specific case or a group of similar cases. Developing appropriate procedures for the management and integrity of data are important features of a well-planned ISPE. Plans for numbering cases and naming folders are useful for keeping track of data and accurately integrating data from different sources for each case. (Worked Well)

Lessons learned regarding data management and integrity include the following:

- Assign a dedicated APOC.
- Establish a clear path for information flow.
- Establish an efficient method for transmitting photographs.
- Accommodate records requests.

Each of these lessons is discussed in the following sections.

Assign a Dedicated APOC

A single APOC should be designated to perform data-quality and consistency checks and to ensure data are complete and correct. The APOC typically performs data-quality and consistency checks to confirm that data are complete and correct. The APOC also coordinates any corrections if data are not accurate or complete. In some areas, law enforcement provides crash tallies periodically (e.g., weekly or monthly) to the APOC. These tallies can be used by the APOC to compare to the list of collected cases and confirm that all cases that met the sampling plan were collected. If possible, the APOC can arrange to collect as much information as possible on missed cases. (Worked Well)

Establish a Clear Path for Information Flow

Establishing a clear pathway for the information flow helps prevent the loss of data. The process described earlier and presented in figure 10 represents the information path used in most highway agencies that participated in the FHWA pilot study. (Worked Well)

Establish an Efficient Method for Transmitting Photographs

Before starting data collection, a method for transmitting photographs from ADC to the APOC should be determined and tested. There will often be numerous photographs to transfer, which can present technical challenges. For example, emailing many large photos can be difficult because some agency servers have size limits on email attachments. There are several alternatives to emailing photographs, including using file-transfer programs and physically exchanging media (e.g., USB thumb drives, Secure Digital (SD) cards, and micro SD flash drives). Investigate this issue and develop a solution before the ISPE begins. (Manageable Challenge)

Accommodate Records Requests

Highway agencies are public agencies; therefore, the public can request information about most activities through open-record requests. Data collectors must be careful not to form conclusions because these conclusions could be misleading when disclosed. The data collector's job is to document and record the facts of the crash. Determining if a device worked correctly or performed as intended is the job of the data analyst or SME and not the data collector. These types of comments and judgments should not appear on any data-collection forms or in any communications about specific crashes. Judgments about performance can only be made using a census of the crash data by someone with the expertise to make a complete evaluation.

Consult the highway agency's legal counsel when planning an ISPE. Federal legislation in 23 U.S. Code. § 409 prohibits the use of highway safety data in tort litigation when data were created for purposes related to safety improvements on roads qualifying for Federal safety improvement funding (Parker 2016). Legal counsel should determine if the ISPE activity is shielded by 23 U.S. Code § 409 in the agency's jurisdiction. (Manageable Challenge)

DATA VERIFICATION AND ANALYSIS

Verify the Data

The statistical validity of the resulting dataset depends on faithfully executing case-inclusion criteria. It is important to attempt to verify that all cases that occur in the defined sampling area during the sampling period are collected or at least accounted for. In some areas, law enforcement independently and routinely distributes a list of crashes to the highway agency. Cross-checking this list with ISPE data confirms that no cases are missed. Missed cases can be assigned a case number even if little or no data are available. Doing so preserves the validity of case counts even if all desired data are not available. Alternatively, the police crash database could be retroactively queried to determine the number of likely cases during the ISPE study period to verify that all eligible cases were obtained. (Not Attempted)

Analyze the Data

Considering data analysis in the earliest planning stages of the ISPE will allow agencies to identify the data needed for valid, reliable conclusions. The analyst should be involved in the ISPE design so that data that are ultimately collected are not statistically biased and of sufficient quality and quantity to make conclusions. (Not Attempted)

CONCLUSION

At the highest level, FHWA's objective in performing this pilot study was to demonstrate that it was feasible for highway agencies to integrate ISPE field procedures into their standard procedures. Highway agencies involved in the pilot study used agency maintenance personnel as their primary data collectors. In cases where the agency had a rapid repair policy (e.g., Massachusetts and the Pennsylvania Turnpike), the ISPE process was particularly straightforward to integrate because there were already personnel specifically assigned to coordinate the agency's quick response to all crashes. Highway agencies that participated in the pilot study integrated ISPE data collection into their standard operating procedures with relatively minor alterations. FHWA's primary objective of demonstrating the "practicality of routine in-service evaluation of end treatments" was, therefore, successfully accomplished (McGee et al. 2017).

While data-collection procedures for the FHWA pilot study generally worked well, there were lessons learned that could improve the efficiency and utility of future ISPE activities. The lessons learned described in previous sections emphasize the importance of thorough planning, training, and interagency communication. Analysis of these data were not possible because essential performance data were not always collected, and the data were biased by the sampling method. The use of a bilevel sampling procedure based on ambulance-transport status also raises questions about potential crash-severity biases. The lessons learned summarized in this chapter outline challenges and possible solutions for agencies new to ISPE data collection. Future ISPEs can overcome these limitations by establishing clear ISPE objectives, thoroughly investigating sources of data, and carefully adhering to inclusion criteria.

CHAPTER 7. NEXT STEPS

The FHWA pilot study demonstrated that highway agencies can integrate data-collection methods into their routine operations and collect information for assessing the performance of roadside hardware that includes GET systems. All five data-collecting agencies participated using relatively minor adjustments to their standard operating procedures. FHWA demonstrated through its pilot study that highway agencies can collect important data with reasonable adjustments to their normal procedures.

Lessons learned in the execution of the FHWA pilot study can be used to make data collection easier and more effective. While the five highway agencies in the pilot study collected data for GET systems, these same procedures and lessons learned apply equally to any type of roadside hardware. The purpose of this chapter is to recommend actions that highway agencies can take to improve ISPE activities that are already in place or start new activities.

ASSESS HIGHWAY AGENCY PERSONNEL AND RESOURCES

The FHWA pilot study showed that highway agencies can collect data to perform an ISPE with only minor adjustments to their existing procedures. All highway agencies are routinely notified of crashes involving public property; therefore, highway agency maintenance personnel already respond routinely to crashes involving GET hardware. Instituting an ISPE primarily involves documenting, transmitting, and storing information to which highway agency first responders already have access at a crash scene. Highway agencies interested in performing an ISPE should examine their internal procedures, availability of agency personnel (i.e., ADCs, APOC, SMEs), and adequacy of existing resources to complete data collection and analysis.

ESTABLISH A CLEAR OBJECTIVE

Framing the objective of an ISPE as a question is often a useful exercise. For example, highway agency personnel may ask what proportion of crashes with each GET system involve fatal or serious injuries. Another question that highway agency personnel might ask is what damage to GET systems do winter-maintenance activities cause. Determining what data to collect in the ISPE flows directly from an examination of these types of questions. It is only necessary to collect the information needed to answer the objective question or questions. Answering questions like these can better establish the objectives of an ISPE.

The number of people sustaining fatalities or serious injuries in crashes involving the studied hardware is usually the definitive measure of roadside-hardware performance. It is critical, therefore, to find a documentable source for crash severity. While hospital records are probably the best source of information on crash-victim injuries, it is usually difficult to obtain because of privacy considerations. One common alternative source is a police report or law-enforcement administrative summary. None of the five highway agencies in the FHWA pilot study routinely included police reports although MassDOT included law-enforcement administrative summaries. Documenting the crash severity in terms of occupant injury is vital regardless of whether the crash-severity information is obtained from the police report, administrative summary, or even direct communication with the responsible law-enforcement officer.

Without reliable crash-severity information, it is not possible to assess the performance of roadside hardware in terms of crash-severity outcomes.

ESTABLISH AND FOLLOW CLEAR CASE INCLUSION CRITERIA

Establishing clear and concise inclusion criteria is an important step in planning an ISPE. The following inclusion criteria may be easier for highway agencies to apply consistently when performing an ISPE of GET than the criteria shown in the Case Inclusion Criteria section of chapter 4:

- The crash must occur between the start and end date of the ISPE data collection.
- The crash must occur on a roadway owned by the highway agency in the specifically designated data-collection area.
- The crash must involve a collision of a passenger vehicle with the impact head of one of the systems designated for study.

These criteria are similar though not identical to those discussed earlier in the Case Inclusion Criteria section of chapter 4. Determining if the crash was a harmful event or if the impact conditions were anticipated by *NCHRP Report 350* or MASH is difficult for an ADC to determine because they often arrive after the vehicle has been removed and they are not trained reconstructionists. Similarly, the ADC cannot consistently determine if another vehicle was involved to conclude that the crash was a single-vehicle crash. Criteria 3, 5, and 6 in the Case Inclusion Criteria section of chapter 4 were removed and criterion 4 was reworded for these reasons. The first two criteria (e.g., limit the study to a specific date range and area) are vital for ensuring the statistical validity of the data.

ESTIMATE THE NUMBER OF CASES NEEDED FOR STATISTICAL ANALYSIS

FHWA did not expect to collect enough data to make occupant injury outcome performance estimates of each of the studied GET systems in this pilot study due to its limited duration and geographical extent. One issue to address when planning or conducting an ISPE is determining how many cases are needed to inform reliable and meaningful decisions. Carrigan provided a guidance document for planning and executing ISPEs of roadside hardware that discusses estimating the number of cases needed to obtain useful statistical results (Carrigan 2021, in press).

An important step in planning an ISPE is to identify a target number of crashes that will provide enough data to allow for the ISPE to lead to meaningful statistics. When the number of cases needed is known, the geographic size of the data-collection area and the length of the data-collection period can be determined. Collisions are rare, random events, so data-collection areas tend to be large and the data-collection period may be long.

The number of cases, size of the measured effect, desired precision of the estimate, and the confidence level are all interrelated quantities. The sample size for an ISPE can be calculated as shown in figure 30. Figure 30 assumes the Central Limit Theorem applies, which is true provided the condition to the right of the if statement in figure 30 is true (Carrigan 2021, in press).

$$n = \frac{z^2 \cdot \hat{p} \cdot (1-\hat{p})}{w^2} \; if \; \min\left(n \cdot \hat{p}, n \cdot (1-\hat{p})\right) > 5$$

Figure 30. Equation. Estimating sample size.

Where:

n = number of crashes.
$\hat{p}$ = estimated effect size.
w = desired precision of the estimate.
z = Z score corresponding to the desired confidence level (e.g., $z = 1.44$ for a two-tailed 85-percent confidence level).

For example, Ray and Carrigan (2018) recently found that typical *NCHRP Report 350* GET systems result in a police-reported serious or fatal injury in 2 to 5 percent of police-reported crashes in which the first and only harmful event is a GET collision (i.e., $0.02 < \hat{p} < 0.05$). If an ISPE GET is being planned where 5 percent of the cases are expected to be serious or fatal injury ($\hat{p} = 0.05$) and the desired precision is 3 percent ($w = \pm 0.03$), then according to figure 30, at least 110 cases are needed to be 85-percent confident so the result is between 2 and 8 percent (i.e., $0.02 < \hat{p} < 0.08$).

The following are three ways to increase the number of cases in an ISPE:

1. Expand data collection statewide.
2. Collect data continuously.
3. Collaborate with other highway agencies studying the same GET systems.

USE A SINGLE-LEVEL DATA-COLLECTION PROCEDURE

The FHWA pilot study used a two-tiered data-collection procedure for all agencies except MassDOT. Agency maintenance personnel collected data and took photographs if the crash did not involve transporting a vehicle occupant by ambulance. NHTSA SCI investigators deployed to investigate crashes involving an ambulance transporting at least one vehicle occupant. While SCI reports were detailed and comprehensive, they took a long time to become available. Some SCI cases that were investigated 4 yr ago still have not been published. Documenting and examining all crashes in the same way is important in an ISPE because lower crash-severity cases are just as important as those of higher severity when assessing hardware performance in the field.

USE EXISTING ISPE RESOURCES

There are more resources available now than ever before for planning and executing ISPEs. Planning new ISPE activities should take advantage of the lessons learned in the FHWA pilot study. *NCHRP Report 490* provides detailed information on planning and executing an ISPE data-collection activity. NCHRP Project 22-33 provides a standardized template of data needed for routine ISPEs and procedures for analyzing and sharing results (Carrigan 2021; Ray et al. 2003). Consulting these resources will promote the efficiency and efficacy of future ISPEs.

CONCLUSION

Highway agencies can collect routine, useful ISPE data that have the potential for making significant improvements to roadside safety while also maximizing the utility of scarce highway agency resources. ISPEs should become a routine part of highway agency asset management of roadside hardware. Collecting data through ISPEs of roadside hardware will allow highway agency engineers to make informed, data-driven decisions about the hardware to deploy and how well it is working.

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