Appendix A

In-Service Performance Evaluation: Guidelines for the Collection, Extraction, and Documentation of Data

The National Cooperative Highway Research Program (NCHRP) is sponsored by the individual state departments of transportation of the American Association of State Highway and Transportation Officials. NCHRP is administered by the Transportation Research Board (TRB), part of the National Academies of Sciences, Engineering, and Medicine, under a cooperative agreement with the Federal Highway Administration (FHWA). Any opinions and conclusions expressed or implied in resulting research products are those of the individuals and organizations who performed the research and are not necessarily those of TRB; the National Academies of Sciences, Engineering, and Medicine; the FHWA; or NCHRP sponsors.

March 18, 2024

Christine E. Carrigan, P.E., Ph.D.
Ethan M. Ray
Malcolm H. Ray, P.E., Ph.D.

RoadSafe LLC

P.O. Box 312
Canton, Maine 04221

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Chapter 1. Introduction

It has been long recognized that roadside safety features have performance limitations and the performance of safety features cannot be fully assessed by crash testing alone. [1-6] "The objective of an in-service performance evaluation (ISPE) is to assess the crashworthiness of safety features under field conditions. A secondary objective is to determine which factors are influencing performance (e.g., maintenance, installation, hardware design, etc.)." [7]

This "In-Service Performance Evaluation: Guidelines for the Collection, Extraction, and Documentation of Data" (*ISPE Data Collection Procedures Manual*) discusses data collection, extraction, and documentation techniques and provides methods of schema and data mapping to develop a standardized ISPE dataset that can be used and interpreted consistently across transportation agencies.

Minimizing traffic exposure to data collectors and maximizing the use and integration of data already being collected are goals of this *ISPE Data Collection Procedures Manual.* The *ISPE Data Collection Procedures Manual* provides guidelines for the proper handling, preservation, and documentation of the collected and extracted data. The *ISPE Data Collection Procedures Manual* ensures that sensitive or private data (i.e., motorist personal information) are not incorporated into the ISPE dataset, therefore minimizing the need to "sanitize" the ISPE dataset for public consumption later.

NCHRP Project 22-33 was recently completed and provided complementary ISPE guidelines which were published as NCHRP Report 1010. The "In-Service Performance Evaluation: Guidelines for the Assembly and Analysis of Data" (NCHRP Report 1010) was designed to encourage maximum participation by the roadside engineering community. [7] Field performance was defined through the NCHRP Report 1010. This *ISPE Data Collection Procedures Manual* is directed toward those responsible for data collection and data management whereas the NCHRP Report 1010 was directed towards those responsible for assembling the data and performing the analysis.

This *ISPE Data Collection Procedures Manual* proposes standardized ISPE data elements and procedures for collecting those data elements for the variety of roadside safety features tested under the current Manual for Assessing Safety Hardware (MASH) or previous crash testing guidelines. In the context of performing an ISPE and for the purpose of this *ISPE Data Collection Procedures Manual*, these terms are defined to foster collective understanding:

- **Data collection techniques** are any methods that involve making measurements or observations of roadside hardware and features in the field. Data collection may be conducted on an ongoing basis, periodically, or on an as needed basis.
- **Data collection procedures** are the documented practices for conducting a data collection activity and extracting and documenting the ISPE dataset.
- **Data extraction and documentation** of the collected data is the translation of the data relevant to the ISPE for incorporation in an ISPE dataset.
- **Performance evaluation** is based upon the ISPE dataset using the analysis techniques for assessing hardware performance outlined in NCHRP Report 1010.

This document presents techniques which capitalize on currently available information accessible to typical transportation agencies. This document should be seen as a living document which should be updated as crash testing evolves, new asset management techniques become widely used, and the use of ISPEs increases providing a larger population of trained individuals and research results to build upon.

1.1 Underlying Philosophy

An ISPE has several major phases: planning, data collection, data assembly, data analysis, and making recommendations and decisions based on the observed performance. This *ISPE Data Collection Procedures Manual* addresses the second (i.e., data collection) and third (i.e., database assembly) phases. The planning, data analysis, and recommendations are addressed within the NCHRP Report 1010. [7] The data available within already collected crash databases are paramount for the successful conduct of an ISPE. An inventory is not necessary to conduct an ISPE. Transportation agencies, however, may find it beneficial to maintain an inventory of roadside hardware to monitor the field performance of roadside hardware and to address more complex questions. Creating an inventory of roadside hardware provides data that supplements the already available crash data.

Transportation agencies can effectively improve their understanding of roadside hardware field performance through the conduct of individual ISPEs, the institutionalization of ISPE programs, or as part of their agency asset management program. Individual ISPEs can be initiated using available crash data. Based on the outcome of the review of the available crash data, transportation agencies may choose to conduct an investigative ISPE which may involve reviewing field crashes as they occur to further improve the understanding of hardware benefits and limitations. Asset management is “a strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on both engineering and economic analysis ….”[8] ISPE programs may complement ongoing asset management activities and allow for the continuous monitoring and documenting of in-service crashes accompanied by the scheduled analysis of ISPE data and development of ISPE reports.

Expanding the data collected under an asset management program could be used to support individual ISPEs and ISPE programs. AASHTO explains that “there are various analytical tools available that agencies can use in prioritization.” [9] This concept is presented as a flowchart in AASHTO’s figure 14. [9] In Figure 1, The AASHTO flowchart has been expanded to indicate where ISPEs can be added to existing analytical tools.

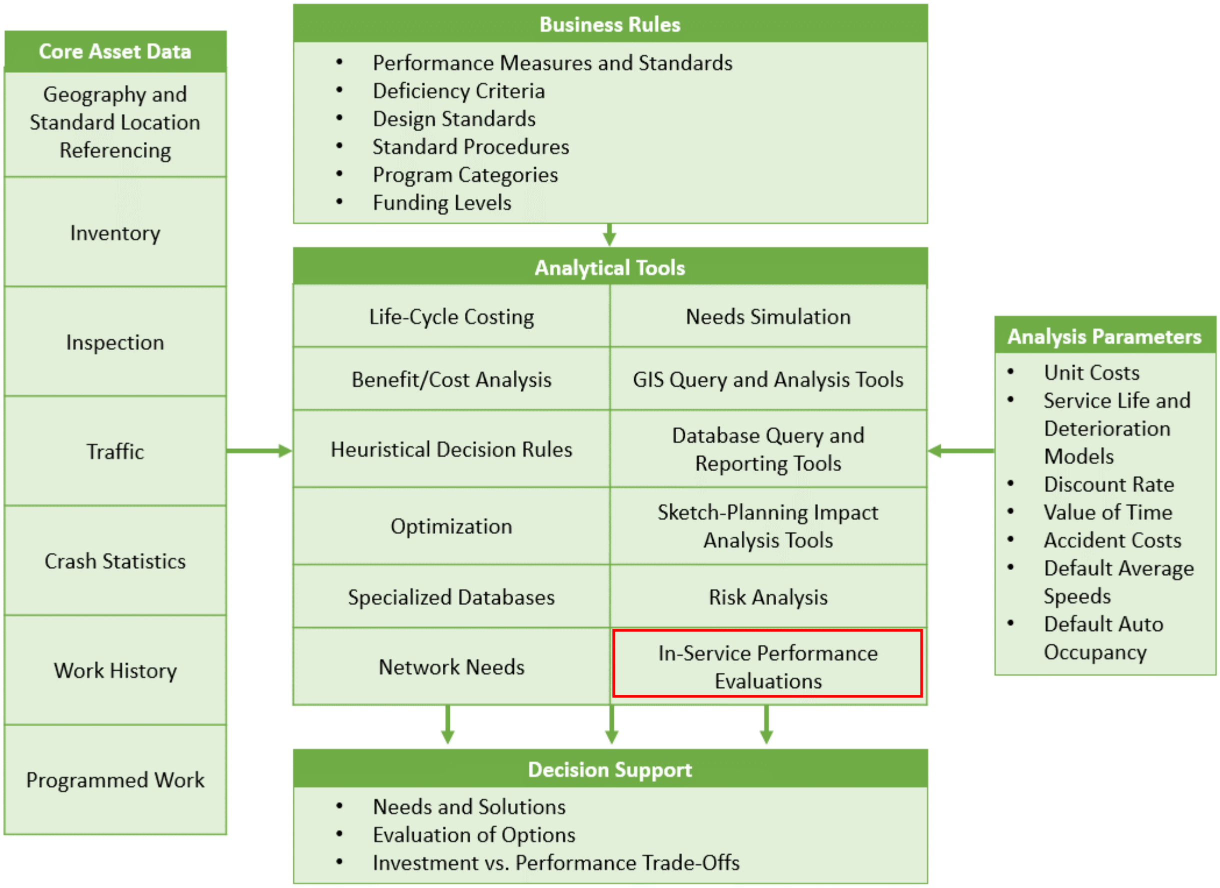


Figure 1. Expanding existing asset management programs to include ISPEs.

Effective data collection procedures support a meaningful assessment of the condition and performance of roadside hardware. This *ISPE Data Collection Procedures Manual* therefore identifies critical data elements, data elements which are most effectively collected at the crash scene, and data elements which may be collected through an asset management program to support ISPE programs. In summary, there is not a one-size fits all approach to institutionalizing ISPEs. Some jurisdictions may experience success by incorporating ISPEs into their asset management programs while others may find success through the targeted study of hardware performance. Even still, others may find continuing routine ISPEs using the available crash data is the best means to evaluate hardware performance. Collecting the same data elements using the same techniques, however, will support the collaboration between jurisdictions. This manual provides guidelines for collecting ISPE data to support individual ISPEs, ISPE programs, and collaboration between jurisdictions.

1.2 Organization of Manual

This Procedures Manual has identified the most useful data elements to collect for the conduct of an ISPE, along with the most common means for collecting those data elements. However, due to the variety of how data is collected, stored, and managed in each jurisdiction this manual cannot purport to cover all possible data elements or data sources that may be useful to a jurisdiction in the conduct of their own ISPEs. Jurisdictions are encouraged to use this manual as a framework to build their own procedures manuals from.

Chapter 2 of this Procedures Manual gives a summary of the data elements identified as useful for the conduct of ISPEs. Chapter 3 discusses potential data sources that can be mined during the data collection task. Chapter 4 provides detailed descriptions of how each data element can be collected and summarizes data collection techniques. Chapter 5 discusses data management, extraction, and the linking of multiple data sources. This Procedures Manual contains one appendix which provides an example on-site form for data collection at the scene of a crash.

This Procedures Manual covers a variety of data elements, some of the elements can be used in every ISPE conducted, however some of the data elements will only be helpful when conducting investigative ISPEs. Furthermore, others will be useful for targeted, large-scale ISPEs that aim to evaluate national guidelines. If a specific data element cannot be determined for a single crash, or for all crashes in the dataset, a value of unknown can be input, as described in these procedures. In summary, it is not necessary to collect every data element for every ISPE. It is, however, beneficial to develop an ISPE plan and identify which data elements are appropriate to support a particular ISPE then reliably collect those elements during that ISPE. NCHRP Report 1010 can be used to plan an ISPE.

Chapter 2. ISPE Data Elements

This *ISPE Data Collection Procedures Manual* focuses on quantitative data elements. Quantitative data has the advantage of being interpreted the same way by different people. Collecting data using terms like “performed as intended” or other similar subjective terms may be interpreted differently by different data collectors. For example, “performed as intended” assumes that the data collector knows how the designer intended the hardware to work. Each data collector may have different opinions about the performance in a particular crash and if that performance was intended. Likewise, does “penetrate” mean the vehicle penetrated through the system or did some part of the system penetrate the occupant compartment? Are going through the guardrail and going over the guardrail both penetrations? Avoiding data elements which require the data collector to make assumptions and draw conclusions (e.g., “performed as intended”) minimizes inappropriate conclusions, unfortunate choices of words by data collectors, and ambiguous results.

NCHRP Report 1010 recommends a two-tiered approach to performing ISPEs. [7] The two tiers include routine and investigative ISPEs, as explained here:

1. *Routine ISPEs* are generally retrospective assessments of safety features that are performed periodically or continuously using readily accessible routinely collected data (e.g., reported crash data, hardware inventories, maintenance records, etc.). The results of a Routine ISPE will determine the need to conduct an Investigative ISPE. If the results of a Routine ISPE indicate that performance is acceptable, then there is no need to perform a more detailed and costlier Investigative ISPE. Routine ISPEs may be one-time, periodic, or continuous efforts.
2. *Investigative ISPEs* involve supplemental data collection, generally through site investigations. If a situation is identified where further investigation is desirable, an Investigative ISPE could be undertaken. Investigative ISPEs may be one-time, periodic, or continuous efforts.

If the first-tier routine ISPE results in acceptable performance, then no additional data collection is needed and the second-tier investigative ISPE is not undertaken. On the other hand, if it is found in the first-tier routine ISPE that additional data elements are needed to form conclusions, then the second-tier investigative ISPE uses the routine ISPE results to plan the data collection area, time frame, and the data elements to collect in the field with the more detailed investigative ISPE.

This manual identifies ISPE data elements which can be collected on an ongoing basis or on an as needed basis. Prior to the consideration of which data elements to collect, the safety feature under evaluation (SFUE) must be declared. This is done to guide the choice of data elements which could support an ISPE. SFUE represents the broad grouping of safety features, including:

1) Longitudinal Barriers,
2) Terminals and Crash Cushions,
3) Truck- and Trailer-Mounted Attenuators and Variable Message Signs and Arrow Board Trailers,
4) Support Structures, Work-Zone Traffic Control Devices, and Breakaway Utility Poles, and
5) Other features.

It is advantageous to routinely collect the data elements identified as critical, as will be discussed in Section 2.1. The routine collection of the other identified elements would benefit any ISPE program. Those elements identified in Section 2.2 are suggested as possible data elements when conducting an Investigative ISPE and/or when planning an asset management program.

One advantage to routinely collecting ISPE data elements is the second, more resource intensive part of the NCHRP Report 1010 methodology, will not be triggered. Not all transportation agencies have the resources for collecting everything on every type of roadside hardware.

The following sections discuss the data elements and nomenclature suggested to populate a transportation agency's dataset for use in conducting ISPEs. It is not necessary to collect all the elements for every ISPEs; some elements are relevant to only one SFUE. The data elements applicable to each SFUE are tabulated as the close of this Chapter.

2.1 CRITICAL DATA ELEMENTS

"A database of crashes is generally the minimum resource necessary for conducting an ISPE." [7] The elements discussed within this section are largely available within a transportation agency's crash database. These data elements are generally considered a baseline for ISPE data elements and an attempt is made to gather these data elements for each ISPE which is undertaken.

Each bullet point starts with the data element description and the suggested nomenclature in parentheses. For example, the crash record number is a critical data element. The bullet point starts with "Crash Record Number" and has the variable name (CRN) in parenthesis. The value CRN is the suggested nomenclature. A brief summary of these suggested data elements is provided in the remainder of this section, an expanded definition of each element is provided in Section 4.2 while the techniques for obtaining each data element are summarized in section 4.3.

- Crash Record Number (CRN): Crash record number is a reference which identifies the crash within the original crash database or crash report for reference back to the original source.
- Crash Date (CRASH_DATE): This field indicates the date that the crash occurred.
- Crash Location (CRASH_LOC): This field captures the location of the crash.
- Number of Units (TOTAL_UNITS): This field is the total number of units involved in the crash.
- Maximum Crash Severity (MAX_SEV): This field records the maximum injury severity to any person in the vehicle which impacted the SFUE.
- Vehicle Type (VEH_TYPE): This field indicates the vehicle type which impacted the safety feature.
- Posted Speed Limit (SPEED_LIMIT): This field records the posted speed limit for the roadway where the safety feature which was impacted was installed.
- Harmful Event Post Impact with Safety Feature (PostHE): This field is intended to capture the harmful event which immediately follows the impact with the safety feature under evaluation.
- Most Harmful Event crash (MHE): This field indicates if the SFUE interaction was coded on the crash report as the most harmful event in the crash sequence.
- First Harmful Event crash (FHE): This field indicates whether the impact with the SFUE was the first harm producing event in the crash sequence.

- Any Harmful Event crash (AHE): This field indicates whether the impact with the SFUE occurred anywhere in the sequence of events.
- First and Only Harmful Event crash (FOHE): This field indicates whether the impact with the SFUE was the first and the only harmful event in the crash sequence of events.
- Roadway Surface Condition (RSUR): This field is used to indicate the environmental condition of the roadway surface that the vehicle traversed just prior to the crash.

Personal information is not needed to conduct an ISPE. While a crash record number has been requested, it is not explicitly used when assessing the assembled data. The crash record number allows for reference to be made to the original records, by the jurisdiction who maintains those records, if necessary.

2.2 OTHER ISPE DATA ELEMENTS

The data elements discussed here will aid in the conduct of an investigative ISPE. Some transportation agencies may find some of these elements can be determined through a detailed review of the standard crash form and, when available, scene photos. Additionally, many of these elements can be collected after a crash has occurred. Another option is to plan to visit the crash scene of each crash which meets the ISPE inclusion criteria.

- Safety Feature Breach (BREACH): This field is limited to safety features designed to capture and redirect an errant vehicle (e.g., SFUE=1, longitudinal barriers). When the impacting vehicle breaches the safety feature (i.e., some or all of the vehicle came to rest on the field side) and is not re-directed away, the safety feature is said to have been breached.
- Predictable Breakaway (BREAK): This field is limited to safety features designed to breakaway or yield in a predictable and controlled manner (e.g., SFUE=4, a sign support, breakaway pole, work zone traffic control device, etc.). This field indicates whether the vehicle activated the breakaway or yielding component of safety feature.
- Controlled Penetration, Redirection, or Stop (PRS): This field is limited to safety features designed for redirection, controlled penetration, or controlled stopping of the impacting vehicle (e.g., SFUE=2 or 3, terminals, crash cushions, truck- and trailer-mounted attenuators, variable message signs, and arrow board trailers). This field indicates when the impacting vehicle was redirected, the impacting vehicle experiences a controlled penetration behind the safety feature, the impacting vehicle came to a controlled stop, or the impacting vehicle experiences none of the above.
- Safety Feature Penetration (PEN): This field is used to indicate if a portion of the safety feature entered the vehicle's occupant compartment. Penetration should only be indicated if the hardware or a portion of the hardware penetrated the occupant compartment.
- Initial Contact Point (ICP): The initial contact point associated with the vehicle's first harmful event of the vehicle which impacted the SFUE.
- Sub Feature Name (NAME): Each type of roadside safety feature usually includes a variety of specific designs that are tested using the same crash test procedures and evaluation criteria. For example, if the safety feature under evaluation were bridge railings, a typical transportation agency may have several bridge railings included in its standard specifications or drawings. The specific type of bridge railing involved in the crash would be captured in this field. A second example is cable barrier. A jurisdiction

may have several different manufactures of high-tension cable barrier on their qualified products list (QPL) or approved products list (APL). It may be desirable to consider each individual design within an overarching safety feature group when it is possible to identify the specific design.

- Placement (OFFSET): This data element is the dimensional measurement of the offset of safety feature from the edge of travel.
- Safety Feature Height (HEIGHT): This data element is the dimensional measurement from the roadway surface to the top of the safety feature.
- Curb Presence (CURB): This element includes the collection of the presence of curbing installed on the traffic side of the impacted SFUE.
- Curb Type (CTYPE): This data element identifies the type of curbing installed on the traffic side of the impacted SFUE.
- Offset from Face of Curb to Safety Feature (CDIST): This data element is a dimensional measurement of the offset of the safety feature from the face of the curb.
- Tapered Edge (EDGE_TAP): This data element indicates if a pavement edge includes a tapered transition from the edge of the paved roadway surface to the unpaved shoulder.
- Ground Condition (GRNDCOND): This data element is used to indicate the condition of the ground, outside of the traveled way, that was traversed by the impacting vehicle, at the time the crash.

The data elements discussed below are not critical to the conduct of routine or investigative ISPEs nor to the conduct of ISPE programs. There may be times when a more detailed, well-funded ISPE is planned. These data fields could be used during a more detailed, well-funded ISPE that is intended to update national guidelines such as MASH or the Roadside Design Guide (RDG). These data elements would largely be collected at a crash scene or determined through a crash reconstruction.

- Initial Contact Point with the Safety Feature (IP_SFUE): This data element is the contact point on the vehicle when it impacted the safety feature.
- Impact Speed (ISPEED): This data element is an estimation of the vehicle speed when it impacted the safety feature.
- Velocity Angle (VANGLE): This data element is an estimation of the angle between the vehicle velocity vector and the safety feature when the vehicle impacted the safety feature.
- Heading Angle (HANGLE): This data element is an estimation of the angle between the vehicle's centerline and the safety feature when the vehicle impacted the safety feature.
- Yaw (YAW): This data element indicates if there was rotation about the vertical axis of the vehicle prior to or at the time of the interaction with the safety feature.

Expanding the data collected under an asset management program could be used to support both individual ISPEs and ISPE programs. The collection of data elements which would be best supported through an existing asset management program are discussed below. These data elements, for example, may support the review of the history of a safety feature at a particular location. These elements include:

- Safety Feature Identification (SFID): This field is a unique identifier for a specific safety feature.

- Location of the Safety Feature (SFLOC_B & SFLOC_E): These fields are used to identify the location of the safety feature.
- Installation Inspected and Documented (INSTALL): This field is used to indicate if the installation of the safety feature was inspected and verified to be consistent with the engineering plans (e.g., design or standard) at the time of installation. This field can also indicate if it was necessary to deviate from agency standards.
- Maintenance Inspection (MAINT): This field is used to indicate if the safety feature is inspected on a routine schedule to provide a reasonable degree of assurance that the safety feature is being maintained in crash ready condition.
- Installation Date (I_DATE): This field indicates the date the safety feature was initially installed.
- Installation Cost (I_COST): This field is used to record the total cost of installing the safety feature, including the material costs, installation costs, and traffic management costs.
- Repair History (R_HIS): This field is a dated history of the repairs to the safety feature and is used in conjunction with R_TYPE and R_COST.
- Repair Type (R_TYPE): This field is a code or description of the repair type and is used in conjunction with R_HIS and R_COST.
- Repair Cost (R_COST): This field is used to record the total costs of repairs and is used in conjunction with R_HIS and R_TYPE.

2.3 DATA ELEMENTS RELEVANCE TO EACH SFUE

This Chapter lists and briefly describes each data element. It is not necessary to collect all the elements for every ISPEs; some elements are relevant to only one SFUE. Recall the SFUEs represents the broad grouping of safety features, including:

1) Longitudinal Barriers,
2) Terminals and Crash Cushions,
3) Truck- and Trailer-Mounted Attenuators and Variable Message Signs and Arrow Board Trailers,
4) Support Structures, Work-Zone Traffic Control Devices, and Breakaway Utility Poles, and
5) Other features.

For example, BREACH is applicable only to longitudinal barriers; BREAK is appliable to support structures, and PRS is applicable to terminals and crash cushions.

Chapter 3. Identifying ISPE Data Element Sources

Detailed planning and realistic expectations for identifying existing data sources and collecting new data provides support for successful data collection and avoidance of problems when using the collected data. NCHRP Report 1010 addresses identifying the data collection areas and data collection durations. [7] Relatedly, NHCRP Report 1010 also discusses the importance of defining the objectives of an ISPE from the outset.

It is generally considered good practice to identify the available existing ISPE data sources prior to collecting new data (see Section 3.1). While it would be ideal to learn every desired data element is already collected and available within existing data, that is not expected to be the norm. Similarly, it would be ideal to be able to access, extract, and link all existing data sources. When existing data cannot be accessed, extracted, and/or linked or when particular data elements do not exist, the collection of new data may be necessary. This chapter also discusses establishing new data collection procedures (see Sections 3.2 and 3.3). It is important to remain aware that the existing and newly collected data will need to be linked to develop an ISPE dataset for analysis.

The Model Inventory of Roadway Elements (MIRE 2.0) was released by FHWA in 2017. The FHWA established a subset of the MIRE as part of the highway safety improvement program (HSIP) Final Rule changes to 23 CFR Part 924, effective April 14, 2016. This subset is referred to as the fundamental data elements (FDEs). Regulations require that States have access to the FDEs on all public roads by September 30, 2026. [23 CFR 924.11(b)]. [10] FDEs include the Route Number, Route/Street Name, Begin Point Segment Description and End Point Segment Description. The FHWA explains that "crash, roadway, and traffic data should be linkable by geolocation, i.e., a unique location identifier, on a highway basemap, which is defined as 'a representation of all public roads that can be used to geolocate attribute data on a roadway.' [23 U.S.C. 148 (a)(2)]" [10]

ISPE data collection should capitalize on the new Federal requirement which expanded the States obligation to include public roads into a State's linear reference system (LRS). This LRS requirement provides at least one means to geospatially locate MIRE data elements. It is desirable to have data with a consistent LRS to facilitate the integration or linking of multiple datasets and limit the duplication of data collected. It is suggested that ISPE data elements be collected on the same LRS as other jurisdictional datasets to support linkage.

A plan for linking ISPE data should be developed in advance of executing a plan to collect new data. Ideally, ISPE data should be collected using the already established LRS. Extracting and linking both existing and newly collected data are further addressed within Chapter 5.

3.1 Identify Potential Existing Data Sources

A routine ISPE includes data elements which can be assembled from a variety of already existing sources. Some of the sources (e.g., crash reports) have been used by researchers and transportation agencies for many years to help guide roadside hardware selection, placement, and policy decisions. Other data elements may be available in maintenance or insurance recovery records that a transportation agency already collects for other purposes. When conducting an ISPE the maintenance, construction, asset management, and insurance cost retrieval sections of the transportation agency may be consulted to determine which ISPE data elements are available and accessible.

3.1.1 Crash Reporting

Reporting data associated with crash events is a function performed by all states using law enforcement agencies. These crash reports are widely used for highway safety studies including ISPEs. Crash reports generally include the ISPE data elements identified as Critical in Section 2.1. Crash reports, or an electronic crash database developed from those reports, is an essential source of crash severity information that is often not available from any other source. Since the primary performance measure in an ISPE is occupant risk, obtaining crash severity information from a crash report is essential. Identifying a source for crash severity and linking that source to other collected data is necessary. If a source for the crash severity cannot be found, the ISPE would be limited to installation and maintenance questions.

3.1.2 Construction and/or Maintenance Records

Construction and/or maintenance records may be available that can be used, after the crashes have been assembled, to identify the hardware present at the time of the crash. Construction and/or maintenance records may also provide an opportunity to evaluate the site design for continued use and for compliance with the appropriate design guidelines.

3.1.3 Asset Inventories

An inventory of existing roadway characteristics and/or hardware may be available that can be linked to the crash records using, for example, route and mile post, global positioning system (GPS) coordinates, and/or the jurisdiction's LRS. While roadside feature asset inventories can be very useful in an ISPE they are not required. Asset inventories allow for a more comprehensive assessment which could include a distinction between various designs of the same category of hardware (e.g., different bridge rail designs) as well as information about the condition of assets that may point to needed improvements in the installation, maintenance, and repair practices or identify areas where maintenance can be deferred.

3.1.4 Insurance Recovery

Another potential source of ISPE data are transportation agencies insurance recovery programs. Since roadside hardware is generally the property of the transportation agency, drivers who damage transportation agency property are often liable for the cost of repairing or replacing that property. Insurance recovery sections may have photographs taken prior to and after the repair which can be used to identify the hardware involved and can be linked to the crash records. Crash reports, damaged hardware photographs, and insurance claim data including costs are generally already linked to crash reports/databases through the insurance recovery section standard procedures. Most often these data are stored with reference to a crash report number.

3.1.5 Hardware Inspection

Generally, there may be two types of hardware inspections performed by transportation agencies. The first is an inspection of the installed or repaired condition of the hardware. This type of inspection provides agencies with confidence that the hardware was installed or repaired correctly (i.e., according to the standard plans, record plans, and/or manufacturer specifications) and that it is crash ready. The second type of inspections are periodic in nature. These inspections are typically performed on a schedule and are often concerned with identifying general conditions rather than whether the hardware is assembled correctly. Both inspection types have value for ISPEs; installation inspections can help determine if a specific hardware crash outcome is due to incorrect installation or repair, while routine inspections can indicate to an agency the hardware is generally crash ready as well as the actual service life of their hardware and the frequency of nuisance hits to a system.

3.2 Establish New Routine ISPE Data Sources

3.2.1 Adding New Data Elements to Crash Forms

The National Highway Traffic Safety Administration (NHTSA) and the Governors Highway Safety Association (GHSA) outline minimum crash data elements (i.e., law enforcement reported data) in the Model Minimum Uniform Crash Criteria (MMUCC) guideline. [11] The MMUCC is a voluntary guideline used by most states since 1998 to standardize and improve their crash reporting forms and datasets. [11] A model crash report, which can be used electronically or manually (i.e., paper copy), is included in Appendix C of the MMUCC. [11] The form is structured in such a way that minimal training is required to fill out the form and most of the fields are in the form of multiple-choice responses. The MMUCC also serves as a detailed data element dictionary. The critical data elements in Section 2.1 of this report were identified with the MMUCC form in mind.

Adding the critical data elements listed in Section 2.1 to the existing crash report form, will aid considerably in collecting the critical ISPE data elements.

3.2.2 Insurance Recovery

Perhaps the transportation agency already has an Insurance Recovery program but does not maintain photographs. Starting or expanding an existing Insurance recovery program has the potential to provide ISPE data elements. The Arizona Department of Transportation (ADOT) describes the beginning of the recovery process as when

> “law enforcement responds to an incident in which guardrail, a bridge or some component of the highway system has been damaged. The officer will mark the damaged item with a sticker that has the incident report number on it. When ADOT is notified of the damage and makes the repair, a member of the Insurance Recovery Unit will contact the responsible party or their insurer to file a claim.” [12]

Prior to ADOT submitting a claim to the responsible party or their insurer the insurance recovery unit will combine the cost of labor, equipment and materials required to make the repair to determine the final repair cost. Similarly, the Pennsylvania DOT (PennDOT) Publication 23 discusses crash damage claims in Chapter 14 where PennDOT requires that all claims filed contain time-stamped before and after digital color photographs of the crash scene. [13] These photographs and cost data are a potential source of ISPE data.

3.2.3 Hardware Inspection

Hardware inspection at the time of installation can provide assurance that the hardware is installed correctly. Periodic inspections may also be performed with the focus of identifying general conditions rather than whether the hardware is assembled correctly. Florida DOT (FDOT) Memorandum 17-01 describes “smart forms [which] use the Survey123 application for ArcGIS”. [14] The memo goes on to state that filling out the smart forms on a mobile device is much preferred to paper forms, and paper forms should only be used as back-up.

3.2.4 Asset inventories

Asset management is “a strategic approach to the optimal allocation of resources for the management, operations, preservation, and maintenance of transportation infrastructure.” [15]

While roadside safety feature asset inventories can be very useful in an ISPE, they are not necessary. An inventory of existing hardware, however, has the potential to provide many of the ISPE data elements and allow for a more streamlined ISPE program. There are many resources currently available when considering the development of a new asset inventory for roadside safety hardware.

Utah DOT lists traffic barriers as "Tier 2 – Condition Based Management" in their tiered approach to asset management. [16] PennDOT describes working towards including additional transportation assets in future editions of their Transportation Asset Management Plan (TAMP), including guardrail and end treatments. [17] Louisiana (LADOTD) "has partial data sets for… sign trusses, guard rails, cable barriers, crash attenuators…; however, these data sets will require significant improvement to allow for addition into the TAMP." [18] Connecticut DOT (ConnDOT) has made progress on implementing asset management processes for among other assets, guardrail. [19]

3.2.4.1 Idaho Roadside Asset Identification and Management

Prior to 2005 the Idaho Transportation Department (ITD) developed, maintained, and used inventories of their roadway assets, however due to some limitations of the system and increased emphasis from the FHWA to eliminate some obsolete roadside hardware, ITD developed a more robust, user friendly application for performing guardrail inventory. [20] The new application is a video logging system developed in-house by ITD staff called GRail. The GRail application is installed in a vehicle that is fully computerized with GPS capability and distance traveled functions which enables GRail to automatically populate fields such as milepost, distance and offset, road name direction, etc. The GRail application allows for guardrail to be inventoried and deficient guardrail to be identified for replacement. ITD is in the process of implementing solutions that connect multiple ITD databases for an increasing number of roadway and roadside features along with work orders and financial information. [20]

3.2.4.2 Minnesota Roadside Asset Identification and Management

In 2014 the Minnesota DOT (MnDOT) published a report which described their Metro Barrier Extraction and LiDAR Project where MnDOT used mobile imaging and LiDAR to inventory beam guardrail and concrete barrier. [21] Prior to the initialization of this project MnDOT did not have an accurate inventory of its barrier systems. MnDOT chose to have the data collection performed by a contractor and do the data extraction in-house to save cost. During the data extraction fifteen attributes were associated with each barrier including route, location, travel direction, barrier system, end treatment type, and height of barrier.

3.2.4.3 Oregon Roadside Asset Identification and Management

The Oregon DOT (ODOT) has employed the use of two systems to store and manage data on a wide variety of roadway appurtenances, including traffic barriers, curbs, impact attenuators and signs. Those two systems are TransInfo and the Features, Attributes, and Conditions Statewide Transportation Improvement Program (FACS-STIP) tool. [22] The data input into TransInfo are field inventory sheets and feature inventory summary sheets while the outputs are reports that can support both internal and external ODOT initiatives and federal and state monitoring requirements.

In addition to the TransInfo software ODOT uses the FACS-STIP tool to provide information on asset location, attributes, and conditions to external users. FACS-STIP is a GIS mapping tool accessible from the internet which allows for nearly real-time updates about highway assets. As soon as information is input from the field, all devices logged into the FACS-STIP tool will see the updated information. Reports from the FACS-STIP tool are output in Microsoft Excel format. As an example of how the FACS-STIP tool works,

> "the Regions are able to use an electronic mobile device to input sign (and other asset) data. The electronic data collection device has GPS capabilities and can collect and populate some data elements automatically. This mobile data collection and management effort increases data collection efficiency, saving time and money". [22]

3.3 Conduct Investigative ISPE Data Collection

An Investigative ISPE data collection effort is undertaken to gather data that is not readily available from other sources within a transportation agency. Developing a clear, concise objective for an Investigative ISPE is essential. Conducting a Routine ISPE in advance of an Investigative ISPE will narrow the scope of the Investigative ISPE to allow for the investigation to focus on issues identified through the Routine ISPE. For example, a Routine ISPE may identify a higher-than-expected likelihood of serious and fatal crashes with longitudinal barriers. An Investigative ISPE would look to isolate what is causing this higher-than-expected value. Optimizing the number of data elements to collect can be done through consideration of which elements are relevant to longitudinal barriers field performance for this example.

3.3.1 Determine if Data Collection will be Retrospective or Prospective

Investigative ISPE data elements may be collected retrospectively or prospectively. In either case, data collection is focused on augmenting already available information such as crash reports or an electronic crash database. Retrospective ISPE data element collection is conducted for crashes which have already occurred. Prospective ISPE data collection occurs as the crashes occur, generally through consideration of each crash scene.

NCHRP Report 1010 utilizes the ISPE data elements identified in Section 2.1 and some of the data elements identified in Section 2.2 of this *ISPE Data Collection Procedures Manual*. Following the review and extraction of ISPE data elements from the available crash database or law enforcement records, additional data collection may be desirable. For example, it may be possible to identify crashes with the SFUE using a crash database but likely the database does not distinguish between the varieties of that SFUE used by the transportation agency. More likely than not, the crash database does not include the data elements identified in Section 2.2. Retrospective data collections of the elements outlined in Section 2.2 may start with the preliminary identification of crashes using the available crash records and subsequent use of the location information and date of each crash to review resources such as agency photo logs or Google Earth to extract any additional desired data elements. This approach allows for minimizing field visits and limits the data collection to locations where crashes have occurred. The focus is data collection to expand already available information while minimizing unnecessary data collection where crashes have not occurred.

Increasing the collection of data elements at the crash scene as crashes occur also provide a viable means to collect the data elements outlined in Chapter 2. The Federal Highway Administration (FHWA) conducted a Pilot Study from September 2015 through January 2019 which demonstrated that transportation agencies can prospectively collect ISPE data elements through integration of data-collection procedures into their normal crash-response activities. [23]

The FHWA Pilot Study resulted in a practice-ready guide which documents successful practices for prospective ISPE data element collection during an investigative ISPE. The FHWA practice-ready guide is largely based on the experiences and lessons learned by five transportation agencies and the Federal Highway Administration (FHWA) while performing the FHWA Pilot ISPE.

Whether collecting data retrospectively or prospectively, "detailed planning and realistic expectations for data collection can help to ensure a successful investigative ISPE and help avoid problems in the data collection, analysis, and evaluation later in the project." [23]

3.3.2 Develop Case Inclusion Criteria

Prior to undertaking the ISPE data collection task for an Investigative ISPE, it is prudent to develop and apply case inclusion criteria. At a minimum the case inclusion criteria will limit the crashes considered to only those which occurred with the stated SFUE, in the identified study area, during the identified study period. The purpose of identifying the case inclusion criteria is to ensure that the resulting ISPE dataset remains unbiased.

The identified study area for an ISPE data collection task could be, for example, an entire state, only state-maintained roads in the state, or it could only consider specific maintenance districts, or roadways. The study area should be large enough to ensure an adequate number of crashes will be collected. Estimating the sample size needed for a desired level of precision is addressed within NCHRP Report 1010. [7] Attention should also be paid to urban and rural designations. If an ISPE will be looking at the performance of crash cushions in rural settings, the study area for the data collection task should be limited to ensure that the identified study area does not include a large urban center.

The study period for an ISPE data collection task is typically identified in full year increments. NCHRP Report 1010 suggests a minimum of three full consecutive years of data collection with five full consecutive years being desirable. [7] When the data collection is concerned with a specific safety feature, the study period must overlap with the timeframe that the safety feature was installed by the jurisdiction.

The following is a good starting point for inclusion criteria for a crash:

1. Did the crash involve an impact with the SFUE anywhere in the sequence of events?
    a. If yes, did the crash occur within the identified study area?
        i. If yes, did the crash occur during the identified study period?
            1. If yes, collect the identified ISPE data elements.

If the answer is No to any of these questions, the identified ISPE data elements need not be collected for that crash.

3.3.3 Form Data Collection Teams

This section has been adapted from the FHWA ISPE Practice-Ready Guide. [23] An Investigative ISPE benefits from the creation and active participation of a data collection team. Each team brings together one or more people to fill the following roles:

- Data collector
- Point of contact
- Data analyst
- Subject matter expert

A team may be staffed in several ways. Transportation agency maintenance personnel may be appropriate for the data collector role, particularly if you are planning a prospective data collection effort and these personnel are already responsible for responding to crashes. Aspects of the data collector role may be contracted to outside entities; however, these procedures and the complementary NCHRP Report 1010 have both been developed assuming that transportation agency personnel are generally performing these roles. More information for each role is discussed below.

- Data collector: Each team should have a minimum of one data collector that has been trained and is thoroughly familiar with the data collection procedures, the data collection area, and the SFUE. Having more than one trained data collector provides flexibility and allows for a larger geographic region to be covered. Data collectors are typically responsible for a specific geographical area (e.g., a transportation agency maintenance district). The data collector transmits data collected to the point of contact.
- Point of contact: A single point of contact is generally appropriate. The data collector transmits the collected data to the point of contact who will often be a transportation agency headquarters staff member. The point of contact is responsible for storing the data and sometimes for obtaining other transportation agency data from other sources. For example, additional data from crash reports, administrative summaries, maintenance reports, insurance recovery reports, etc. may be obtained by the point of contact from other agency departments and added to the case files.
- Data analyst: A single data analyst is generally appropriate and may also have point of contact responsibilities. The data analyst is responsible for building and maintaining the electronic ISPE dataset. The collected data are entered into an electronic database. Data entry can be accomplished with electronic data collection techniques (e.g., mobile device applications) or can be accomplished manually by extracting information from paper or electronic forms. The data analyst should also perform quality control checks to detect any coding errors or inconsistencies. This quality control is also intended to ensure all applicable cases are being collected. The data analyst is responsible for conducting the analysis, as outlined through NCHRP Report 1010.
- Subject matter expert: It is often useful to have subject matter experts available to the ISPE team. The subject matter expert should be thoroughly familiar with the mechanics and design of the SFUE. A subject matter expert provides an important resource in the planning and execution of the ISPE. The subject matter

expert can help answer questions about how to identify devices in the field, how devices are supposed to be installed in the field, and many other important questions. The subject matter expert can be particularly valuable in training data collectors and helping with the planning of the ISPE. The subject matter expert may be an employee of the transportation agency performing the ISPE, the local FHWA Division Office, FHWA Office of Safety and Operations, or a consultant.

It is not necessary to identify a separate individual for each role, one individual may fulfill several roles.

3.3.4 Identify the Data Collection Area and Period

This section has been adapted from the FHWA ISPE Practice-Ready Guide and NCHRP Report 1010. [7, 23] An early step in the planning process to collect Investigative ISPE data is to determine how many cases are needed for statistically significant results and to use that information to estimate how large the data collection area may be and how long data collection may take place. A larger geographic area generally means a shorter data collection period and vice versa. Identifying the data collection area and period generally includes these steps:

- Estimate the number of cases needed and expected.
- Examine historical crash data.
- Determine study area and period.

Conducting a Routine ISPE in advance of deciding to conduct an Investigative ISPE will provide valuable insight when designing an Investigative ISPE. The Routine ISPE can be used to accomplish the above three steps and limit investigative data collection to specific data elements. Estimating the number of cases needed is addressed within NCHRP Report 1010 which provides guidelines on determining sample sizes. [7] Alternatively, the sample size can be calculated as shown in Equation 1. Equation 1 assumes the Central Limit Theorem applies which is true provided the condition on the right of Equation 1 is true [7, 24, 25].

Equation 1. Estimating sample size.

$$n = \frac{z^2 \times \hat{p} \times (1-\hat{p})}{w^2} \text{ if } \min\big(n \times \hat{p}, n \times (1-\hat{p})\big) > 5$$

where:
n = Number of crashes.
$\hat{p}$ = Estimated point estimate.
w = Desired precision of the estimate.
z = Z score corresponding to the desired confidence level (e.g., z = 1.44 for two-tailed 85 percent confidence level).

As an example, the SFUE may experience a law enforcement-reported serious or fatal injury in five percent of law enforcement reported crashes where the first and only harmful event is the SFUE collision. If an ISPE 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 = ± 0.03), then according to Equation 1, at least 109 cases are needed to be 85-percent confident that the result is between 2 and 8 percent (i.e., $0.02 < \hat{p} < 0.08$). The practical implications of this are that about 109 cases each (i.e., 1.44^2 x 0.05 x (1-0.05)/0.03^2 = 109) for the two or three most common variety of the SFUE (e.g., standard bridge rails used by the transportation agency) be obtained during the data collection activity. Notice that the condition on the right side of Equation 1 is satisfied (i.e., 109 x 0.05=5.45>5 and 109·[1-0.05]=103.55) so the Central Limit Theorem applies.

When a Routine ISPE does not precede the Investigative ISPE data collection, the approximate number of cases that might be expected can be determined using the transportation agency's historical crash data. For example, the Ohio crash report asks the person filling out the report to indicate the sequence of events by selecting from a list of over 50 types of collision and non-collision events. [26] There are more than 50 types of events listed including many events which can be loosely affiliated with an SFUE. The number of SFUE cases in a particular region (e.g., a county, city, or maintenance district) in a select range of years can easily be determined to estimate the upper bound of the number of potentially eligible cases for a specific time period and/or region. Another example of using event codes comes from Texas where the Texas Department of Transportation (TxDOT) Crash Records Information System (C.R.I.S.) Query Tool includes a field called "Object Struck" that is extracted from the crash report narrative. [27] Crashes which have an "object stuck" that can be affiliated with the SFUE can be identified. These types of "scoping" exercises can be performed to help identify the data collection area such that a meaningful analysis can occur.

Similarly, it is important to choose a data collection area where there is enough inventory of the SFUE and where data collection will not disrupt normal traffic operations or place data collectors at increased risk. Based on the desired sample size and a review of past crashes, establish a data collection area and timeframe.

As an example, a fictional District 4 may be expected to have around 50 SFUE cases per year, with two particular systems representing 75 percent of the hardware. It would likely take about 6 years to generate 109 cases for each of the two most commonly used systems ([109 cases per system × 2 common system] ÷ [50 cases per year × 0.75 of the cases are the two most common systems] = 5.8 years rounded up to 6 years). If 6 years is too long a period, the data collection area could be increased in size. If a fictional District 3 were added, 60 more cases per year would be likely which would decrease the study period to 3 years. Depending on the priorities and resources available, an appropriate data collection area and time period can be selected.

3.3.5 Investigate Law Enforcement, Maintenance, and Traffic Operations Procedures

This section has been adapted from the FHWA ISPE Practice-Ready Guide. [23] The FHWA ISPE Pilot study showed it is possible and effective to integrate ISPE prospective data collection into the already established crash scene procedures. Consideration should be given to the existing procedures and responsibilities of these groups when designing a prospective data collection study:

- Law enforcement,
- Transportation agency maintenance, and
- Traffic operation center.

Law enforcement personnel generally have control of the crash scene until all crash victims leave the scene, any damaged vehicles are removed, and the roadway and roadside are cleared to allow safe passage of traffic. Law enforcement personnel may not understand the value in making the law enforcement crash reports available to the data collection team. Explaining the objectives of the ISPE data collection and the need for the law enforcement crash report to make informed decisions about roadside safety is important for establishing cooperative relationships with the law enforcement agencies. Establishing a good relationship with the law enforcement personnel provides a possible means to receive notification of a crash and to obtain the crash reports when it is permissible for law enforcement to share reports.

The maintenance personnel responsible for responding to crashes likely have procedures in place for responding to a crash including arranging for towing the vehicles, clearing the damaged SFUE materials, and repairing damaged SFUEs. These procedures may include the taking of photographs of the damaged hardware, cataloging damaged hardware components which need to be replaced, and/or other procedures that may complement the ISPE data collection. Maintenance personnel likely have extensive local knowledge about SFUE inventory and local procedures that will be valuable to the data collection effort. When establishing data collection protocols, the data collection team should attempt to build from the existing maintenance procedures to the greatest extent possible to minimize additional effort needed to collect the data.

The traffic operations center is usually the part of the transportation agency that serves as the interface between the public, law enforcement personnel, towing and salvage companies, rescue, and ambulance services, as well as the transportation agency maintenance staff and cleanup crews. Traffic operations centers usually maintain call-out logs that document which first responders were dispatched to the scene, location information, and date/time information. The traffic operations center procedures for being notified of crashes and responding to them should be investigated and, when appropriate, integrated into the ISPE data collection process.

3.3.6 Develop Forms, Database, and Training Aids

This section has been adapted from the FHWA ISPE Practice-Ready Guide. [23] Once the objectives of the ISPE have been established and the associated data elements determined, the ISPE team should prepare draft materials that will be used in the ISPE data collection.

Training materials support training all ISPE personnel in properly identifying the SFUE, understanding how each SFUE functions, understanding the role of all participants, and understanding the objectives of the ISPE. These training materials can be provided to the team members so that they can be retained for future reference while performing the data collection.

When conducting an Investigative ISPE, these materials usually include data collection forms, training materials, and an electronic file structure. Forms that can be used as a template for developing data collection forms are provide in the appendix of this manual. Furthermore, if prospective data collection is planned, crash notification procedures are necessary.

An electronic file structure can support the collected data and should be planned to promote ease of data access and extraction. In some instances, particularly in retrospective data collection, it may be beneficial to forgo forms and enter the data directly into a database with the appropriate fields for each data element.

3.3.7 Training

This section has been adapted from the FHWA ISPE Practice-Ready Guide. [23] Training of the whole data collection team prior to the start of data collection is recommended. The training would address specific aspects of the ISPE. Examples of items for inclusion in the training are:

- Know how to identify each SFUE included in the study.

  While some SFUEs are easily distinguished from others, some SFUEs are very similar in appearance. The ISPE data collection team members should be provided with information that helps to distinguish each type of SFUE included in the study.

- Understand how each SFUE is designed to function in a crash.

  The ISPE data collection team is not expected to make a judgement about whether the SFUE performed correctly or not in a crash. Understanding the mechanics of the SFUE in a collision will allow the data collectors to take additional photographs or make extra notes of unusual or unexpected damage beyond the data elements outlined for the study. This additional supplementary information may help a subject matter expert evaluate the outcome. Viewing crash test videos of the SFUE included in the ISPE is one particularly instructive activity that can be included in the training.

- Understand the roles of all the participants in the ISPE.

  Each team member should know their own role and responsibilities as well as those of other team members. Doing so ensures that data are not missing or lost due to a misunderstanding about who is responsible for each step in the process.

The subject matter expert will generally provide the training to the other ISPE data collection team members. The training may be formal including face-to-face instruction time or it may be more informal question-and-answer style. It is very helpful for all team members to actually see the SFUE to be studied and examine it. Some transportation agencies have demonstration units set up in a maintenance yard, but all data collection teams can visit field installations to see the SFUE in place.

The subject matter expert may produce training aids in the form of handouts, notes, or presentations. These training aids provide all members of the team information which can be retained and referenced in the future as they encounter real-world situations during the data collection.

It may also be useful to have re-fresher training after the start of data collection. A review of technical information pertaining to the SFUE can be useful because after collecting some cases all team members may be more aware of potential issues that should be discussed with the team. Re-fresher training deals with the actual experiences of the team members and need not be formal.

3.3.8 Establish Crash Notification Procedures

This section has been adapted from the FHWA ISPE Practice-Ready Guide. [23] When it has been determined that prospective data collection will be used, the procedures for notification when an eligible study crash occurs and for deploying data collectors in a timely manner should be established and tested prior to the start of the prospective ISPE data collection. Notification is often one of the most difficult logistic arrangements to make since it often involves personnel in various divisions of a transportation agency, as well as law enforcement agencies and sometimes transportation agency contractors. Developing strong connections between these organizations to promote timely response to crash events and protect the integrity of the data collected is extremely important. The notification procedures may take this (or a similar) form:

- The traffic operations center is notified of a crash (i.e., ISPE cases and all other cases) from a variety of law enforcement agencies, the general public, and the transportation agency.
- The traffic operations center notifies the data collector (e.g., crash recovery or traffic control specialist in the appropriate maintenance district).
- The data collector determines if the case fits the study inclusion criteria. When the ISPE is particularly limited in scope, it may be appropriate to consult subject matter experts in the inclusion determination.
- The data collector deploys to the crash location and collects the pre-determined data elements.
- The data collector forwards the collected data (e.g., forms, crash report number, photographs, maintenance forms) to the point of contact. This information sharing may be automatic via a mobile device application, may include an email for each crash event, or may be accomplished using a previously identified method.
- The data analyst adds the data to the repository of collected materials.

A flow chart that illustrates a typical ISPE notification process is shown in figure 2. [23]

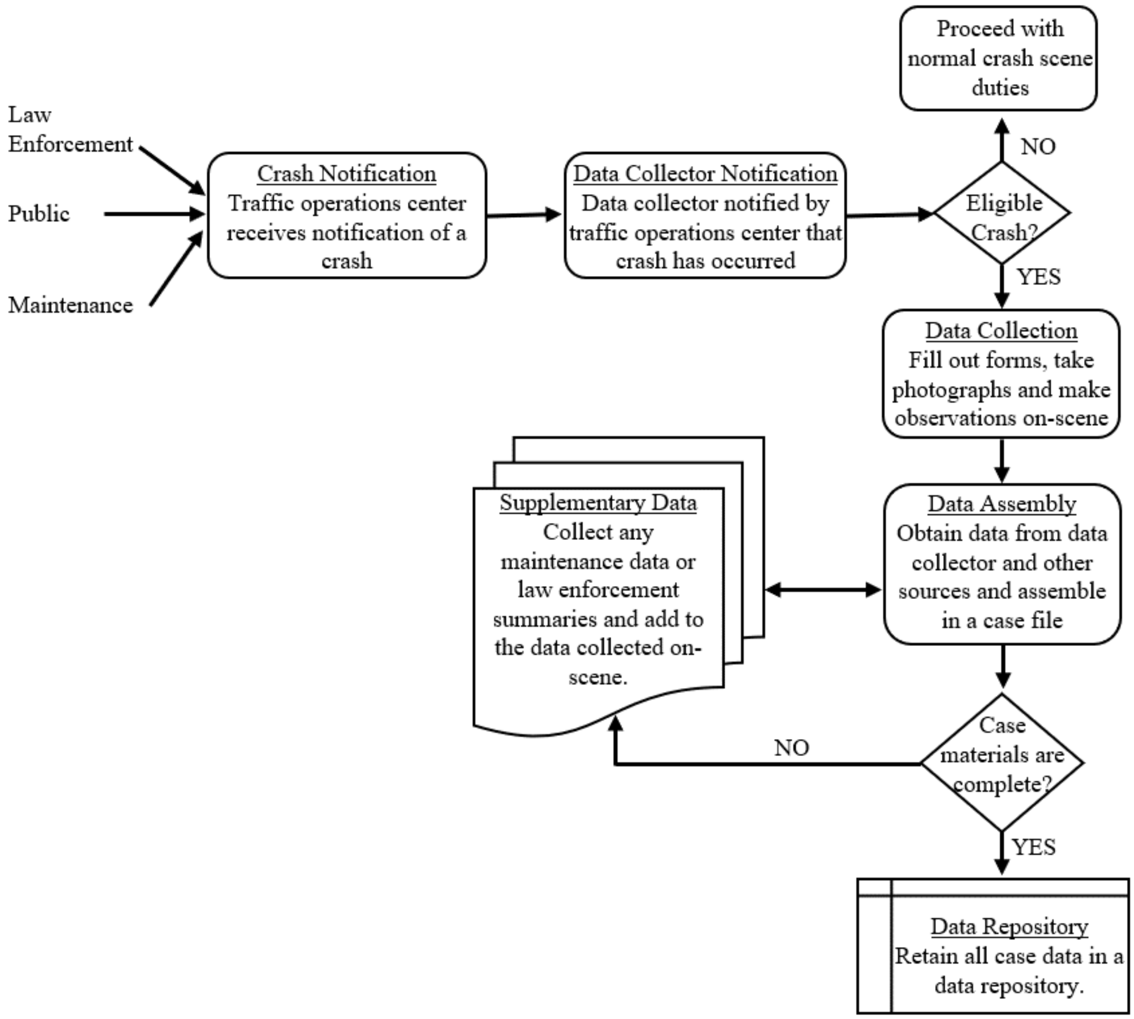


Figure 2. Data collection process flow chart.

3.4 SUMMARY

A summary of the data elements and some possible sources of these data are shown in Table 1. Quantitative data collection will provide objective and unbiased data collection, in turn leading to objective and unbiased data analysis. Data collection can focus on these quantitative data to support the subsequent analysis.

Table 1. ISPE Data Elements.

Data Element	Possible Element Sources						
	Crash reporting	Crash scene	Record plans	Maintenance records	Asset inventory	Insurance recovery	Inspection reports
SFUE	X	X	X	X	X		
CRN	X						
CRASH_DATE	X	X				X	
CRASH_LOC	X	X	X	X		X	
TOTAL_UNITS	X	X				X	
MAX_SEV	X						
VEH_TYPE	X	X					
SPEED_LIMIT	X	X			X		
PostHE	X	X					
MHE	X						
FHE	X	X					
AHE	X	X					
FOHE	X	X					
RSUR	X	X				X	
BREACH	X	X				X	
BREAK	X	X				X	
PRS	X	X				X	
PEN	X	X				X	
ICP	X	X					
NAME		X	X	X	X		
OFFSET		X	X		X		X
HEIGHT		X	X		X		X
CURB		X	X		X	X	X
CTYPE		X	X		X	X	X
CDIST		X	X		X		
EDGE_TAP		X	X		X	X	X
GRNDCOND	X	X				X	
IP_SFUE		X					
ISPEED		X					
VANGLE		X					
HANGLE		X					
YAW		X					

Table 1. ISPE Data Elements. Continued.

Data Element	Possible Element Sources						
	Crash reporting	Crash scene	Record plans	Maintenance records	Asset inventory	Insurance recovery	Inspection reports
SFID			X		X		X
SFLOC_B			X		X		X
SFLOC_E			X		X		X
INSTALL			X	X	X		X
MAINT				X	X		X
I_DATE			X	X	X	X	X
I_COST			X	X	X	X	
R_HIS			X	X	X	X	X
R_TYPE				X		X	X
R_COST			X	X	X	X	

Chapter 4. Data Collection

Data collection techniques in the context of performing an ISPE are any methods that involve making measurements or observations of roadside hardware and features either in the field or office. Techniques range from data collectors visiting roadside locations and making observations and measurements with simple hand tools to more technologically sophisticated methods like using photographs or laser scans from data-logging vehicles travelling along the roadways. Some methods are limited to data elements like location and hardware type whereas other methods can be used to collect a wider variety of data elements.

4.1 Data Collector Safety

This section has been adapted from the FHWA ISPE Practice-Ready Guide. [23] While obtaining ISPE data is important, the health and safety of the data collector is of paramount importance. The traffic control needs and basic steps for data collector safety must be considered. Having appropriate traffic control and wearing appropriate personal protective equipment (e.g., reflective vests, hardhats, proper footwear, etc.) while data collectors are on site will improve safety in the field. Figure 3 shows examples of typical safety gear that data collectors may use. All transportation agencies have procedures and policies for worker safety while engaged in performing maintenance activities on roadways with live traffic. The ISPE data collectors should use the same procedures and policies that workers would use when performing maintenance or repair activities at the same types of sites.

Figure 3. Typical safety gear for data collectors while on the crash scene.

The agency's safety procedure may address the data collector's time on scene including when law enforcement personnel are present and if it will be necessary to collect data after law enforcement have left the scene. The procedure may address the need for temporary traffic control at the scene. Some areas may require additional safety measures (e.g., high speed or high-volume locations) or law enforcement presence depending on agency policies and procedures. The procedure may require all data collectors wear suitable high-visibility, retro-reflective outerwear while on scene. Examining and following the agency's existing procedure is recommended.

4.2 ISPE DATA ELEMENTS

The following sections have been largely adapted from NCHRP Report 1010. [7]

4.2.1 Crash Record Number (CRN)

The CRN data element is a reference which uniquely identifies a crash within the original database or report for reference back to the original source. The CRN will most often be the crash report number or case number. The format of this field varies by jurisdiction. When the crash was reported, but the record number is unknown, record the CRN as UNK. If the ISPE data collection was designed to include unreported crashes, a CRN will not available, and a value of UNREP is recorded. It is not necessary to include unreported crashes in an ISPE. Unreported crashes should only be included if these types of crashes can be reliably identified.

4.2.2 Crash Date (CRASH_DATE)

The CRASH_DATE data element is the date the crash occurred. The crash date is recorded as a series of eight integers using the international format defined by the International Organization for Standardization (ISO) Standard 8601 (ISO 8601) as follows: YYYYMMDD where:

- YYYY is the year.
- MM is the month.
- DD is the day.

If the date is not known, record the CRASH_DATE as UNK.

4.2.3 Crash Location (CRASH_LOC)

The CRASH_LOC data element can typically be found on the crash report or electronic crash database and captures the location of the crash. The CRASH_LOC should be input using the LRS adopted by the jurisdiction. Common methods for identifying a crash location in the electronic crash database include GPS coordinates, and route/mile post along with side of the road.

4.2.4 Number of Units (TOTAL_UNITS)

The TOTAL_UNITS data element represents the total number of units involved in the crash, recorded as an integer number. Units may include, for example, vehicles, pedestrians, bicycles, etc.; but should not include witnesses. The preferred source for the number of units is the crash report or electronic crash database. When the total number of units is unknown, record the value as UNK.

4.2.5 Maximum Crash Severity (MAX_SEV)

The MAX_SEV data element represents the maximum injury severity to any occupant of the vehicle which impacted the SFUE. In some cases, this value may not be equal to the maximum severity of the crash. For example, the maximum crash severity may have occurred in a second vehicle that did not interact with the SFUE. The preferred source for this information is the crash report or crash database. Use the jurisdiction's values for crash severity. For example, if the jurisdiction uses a numeric scale, record the numeric value corresponding to the maximum severity of the occupants of the vehicle which interacted with the SFUE. If the crash severity is not known or the crash has not been reported, record the value as U for unknown.

4.2.6 Vehicle Type (VEH_TYPE)

The VEH_TYPE data element captures the vehicle type which impacted the safety feature. When a multiple vehicle crash is observed, the vehicle type which impacted the safety feature should be recorded. When one crash leads to two or more vehicles interacting with the SFUE, then these multiple interactions should be captured as separate events. For example, if one vehicle rear ends another in the traffic stream and both vehicles leave the road to the right and strike a guardrail this would be entered as two cases.

The vehicle type may be found on the crash report, within the electronic crash database, or through observation at the crash scene. The number of trailers is not considered for tractor trailers or for passenger vehicles, this is considered incidental to the vehicle type and the in-service exposure. When the crash report or crash database are used for this information, the value should be converted to the codes below. When VEH_TYPE is collected at the crash scene, the following codes are suggested:

- MC: When the vehicle that interacted with the safety feature is a motorcycle. Use this input for 2- and 3- wheeled motorized vehicles. Motorcycles are not currently addressed by crash testing criteria during safety feature design and development; however, it is anticipated that these vehicle types will be specifically addressed in the development of safety features at some time in the future.
- PC: When the vehicle that interacted with the safety feature is a passenger car. Use this input for typical 2- and 4- door sedans, compact cars and luxury cars. Passenger sedans are used in crash testing of roadside hardware at all test levels.
- PU: When the vehicle that interacted with the safety feature is a pick-up truck or sport utility vehicle. Use this input for compact to ¾ ton pick-up trucks, all size SUVs, and most vans. Pick-up trucks are used in crash testing of roadside hardware at all test levels.
- SUT: When the vehicle that interacted with the safety feature is a non-articulated, single-unit truck. These vehicles are typically box trucks used for short haul and commercial purposes. Single unit trucks are used in crash testing test level 4 safety features.
- TT: When the vehicle that interacted with the safety feature is a tractor trailer combination. Tractor van trailers are used in crash testing when evaluating test level 5 safety features. All articulated vehicles, including multi-trailer vehicles, are represented in these guidelines in a single category of tractor trailer (TT).
- TANK: When the vehicle that interacted with the safety feature is a tractor tanker. Neither the MMUCC nor FHWA classifications capture tractor tankers. This largely precludes consideration of test level 6 safety features unless the ISPE gathered data prospectively (see Section 3.3).
- BUS: When the vehicle that interacted with the safety feature is a bus. All school buses, city busses and inter-city busses belong in this category. Busses are not currently addressed by crash testing criteria during safety feature design and development; however, it is anticipated that these

vehicle types may be addressed in the development of safety features at some time in the future.

OTR: When the vehicle that interacted with the safety feature is one other than those listed above. Examples of vehicle in the OTR category include snowmobiles, farm equipment, and golf carts. These vehicles are not likely to be addressed in safety feature development, but none-the-less, may be exposed to roadside safety features.

UNK: When the vehicle type that interacted with the safety feature is unknown.

4.2.7 Posted Speed Limit (SPEED_LIMIT)

The SPEED_LIMIT data element is used to record the posted speed limit, in miles per hour, for the roadway where the safety feature which was impacted was installed. This value can generally be obtained from the crash report or the jurisdictions roadway logs. Record this value as a two-digit integer in miles per hour. If the posted speed limit is not known, record UNK. If the roadway is not posted, record NO_POST.

4.2.8 Harmful Event Post Impact with Safety Feature Under Evaluation (PostHE)

The PostHE data element is intended to capture the harmful event which immediately follows the impact with the SFUE. Harmful events are defined as "injury- or damage-producing event of the crash." [28] The preferred source for this information is the crash report or the electronic crash database. In an Investigative ISPE, this information may be obtained through observation of the crash scene and/or review of the crash report, if available. The PostHE data can be recorded using the following codes:

RFS: When the impacting vehicle rolls over to the field side of the safety feature under evaluation after striking it on the traffic side. (i.e., rolls to field side).

RSS: When the impacting vehicle rolls over after striking the traffic side of the safety feature and remains on the traffic side of the safety feature (i.e., rolls same side).

ROLL: When the impacting vehicles rolls over after interacting with the roadside feature, but it is not known if the vehicle rolled over on the field or traffic side. This data field is also used when the vehicle rolls over after impact and the safety feature under evaluation is not designed for redirection (e.g., breakaway sign).

TER: When the impacting vehicle does not roll over but does impact a terrain feature such as a ditch or cut slope.

VEH: When the vehicle strikes a motor vehicle in transport after striking the SFUE.

PED: When the vehicle strikes a non-motorized roadway user (e.g., pedestrian, bicyclist, etc.) after interacting with the SFUE.

FO: When the vehicle strikes a non-breakaway fixed object after the impact with the SFUE. This impact may occur while still in contact with the safety feature (e.g., impact with a w-beam guardrail that deflects sufficiently to also impact a tree just behind the guardrail or gating through a guardrail terminal and impacting a bridge pier downstream and behind the guardrail). Use this field for all fixed objects which are not known to be breakaway.

BA: When the vehicle strikes a breakaway safety feature after interacting with the SFUE. Use this field for all breakaway fixed objects (e.g., small sign supports, breakaway poles, etc.).

BAR: When the vehicle is redirected back into traffic after interacting with the SFUE, then has a secondary impact with the same or a different longitudinal barrier.

TCC: When the vehicle is redirected back into traffic after interacting with the SFUE, then has a secondary impact with a terminal or crash cushion. This field is also used when the vehicle experiences a secondary impact with the same terminal or crash cushion.

OTR: When the vehicle experiences a harmful event post impact with the SFUE and the nature of that event is known but it is not captured by one of the codes listed above (e.g., fire or immersion in water).

NONE: When no harmful events occur after interaction with the SFUE.

UNK: When it is unknown if any harmful event followed the interaction with the SFUE.

4.2.9 Most Harmful Event Crash with the Safety Feature Under Evaluation (MHE)

The MHE data element is collected from the crash report or electronic crash database. This is not an assessment made by the data collector, but rather is recorded within this ISPE dataset only when the standardized crash report for the jurisdiction includes a standard code for MHE. Law enforcement may or may not code the interaction with the SFUE as the most harmful event (MHE) of the crash. MHE can be recorded with one of these values,

YES: When the interaction with the safety feature is listed on the crash report or within the crash database as the most harmful event in the crash sequence.

NO: When the crash report or crash database does capture the most harmful event, however, the interaction with the safety feature was not the most harmful event of the crash.

UNK: When a crash report is not available. If the jurisdiction’s crash report or electronic crash database does not include information for MHE, do not interpret the crash but rather record this information as UNK.

4.2.10 First Harmful Event Crash with the Safety Feature Under Evaluation (FHE)

The FHE data element can be determined from the crash report or the electronic crash database and indicates if the impact with the safety feature under evaluation was the first harmful event in the crash sequence. When a jurisdiction does not code FHE the data collector may need to systematically review the crash sequence of events or the officer’s narrative description in the crash report to determine if harm producing events preceded the event with the safety feature under evaluation.

YES: When the interaction with the safety feature was the first harmful event of the crash sequence.

NO: When a harmful (damage producing) event preceded the interaction with the safety feature in the crash sequence.

UNK: When it is unknown if a harmful event preceded the interaction with the safety feature in the crash sequence.

4.2.11 Any Harmful Event Crash with the Safety Feature Under Evaluation (AHE)

The AHE data element can be determined from the crash report, electronic crash database, or visiting the crash scene and indicates if the interaction with the safety feature was any part of the crash sequence. Data entry codes for AHE include:

YES:	When the interaction with the safety feature was any event in the sequence of events of the crash.
NO:	When the interaction with the safety feature was not an event in sequence of events of the crash.

4.2.12 First and Only Harmful Event Crash with the Safety Feature Under Evaluation (FOHE)

The FOHE data element can be determined from the crash report, or electronic crash database, or visit to the crash scene. FOHE indicates if the impact with the safety feature was the first and only harmful event in the crash sequence. Restated, harm producing events neither preceded nor followed the interaction with the safety feature under evaluation. Data entry codes for FOHE include:

YES:	When the interaction with the safety feature is the first and only harmful event in the crash sequence. If non-harmful events occur in the sequence but interaction with the safety feature is the only harm producing event in the sequence, record a value of YES.
NO:	When the interaction with the safety feature is not the only harmful event in the crash sequence.
UNK:	When it is unknown if the interaction with the safety feature was the first and only harmful event in the crash sequence.

4.2.13 Roadway Surface Condition (RSUR)

The RSUR data element indicates the roadway surface condition at the time and place of the crash and can be determined from reviewing the crash report, scene photos, or a review of the crash scene. The possible data entries for this field mirror the fifth edition of the MMUCC for Roadway Surface Condition. [28] Data entry codes include:

DRY:	When the roadway surface is dry.
ICE:	When the roadway surface is icy or frosty.
MUD:	When the roadway surface is muddy.
DIRT:	When the roadway surface is dirt.
GRAV:	When the roadway surface is gravel.
OIL:	When the roadway surface is oil covered.
SAND:	When a layer of loose sand exists the roadway surface.
SLUSH:	When the roadway surface is slush (e.g., mix of snow and liquid water).
SNOW:	When the roadway surface is covered in snow.
WATER:	When the roadway surface is water covered, either standing, moving.
WET:	When the roadway surface is wet.
OTR:	When the roadway surface is not covered by one of the above categories.
UNK:	When the state of the roadway surface is unknown.

4.2.14 Safety Feature Breach (BREACH)

The BREACH data element may be determined from the electronic crash database when such a field exists, reviewing crash reports and photos, or visiting the scene. BREACH is limited to safety features designed to contain and redirect an errant vehicle (e.g., SFUE = 1, longitudinal barriers). When the impacting vehicle comes to rest with any portion of the vehicle on the field side of the barrier, the safety feature is said to have been breached. This field indicates if and how the vehicle breached using the following selections:

RFS:	When the impacting vehicle rolls over the safety feature.
VLT:	When the impacting vehicle vaults the safety feature.
STR:	When the impacting vehicle structurally fails the safety feature.
UND:	When the impacting vehicle underrides the safety feature.
BUNK:	When the impacting vehicle breaches the safety feature, but it is not known how.
CNTD:	When the impacting vehicle is contained on the traffic side of the safety feature (i.e., safety feature not breached).
UNK:	When it is unknown if the vehicle breached the safety feature.

4.2.15 Predictable Breakaway (BREAK)

The BREAK data element can be determined from the electronic crash database when such a field exists, reviewing crash reports and photos, or from field observations made at the crash scene. BREAK is limited to safety features designed to breakaway or yield in a predictable and controlled manner (e.g., SFUE = 4 devices, small sign supports, breakaway poles, work zone traffic control devices). Data entry codes for BREAK include:

BREAK:	When the vehicle engages the breakaway or yielding mechanism of the safety feature during impact.
NOBREAK:	When the vehicle does not engage the breakaway or yielding mechanism of the safety feature during the impact.
UNK:	When it is unknown if the vehicle engaged the breakaway or yielding mechanism of the safety feature during the impact.

4.2.16 Controlled Penetration, Redirection, or Stop (PRS)

The PRS data element can be determined from the electronic crash database when such a field exists, reviewing crash reports and photos, or visiting the scene. PRS is applicable to devices which were designed for redirection, controlled penetration, or controlled stopping of the impacting vehicle (e.g., SFUE = 2 or 3, terminals, crash cushions, truck- and trailer-mounted attenuators). Data entry codes for PRS include:

REDR:	When the impacting vehicle is redirected toward the impact side of the safety feature.
CPEN:	When the impacting vehicle penetrates behind the safety feature in a controlled way, such that the impacting vehicles comes to rest on the field side of the safety feature.
CNTL:	When the impacting vehicle comes to a controlled stop when impacting on the nose of the system.
NOCNTL:	When the impacting vehicle experiences none of the above.

UNK: When it is unknown if the vehicle was redirected, experienced controlled penetration of the system, or came to a controlled stop.

4.2.17 Safety Feature Penetration into Occupant Compartment (PEN)

The PEN data element can be determined from inspection of the vehicle either at the crash scene or later. PEN is used to indicate if a portion of the safety feature entered the vehicle's passenger compartment. Penetration should only be indicated if the hardware or a portion of the hardware penetrated into the occupant space. Deformations of the door or other parts of the vehicle are not considered penetration of the occupant compartment. Data entry codes for PEN include:

YES: When a portion of the safety feature penetrated the occupant compartment of the impacting vehicle.
NO: When no portion of the safety feature penetrated the occupant compartment of the impacting vehicle.
UNK: When it is unknown if the safety feature penetrated the occupant compartment of the impacting vehicle. This field is typically used when the impacting vehicle has not been inspected by the data collector.

4.2.18 Initial Contact Point (ICP)

The ICP data element can be determined from the electronic crash database or crash report when such a field exists, from scene photos, or inspection of the crash scene. The initial contact point of the vehicle which interacted with the safety feature is recorded. The ICP may or may not be the interaction with the safety feature under evaluation. The possible data entries for ICP mirror the fifth edition of the MMUCC for initial contact point. [28] Data entry codes for ICP include:

1-12: When the initial contact point is as indicated in Figure 4.
13: When the initial contact point is the top (e.g., vehicle roof) of the vehicle.
14: When the initial contact point is the undercarriage of the vehicle.
15: When lost cargo is the initial contact point.
16: When the vehicle is not at scene.
99: When the initial contact point is unknown.

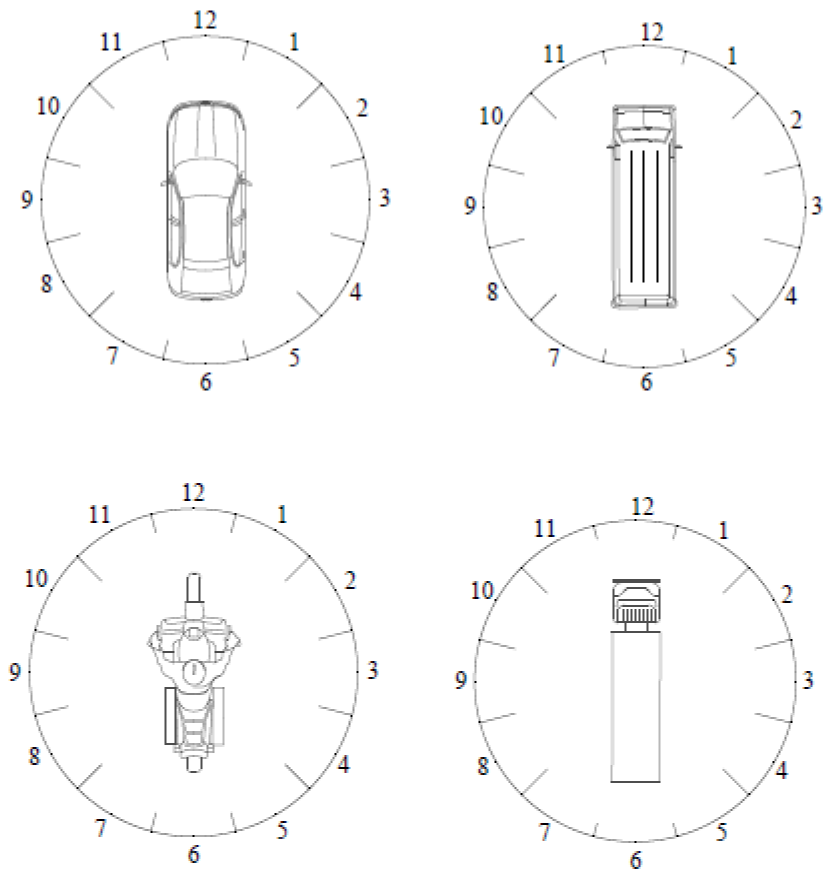


Figure 4. Initial Contact Point (ICP).

4.2.19 Sub Feature Name (NAME)

The NAME data element can be determined using roadway logs, inventory management systems, construction/maintenance records, through a review of scene photos, or by visiting the scene. While the general categorization of SFUE was discussed in Chapter 2 , the NAME field is used to define the specific characteristic or hardware type.

Each category of roadside safety feature usually includes a variety of specific designs that are tested using the same crash test procedures and evaluation criteria. For example, if the safety feature under evaluation were bridge railings, a typical transportation agency may have several bridge railings included in its standard drawings. The specific type of bridge railing involved in the crash is captured in this field. A second example is cable barrier. A jurisdiction may have several different manufactures of high-tension cable barrier on their QPL/APL. It may be desirable to consider each design within an overarching safety feature group when it is possible to identify the specific design. A third scenario is a jurisdiction may conduct an ISPE of longitudinal barriers which includes all longitudinal barriers installed in the jurisdiction (e.g., w-beam, cable, concrete, etc.)

Caution is required when populating this field to apply consistent identifiers for each system or device. As an example, the inputs: 1) 36-inch-tall combination bridge rail MASH TL-4 and 2) 36-inch-tall concrete/steel bridge rail MASH TL4 may indicate the same bridge rail. It is suggested that the value recorded is the same value used by the jurisdiction within their standard drawing and/or on their QPL/APL.

The variety of sub features within a safety feature group cannot be predicted since new designs are being developed continuously so they cannot be specified here. Documentation for each value of NAME should be developed and provided to the data collectors through training, as explained in Sections 3.3.6 and 3.3.7.

The Roadside Safety Hardware Identification Methods Report to Congress was recently conducted which outlines various methods of identifying roadside hardware for incorporation into ISPEs and asset management. [29] The methods reviewed in the research included 1D/2D barcodes, passive and active radio frequency identification (RFID), and serial numbers to be used to allow integration into an agencies ISPE or asset management programs. All the identification methods were deemed to have advantages and disadvantages in the field. A performance matrix of all safety feature identification methods was developed through the research. [29]

4.2.20 Safety Feature Offset (OFFSET)

The OFFSET data element can be determined from a crash site visit, roadway logs, or record plans. OFFSET is a dimensional measurement which records the distance from the edge of traveled way to the pre-impact location of the safety feature at the point where the impact with the safety feature occurred. This value is recorded in decimal feet.

This measurement should be taken from the center of the nearest solid edge line, as shown in Figure 5. When an edge line is not present, take the measurement from the edge of the pavement as illustrated in Figure 6.

When a truck- or trailer-mounted attenuators or variable message signs or arrow board trailers are placed in the roadway within a lane closure, the OFFSET should be measured from the temporary edge of travel which may be marked by cones, drums, or temporary pavement markings. The measurement is depicted in the schematic in Figure 7.

The value recorded in OFFSET should reflect the original placement of the safety feature prior to the crash, not the final location.

Figure 5. Offset measurement of longitudinal barrier, this offset is 6.9 feet (83 inches).

Figure 6. Offset measurement of sign support, this offset is 3.4 feet (41 inches).

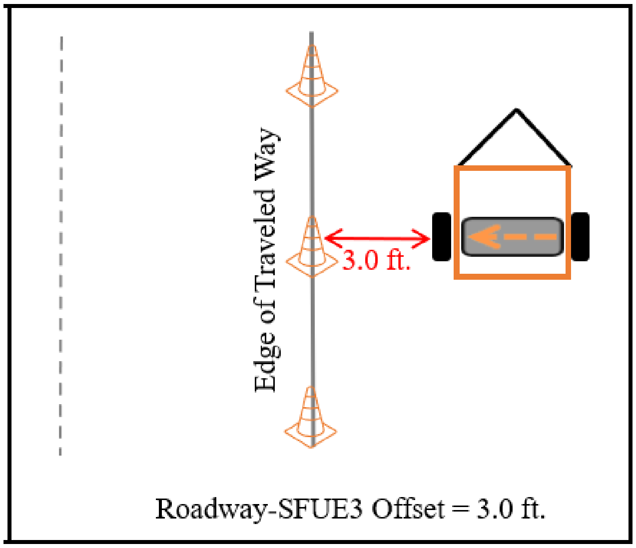


Figure 7. Offset measurement methodology for SFUE3 devices.

4.2.21 Safety Feature Height (HEIGHT)

The HEIGHT data element can be determined from a crash site visit or a hardware inventory. HEIGHT is a dimensional measurement which records the distance from the surface of the traveled way to the top edge of the safety feature at the point where the impact with the safety feature occurred. HEIGHT is limited to longitudinal barriers and terminals. This value is recorded in decimal inches.

This measurement is taken from the roadway surface to the top of the longitudinal element. The value recorded in HEIGHT reflects the original placement of the safety feature prior to the crash, not the final location.

4.2.22 Curbing (CURB)

The CURB data element mimics the data collected under element 53 of MIRE 2.0 and can be retrieved from this existing database if the jurisdiction collects the field. [30] MIRE 2.0 indicates when curb is on the left, right, or both sides of the roadway. This field can be completed by referencing the crash report data to query which edge the vehicle left the road and impacted the SFUE with whether curbing was present on that edge. This element can also be determined, for example, from visiting the crash site or reviewing roadway logs or record plans. This data field identifies locations where curb is installed in front of the impacted safety feature.

When a truck- or trailer-mounted attenuators or variable message signs or arrow board trailers are placed in the roadway, in a lane closure, the data fields for CURB should indicate NO. Conversely, when placed on the roadside behind a curb which is traversed prior to impacting the truck- or trailer-mounted attenuators or variable message signs or arrow board trailer, the CURB field is completed as shown below.

YES: When the impacting vehicle traversed a curb prior to impacting the SFUE.
NO: When the impacting vehicle did not traverse a curb prior to impacting the SFUE.
UNK: When it is unknown if curbing was traversed.

4.2.23 Curb Type (CTYPE)

The CTYPE data element mimics the data collected under element 54 of MIRE 2.0 and can be retrieved from this existing database if the jurisdiction collects the field. [30] When field CURB indicates YES, MIRE 2.0 element 54 can be used to complete this field. This field can also be determined, for example, from visiting the crash site or reviewing roadway logs or record plans. This data field identifies the type of curbing that was installed in front of the impacted safety feature. Possible data entry codes include:

1:	No curb
2:	Sloping curb - A curb that does not exceed a 4-inch height (for a slope steeper than 1V:1H) or a 6-inch height (for a slope equal to or flatter than 1V:1H).
3:	Vertical curb - A curb that is steeper or taller than the ranges given for a sloping curb.
UNK:	When the curb type is unknown.

When curb measurements are taken at the crash scene, the measurement is taken, as shown in Figure 8, at the location where the impacting vehicle traversed the curb.

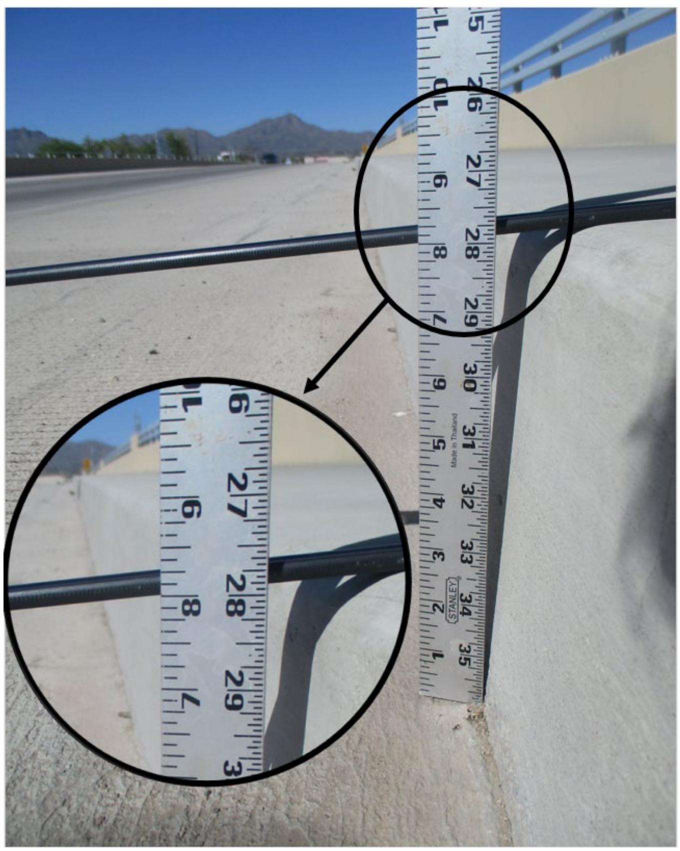


Figure 8. Measuring curb height; this curb has an 8-inch reveal.

4.2.24 Curb to Safety Feature Distance (CDIST)

The CDIST data element may be determined by visiting the crash scene, reviewing roadway logs or record plans and is a dimensional measurement which records the distance from the face of the curb to the nearest edge of the safety feature. This field is entered in decimal feet. When the impacted safety feature is flush with the curb, a value of 0 is entered. When curb is not present, a value of NA is entered. When this value is not known, the value UNK is recorded. Examples of this measurement are shown in Figure 9 and Figure 10.

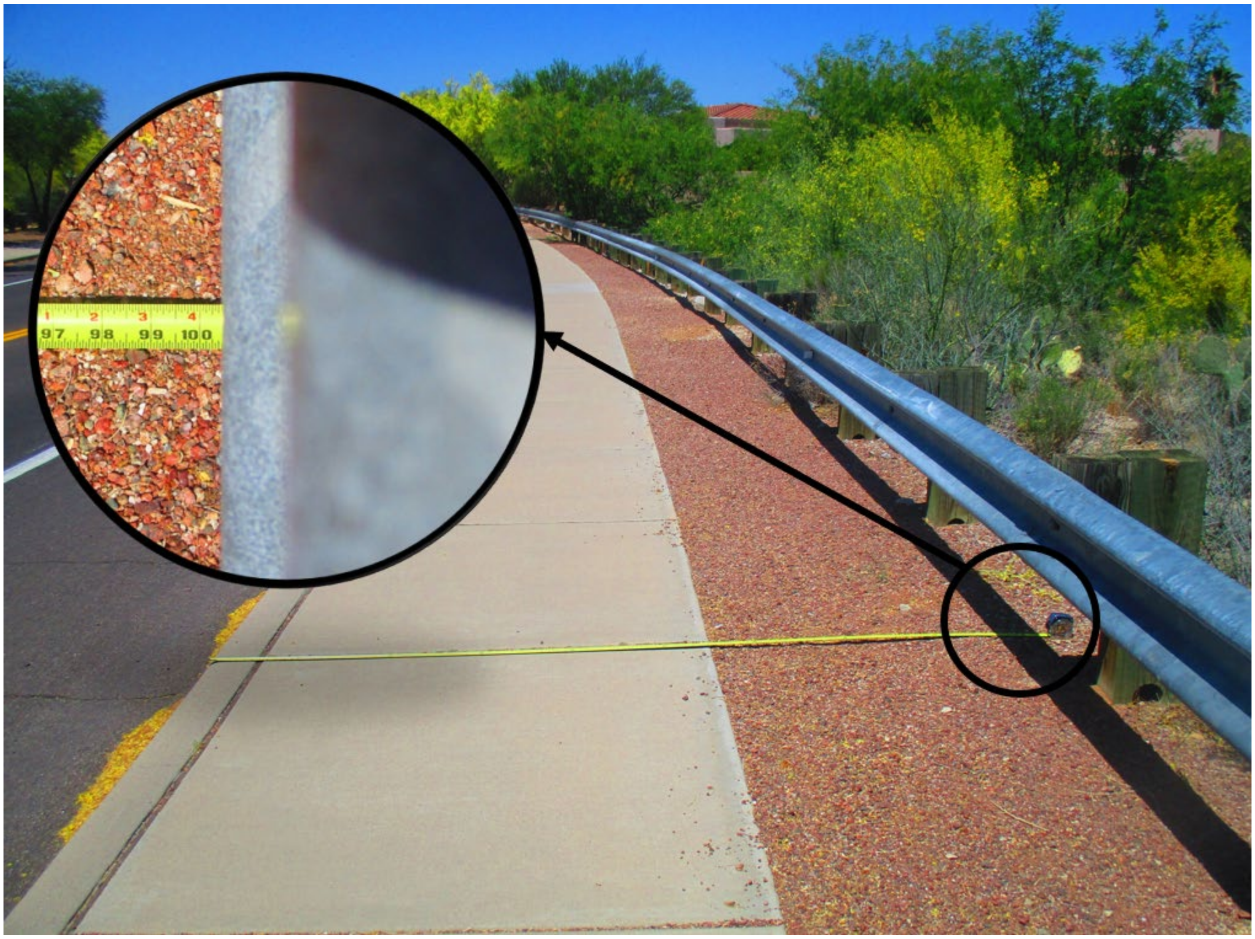


Figure 9. Measuring CDIST, this longitudinal barrier has a curb offset of 8.4 feet (101 inches).

Figure 10. Measuring CDIST, this sign support has a curb offset of 1.8 feet (22 inches).

4.2.25 Tapered Edge (EDGE_TAP)

The EDGE_TAP data element indicates if the pavement edge where the vehicle left the road is tapered from the edge of the paved roadway surface to the unpaved shoulder or not. This same element is collected under element 69 of MIRE 2.0 and can be retrieved from this existing database if the jurisdiction collects the field. [30] Alternatively, this element can be determined by visiting the crash site. Data entry codes for EDGE_TAP include:

YES:	When the impacting vehicle traversed a tapered edge prior to impacting the SFUE.
NO:	When the impacting vehicle did not traverse a tapered edge prior to impacting the SFUE.
UNK:	When it is unknown if a tapered edge was traversed.

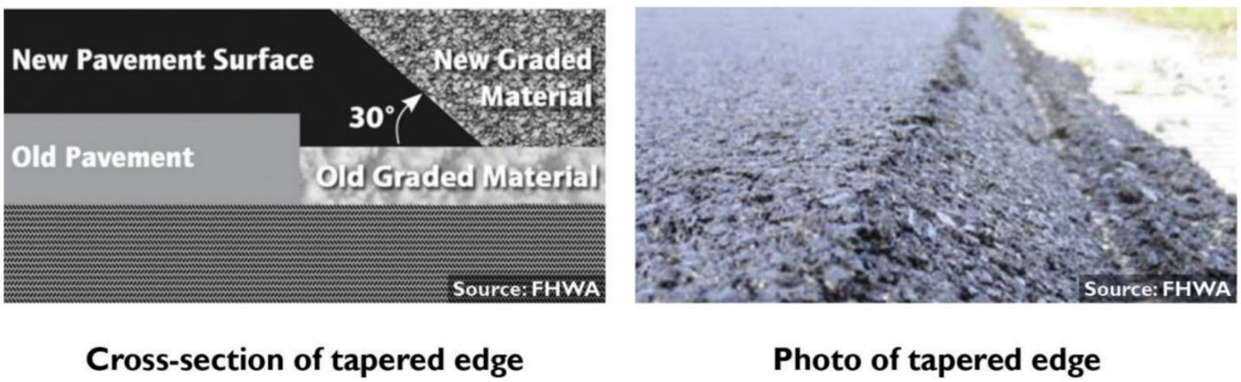


Figure 11. Tapered Edge Examples. [30]

4.2.26 Ground Condition (GRNDCOND)

The GRNDCOND data element indicates the condition of the ground, outside of the traveled way, in the vicinity of the point of impact with the safety feature at the time of the crash. A value for this field can be determined from reviewing the scene photos or a review of the crash scene. Data entry codes for this data field include:

FZN:	When the ground is likely frozen or has ice or snow on top.
WET:	When the ground is muddy, waterlogged, the soil is saturated, or if there is standing water.
SAND:	When the ground is dry and generally comprised of loose sand or other uncompacted borrow material.
NORM:	When the ground is dry and generally compacted (i.e., not frozen or wet and little loose material).
UNK:	When the ground condition is unknown.

4.2.27 Initial Contact Point with the Safety Feature Under Evaluation (IP_SFUE)

The IP_SFUE data element is obtained through inspection of crash scene or scene photographs. The point on the vehicle which interacted with the safety feature is recorded. The possible data entries for IP_SFUE mirror the values used for ICP. When the impact with the SFUE is the first harmful event, the value of IP_SFUE and ICP will be equal.

4.2.28 Impact Speed (ISPEED)
The ISPEED data element is not critical to the conduct of a routine or investigative ISPEs. ISPEED could be used during more detailed, well-funded ISPEs intended to update national guidelines such as MASH and the RDG. ISPEED is an estimation of the vehicle impact speed with the safety feature, entered in miles per hour. ISPEED could be calculated during law enforcement's activities to reconstruct a crash. Record a value of UNK when the impact speed is not known.

4.2.29 Velocity Angle (VANGLE)
The VANGLE data element is not critical to the conduct of routine or investigative ISPEs. VANGLE could be used during more detailed, well-funded ISPEs intended to update national guidelines such as MASH and the RDG. VANGLE is an estimation of the angle between the vehicle's velocity vector and the impacted safety feature recorded in decimal degrees. VANGLE could be calculated during law enforcement's activities to reconstruct a crash. Record a value of UNK when the velocity angle is not known.

4.2.30 Heading Angle (HANGLE)
The HANGLE data element is not critical to the conduct of routine or investigative ISPEs. HANGLE could be used during more detailed, well-funded ISPEs intended to update national guidelines such as MASH and the RDG. HANGLE is an estimation of the angle between the vehicle's centerline and the impacted safety feature recorded in decimal degrees. HANGLE could be calculated during the law enforcement's activities to reconstruct a crash. Record a value of UNK when the heading angle is not known.

4.2.31 Yaw (YAW)
The YAW data element is not critical to the conduct of routine or investigative ISPEs however could be used during more detailed, well-funded ISPEs intended to update national guidelines such as MASH and the RDG. The vehicle is said to be yawing when it is rotating about its vertical axis. This value is determined through a review of the crash scene or scene photographs. Possible data entry codes include:

YES:	When tire marks are present on the paved surface or in the earthen surface approaching the impact point of the safety feature and the total number of tire marks is greater than the impacting vehicle's number of axles.
NO:	When tire marks are present on the paved surface or in the earthen surface approaching the impact point of the safety feature and the total number of tire marks is equal to the impacting vehicle's number of axles.
UNK:	When tire marks are present on the paved surface or in the earthen surface approaching the impact point of the safety feature and the total number of tire marks is less than the impacting vehicle's number of axles or when it is not known if there were tire marks left at the crash scene.

4.2.32 Safety Feature ID (SFID)
The SFID data element is a unique identifier for a specific safety feature installed at a unique location. The value is initially assigned by the transportation agency installation, maintenance, inspection, or inventory team. The format of the value matches that used by the transportation agency.

4.2.33 Safety Feature Location (SFLOC_B & SFLOC_E)

The SFLOC_B and SFLOC_E data elements represent the geographic location of the safety feature, at its beginning and ending, respectively. This data is collected and recorded within these two fields. This element may be recorded using the jurisdiction's established LRS. The format of this field should agree with other choices made by the jurisdiction for referencing their assets and crash data. Each asset is assumed to have a beginning and ending point, measured along the roadway. For safety features such as signs, the difference between the beginning and ending points will obviously be small and impractical to measure. In these situations, the value in both fields will be equal. On the other hand, longitudinal barriers will have a greater distance between points.

For truck- or trailer-mounted attenuators or variable message signs or arrow board trailer the SF_LOC fields indicate where the safety feature was placed prior to impact.

The beginning point is differentiated from the ending point in the same manner used by the jurisdiction to record other assets. For example, if route/mile post are used, the beginning point may be the lower mile post. Other jurisdictions may consider the point located closer to the agency's headquarters as the beginning point. In any case, adopting the agency's means to locate other assets is necessary for this field to be appropriately used to integrate this asset within the existing assessment data and link to crash data.

4.2.34 Installation Inspected and Documented (INSTALL)

The INSTALL data element can be determined by reviewing the transportation agencies' record plans, inspection reports, or other available documents. This field indicates if the safety feature was inspected upon installation and that the installation of the safety features was confirmed to comply with the jurisdiction's standards. There may be instances when a design will deviate from the jurisdiction's standards due to site-specific constraints, which can be noted when recording the values for this field. Data entry codes for INSTALL include:

- YES: When the safety feature is inspected upon installation and the installation is verified to be in conformance with the jurisdiction's standards.
- YES_MOD: When the safety feature is inspected upon installation and the installation is verified to be consistent with the site-specific design. The site-specific design necessitated deviation from jurisdictional standards due to site constraints.
- NO: When the safety feature is not inspected upon installation and the initial installation cannot be verified.
- UNK: When it is unknown if the safety feature was inspected upon installation.

4.2.35 Maintenance Inspection (MAINT)

The MAINT data element can be determined through review of maintenance records, inspection reports, asset management records, or other available documents. This field indicates whether the safety feature has been inspected on a routine schedule to provide a reasonable degree of assurance that the need for maintaining the safety feature in crash ready condition is addressed. This field is not an indication that the safety feature was in crash ready condition prior to the crash, but an indication that routine inspections are performed to give confidence that it was more likely than not in crash ready condition. Data entry codes for MAINT include:

- YES: When the safety feature is inspected on a routine basis.

NO: When the safety feature is not inspected on a routine basis.
UNK: When it is unknown if the safety feature is inspected on a routine basis.

4.2.36 Installation Date (I_DATE)
The I_DATE data element indicates the date that the safety feature was initially installed. The installation date is recorded as a series of eight integers using the international format defined by ISO (ISO 8601) as follows: YYYYMMDD where:

- YYYY is the year.
- MM is the month.
- DD is the day.

If the date is not known, record the I_DATE as UNK

4.2.37 Installation Cost (I_COST)
The I_COST data element includes the material costs, installation costs, and traffic management costs associated with the installation of the safety feature. The I_COST data field can be determined using the construction or maintenance records, or other similar documentation. The cost is recorded in US dollars. When the cost is not known, the value of UNK is recorded.

4.2.38 Repair History (R_HIS)
The R_HIS data element records the date repairs are made to the safety feature. The repair date is recorded as a series of eight integers using the international format defined by ISO (ISO 8601) as follows: YYYYMMDD where:

- YYYY is the year.
- MM is the month.
- DD is the day.

If the date is not known, record R_HIS as UNK

4.2.39 Repair Type (R_TYPE)
The R_TYPE data element indicates the type of maintenance activity that was performed on the safety feature identified in R_HIS. Most jurisdictions have codes for maintenance activities which indicate the type of repair that was performed. These maintenance codes will typically have a standard unit of measure (e.g., per EA., per linear foot) and a basic description of the work. The full extent of the repair work performed can be retrieved by linking the SFID, R_HIS, and R_TYPE fields to a maintenance database or workorder forms.

If the jurisdiction does not have standard maintenance activities codes this field can be a free-form text field that may include a text description of the repair type and unit of measure, or a code which can be used with a reference sheet to determine the repair type.

4.2.40 Repair Cost (R_COST)
The R_COST data element is a cost history of repairs made to the safety feature identified in R_HIS. This data field is linked with the R_HIS and R_TYPE field, with all three fields being updated for each repair. R_COST includes all materials, labor, and traffic management costs. The repair cost is recorded in US dollars. When the cost is not known, the value of UNK is recorded.

4.3 Data Collection Techniques

There are two basic categories of data collection techniques: on-site and remote. On-site techniques are those where the data collector physically visits the roadside. On-site techniques include manual data collection, GPS data logger, robotic total station, and cellular applications. Remote techniques are those where the data is acquired using drive-by vehicles without physically visiting the feature. Remote techniques include mobile imaging and LIDAR.

4.3.1 On-Site Data Collection Methods

4.3.1.1 Manual

The most basic data collection technique is for a data collector to physically visit a site and make observations and measurements with simple hand tools and visual observations. Data collectors who physically visit a site should refer to Section 4.1 and use the appropriate safety procedures established by the transportation agency for other similar types of road work.

Measuring wheels, tape measures, and folding rulers enable a data collector to measure lengths of longitudinal features as well as individual features of the system.

Each measurement in a manual data collection effort takes roughly one minute to make. In such an effort, the range and number of measurements required per feature will vary widely in accordance with the scope of the data collection. For this reason, the data collector may need to be on site at each location from a few minutes to as much as an hour depending on the number of measurements required. Additional time considerations may be made for walking around at each site and the time required to navigate between sites. When manual data collection is undertaken, there may be additional time to transcribe the observations and measurements into some electronic database.

The equipment needed for manual data collection is inexpensive, widely available, and uncomplicated. All the measuring equipment and safety equipment is common and can be purchased at a local hardware store and can be used without the need for extensive training. The data collector will require a vehicle of some type to go from site to site. Since the financial investment for equipment and technology is low, the most substantial cost to an agency implementing this method will be the cost of labor for the extensive field time required for data collectors to visit each site and acquire the required data elements. Physical proximity, however, lends itself to up close, detailed, and investigative discovery of asset condition and relevant factors. The AASHTO-ARTBA-AGC Asset Management Data Collection Guide states that “the most common method used to collect the original [asset] inventory and update inventory attributes for each asset was a manual survey.” [15]

4.3.1.2 Data Collection Forms

Field data collection benefits from the creation of forms to support data collectors and ensure data elements are not overlooked. These forms may be paper, cellular applications, or PDF fillable forms.

The traditional printed form technique uses paper forms which are organized to structure the collection of the necessary data. These forms are filled out using a pen or pencil which restrict the input to written data and check boxes. A hardcopy form maintains its appearance and allows for organized representation of prompts to the data collector, enabling a level of consistency in the collected data. This method is versatile in its application and can be useful for documenting data elements from both inspection and inventory type surveys since it is simply a means for a person to record their observations of an asset or a feature. Hardcopy forms are easily created using standard word processing software and office equipment. Hardcopy forms have been widely used in past ISPE projects and examples are available in the literature including NCHRP Report 490 and the FHWA Pilot ISPE. [23, 31]

After the data elements that are necessary to perform an ISPE have been determined, data collection forms could be developed. An example form for on-site crash data collection has been developed and is included here in Appendix A of this manual. Each transportation agency performing an ISPE may develop its own forms to conform to the data sources and practices applicable in that agency.

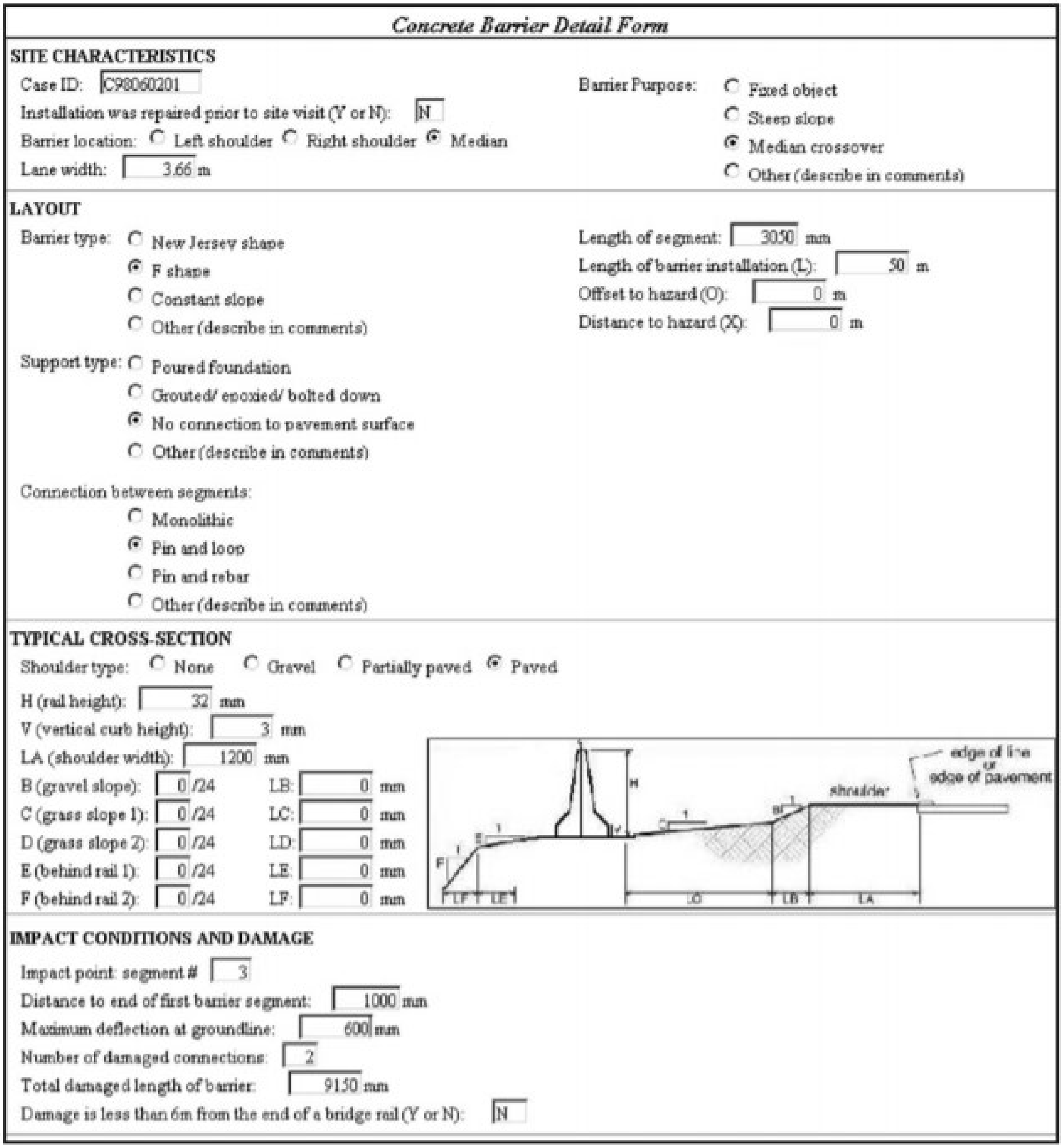
It is not necessary to collect data elements on the form that are already being collected elsewhere (e.g., law enforcement agency reports, maintenance report). For example, the law enforcement agency will collect the crash severity on the crash report. The data collection forms need not include a field for crash severity but could instead include a field for the law enforcement agency report number.

4.3.1.3 Fillable PDF Forms

Portable Document Format (PDF) is a type of electronic document which can be saved in such a way that its format cannot be altered but that can still be easily shared and filled out. PDF forms are popular since the document contents can be designed as neat, organized forms with categories and questions that can be distributed by email or webpage. The types of data that can be recorded with a fillable electronic PDF include typed text, dropdown list selections, check boxes and even photo attachments. This method is versatile in its application and can be useful for documenting data elements from both inspection and inventory type surveys since it is simply a means for a person to record their observations of an asset or a feature.

Fillable PDF forms are an incremental advantage over hardcopy forms. The form can be designed such that it is organized and structured, but the fillable feature makes it possible to fill the form out electronically using typed text on a computer or a handheld device such as a cell phone or a tablet. In a data collection effort, the form template can be used for each asset or feature and saved as an individual file as if they were separate printed copies. Alternatively, the form can contain a “submit” button which automatically submits the form over the internet to an email address or a server. The text in a fillable electronic form is typed making it easily extractable to a separate computer program for processing.

A PDF form can be converted into a mobile application or an internet webpage to improve its accessibility and functionality. Figure 12 shows one of the five web-based fillable forms presented in the NCHRP Report 490 procedures manual which uses push-button selections and short-response text boxes to structure and standardize data collection in the field. [31]



Concrete Barrier Detail Form

SITE CHARACTERISTICS

Case ID: C98060201

Installation was repaired prior to site visit (Y or N): N

Barrier location: ○ Left shoulder ○ Right shoulder ◉ Median

Lane width: 3.66 m

Barrier Purpose: ○ Fixed object ○ Steep slope ◉ Median crossover ○ Other (describe in comments)

LAYOUT

Barrier type: ○ New Jersey shape ◉ F shape ○ Constant slope ○ Other (describe in comments)

Length of segment: 3050 mm

Length of barrier installation (L): 50 m

Offset to hazard (O): 0 m

Distance to hazard (X): 0 m

Support type: ○ Poured foundation ○ Grouted/ epoxied/ bolted down ◉ No connection to pavement surface ○ Other (describe in comments)

Connection between segments: ○ Monolithic ◉ Pin and loop ○ Pin and rebar ○ Other (describe in comments)

TYPICAL CROSS-SECTION

Shoulder type: ○ None ○ Gravel ○ Partially paved ◉ Paved

H (rail height): 32 mm

V (vertical curb height): 3 mm

LA (shoulder width): 1200 mm

B (gravel slope):	0 /24	LB:	0	mm
C (grass slope 1):	0 /24	LC:	0	mm
D (grass slope 2):	0 /24	LD:	0	mm
E (behind rail 1):	0 /24	LE:	0	mm
F (behind rail 2):	0 /24	LF:	0	mm

IMPACT CONDITIONS AND DAMAGE

Impact point: segment # 3

Distance to end of first barrier segment: 1000 mm

Maximum deflection at groundline: 600 mm

Number of damaged connections: 2

Total damaged length of barrier: 9150 mm

Damage is less than 6m from the end of a bridge rail (Y or N): N

Figure 12. Example web-based fillable form for longitudinal concrete barriers. [31]

4.3.1.4 GPS Data Logger

A global positioning system (GPS) data logger is a handheld device that looks like a cellular phone or tablet. GPS data loggers acquire location information including latitude, longitude, and elevation. These units often have an integrated camera that can take geo-tagged photographs and they can be equipped with barcode scanners for recording barcode or QR code data as well. Some GPS data loggers allow for additional attributes to be collected such as feature descriptions or crew entered notes. All data that is collected is stored in the data logger for later download and use minimizing the need for manual data transcription.

After the unit has been initialized, the data collector can record location data while holding the device directly on or next to the object of interest. Subsequently, other attributes and data can be entered or captured and stored along with the location record. Initialization can take from 5 to 15 minutes but once it has been established, the unit will generally maintain triangulation even while in motion unless it loses contact with the satellites. Loss of contact can occur in downtown areas with tall buildings, in densely overgrown areas, or while in a deep ravine, where the line of sight is disrupted. In such locations, the GPS data logger would not be an effective data collection method.

The equipment required for data collection with this method is relatively inexpensive and uncomplicated. For example, a Trimble Yuma 2 which has all the features discussed in this section, costs about $2,500 new and can be operated without the need for extensive training. [32] This and similar units can be purchased from most survey supply stores and retailers. The data collector will require a vehicle to travel from site to site. Since the cost of equipment is moderate, the most substantial cost to an agency implementing this method will be the cost of labor needed for data collector to visit each site and acquire the requested data elements.

Once at a location, it takes about one minute to collect data on an object or feature. Data collection time is high for these methods due to the time it takes to travel between locations and the time spent collecting data at each location. Data collectors must walk directly up to each object or feature to be recorded, thereby exposing data collection personnel to traffic. The data collector safety procedures discussed in Section 4.1 should be observed.

4.3.1.5 Photography

This section has been adapted from the FHWA ISPE Practice-Ready Guide. [23] Photographs can be very useful during subsequent review of the crashes. Good photographs can help verify the identification of the SFUE and assist the subject matter expert in assessing the circumstances of the crash.

Digital photographs are both convenient and commonly available. Digital photographs can be taken with hand-held cameras, smart phones, or tablets. Regardless of the particulars of the camera device, strive for the highest-quality images possible. Typical images will be approximately 3 MB for smartphone cameras and 15 MB for hand-held digital cameras. An ISO setting of 100 is ideal but may only be achievable using handheld cameras. For this reason, ISO 50 is considered a minimum setting.

The resulting images can be transmitted by email, cellular short message service (SMS), multimedia messaging service (MMS) or a variety of file transfer programs (e.g., Dropbox or SharePoint). The images can be stored on a computer, universal serial bus (USB) flash drive, secure digital (SD) cards, or on a cloud service. Any of these technologies are acceptable for use in an ISPE. A discussion with transportation agency information technology (IT) department in the planning phase of the ISPE may be beneficial to identify the technologies which can be easily integrated with existing systems. Many transportation agencies have attachment size limits for emails or firewall protections for transferring files. These details need to be investigated before the start of data collection.

Depending on the policies of the transportation agency, photographs may need to have any personal identification material redacted from the photographs.

The data collector will take the photographs in the field while visiting the crash scene. Once the data collection activity is complete, the digital photographs are transmitted using the method recommended by the transportation agency IT department. The ISPE data assembly person stores the digital images in a folder for each specific case along with any other relevant case materials (e.g., forms, crash reports, administrative summaries).

When this data collection method is used, it is suggested that a schematic be developed to indicate to the data collector which photographs are desired, and in which order the photos will be taken. An example of a schematic diagram with the appropriate locations for taking the desired photographs is shown in Figure 13 while sample images are provided in the Figures 14 through 17. The diagram and photographs were developed for an ISPE of terminals. [23] Such a schematic could be accompanied by text which describes the desired photos, such as this example:

- Downstream (Recommended Photograph 1) – a view of the crash area looking in the direction that the impacting vehicle was traveling prior to striking the safety feature.
- Upstream (Recommended Photograph 2) – a view of the crash area looking in the opposite direction that the impacting vehicle was traveling prior to striking the safety feature.
- Traffic Side View (Recommended Photograph 3) – a view of the crash area taken from the road looking toward the damaged safety feature. In the case of safety features installed within a median, the traffic side view photograph is taken from the impacting vehicle's original direction of travel.
- Field Side View (Recommended Photograph 4) – a view of the crash area taken from the area behind the safety feature looking back toward the departure edge of the impacting vehicle. In the case of safety features placed in a median, the field side view is taken from the side of the safety feature opposite the impacting vehicle's original direction of travel.
- Vehicle at Final Rest (Optional Photographs) – a view of the final rest position of the impacting vehicle, including the impacted safety feature within the frame.
- Tire Marks (Optional Photographs) – when tire marks are present, photographs of the tire marks which show the tire marks in relation to the impacted safety feature are generally informative.
- Additional Photographs: For safety features that first responders must cut apart to facilitate response, cut points can be numbered and photographed by the data collector either before or after being cut into segments if the data collector is on site when these activities occur.

Additional photographs may be needed to fully document the final condition and position of the safety feature components. The data collector is encouraged to coordinate with the subject matter expert and take as many pictures as appropriate for the subject matter expert to make determinations of the crash events.

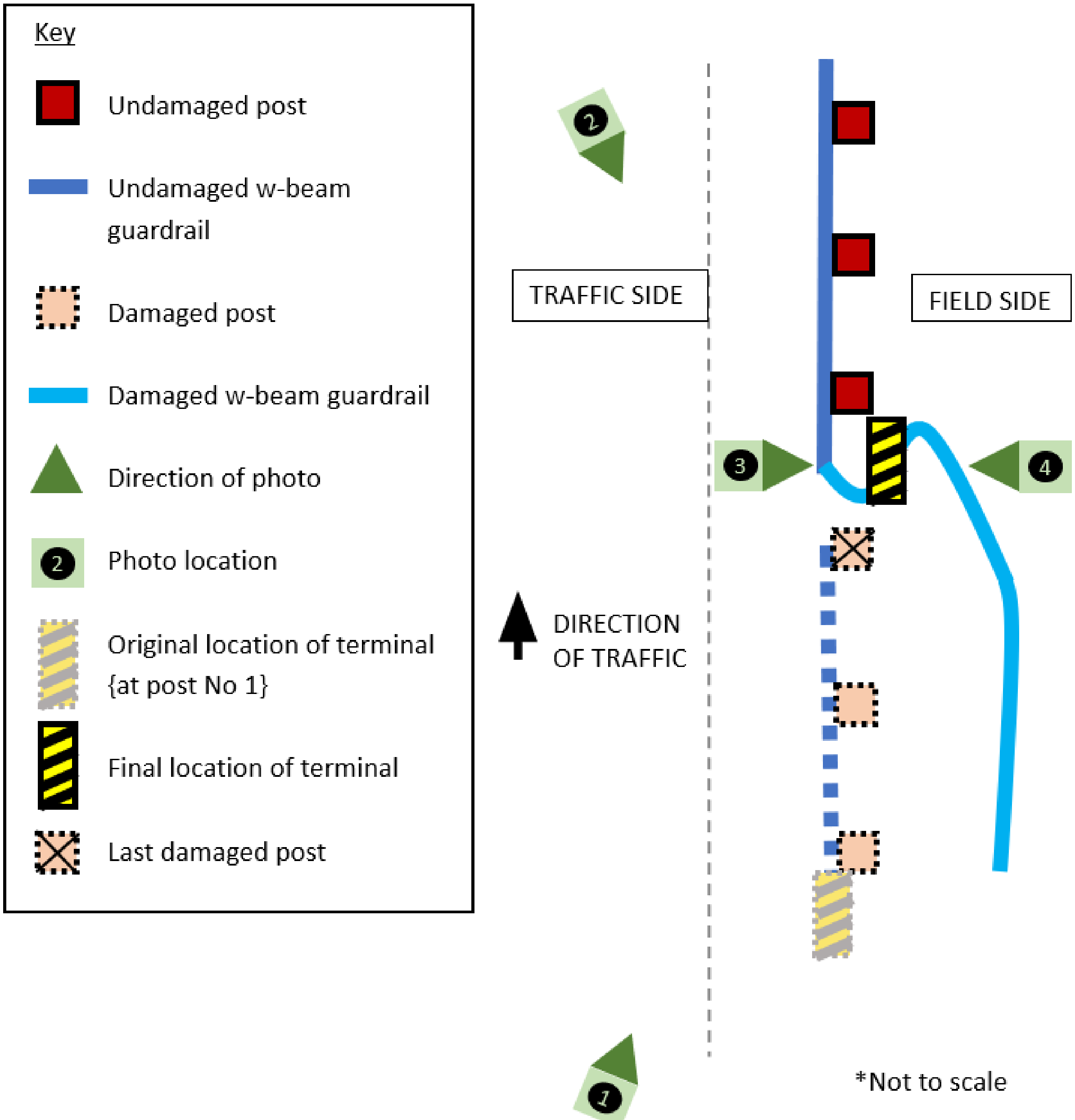


Figure 13. Schematic of recommended photographs 1-4 locations.

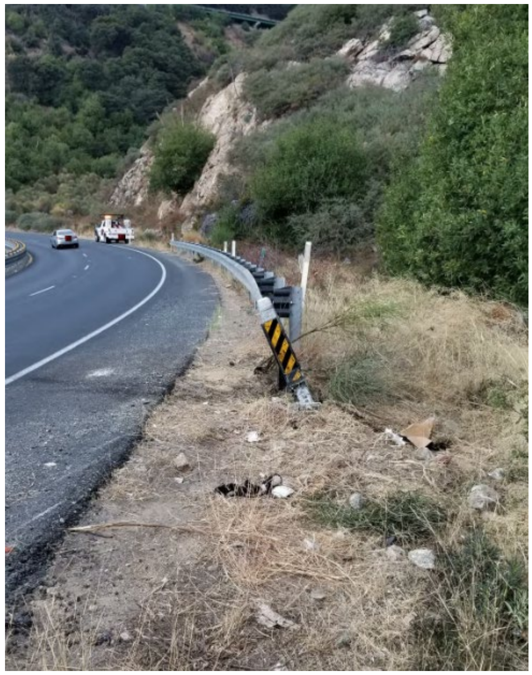


Figure 14. Example of Recommended Photograph 1 – Crash environment looking downstream (CA-SoftStop_3).

Figure 15. Example of Recommended Photograph 2 – Crash environment looking upstream (CA-XLT_20).

Figure 16. Example of Recommended Photograph 3 – Crash environment traffic side view (CA-ET4_21).

Figure 17. Example of Recommended Photograph 4 – Crash environment field side view (CA-FLEAT_9).

4.3.1.6 Cellular Applications

Cellular applications are computer programs that are accessible using a handheld mobile cellular device such as a cell phone or a tablet. They provide a tool which enables a field inspector to collect many different types of data, efficiently, consistently and in some cases, automatically. The efficiency of cellular applications is derived from their electronic nature which lends itself to ease of access and use. Cellular applications can be customized to fit a wide variety of data collection efforts including asset inventory and asset inspection. A site visit would make available a greater number of observations and measurements for a particular roadside feature whereas a drive by application would limit the number of observations.

The types of data collection tools that can be integrated into a cellular application include recording the date and time data of the observation, the GPS coordinates of the SFUE, requested photographs, and quick response (QR) code acquisition for reading feature QR data. Many of these data elements (e.g., date, time, and GPS location) can be automatically collected without any action by the user. Other data elements (e.g., QR codes, photos, etc.) can be captured using internal software already available on most cellular devices. Cellular applications often require the user to log in which makes it possible to automatically acquire the name of the data collector, associated agency, phone number, and the preferred means of transmitting the data. At a minimum, the data collection forms could be made available within a cellular application.

Backend features are those that are available through actions on a database and can be incorporated into mobile cellular applications on the front end, making it possible to provide data collectors with useful information about the assets while in the field, such as historical asset data, asset locations represented on a map, and priority ranked list of assets based on last reported condition or agency policy. Figure 18 shows asset locations represented on a map in a cellular application. [33]

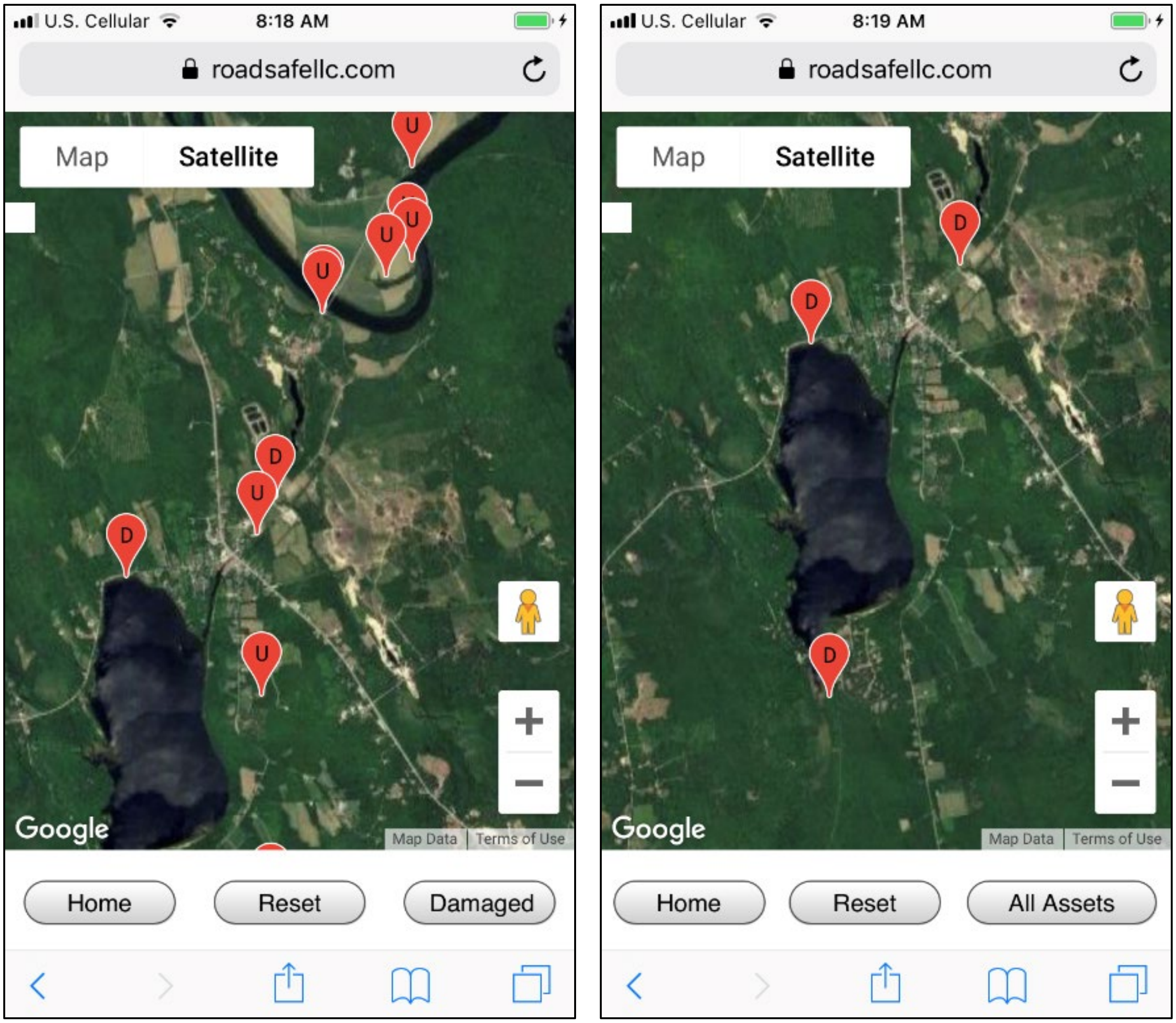


Figure 18. Showing the location of all assets (left) and damaged assets (right) in a cellular application. [33]

The time that it takes to use a mobile cellular application varies widely based on the number of data elements that are required in the data collection for each feature. In general, it takes less than 1 minute to acquire each data element but depending on the number of elements required, a data collector may spend from one minute to as many as 30 minutes at each location. Additional time is also necessary for walking around at the site and the time required to navigate between sites.

The task of building and programming a cellular application can be relatively expensive, from $30,000 for a basic application to $100,000 for an application with many features and advanced functions. However, the equipment used in collecting data with mobile applications is relatively inexpensive and usually already available to agency personnel (e.g., cell phones and tablets). Applications are designed to be straight forward to use without the need for extensive training and provide a structured means of collecting the data needed for the ISPE. Aside from the cost to develop the application, in most cases, the most substantial cost to an agency implementing this method will be the cost of labor required for data collectors to visit each site and acquire the required data. On-site cellular application data collection exposes the data collector to operational traffic since personnel must be present on the roadside. The data collector safety procedures discussed in Section 4.1 should be observed. This approach, while initially expensive to develop, will save transcription time and data transfer time on the backend.

4.3.1.7 Robotic Total Station

The robotic total station data collection method uses laser transmitted pulses of light to measure the distance to an object based on the time required for the light to travel from the instrument to the target and back. In addition to this distance measuring system, the total station instrument integrates an electronic theodolite which uses a moveable telescope to measure angles in both the horizontal and vertical planes. [34] A retro-prism mounted on a pole is placed directly next to or on the object being measured and the distance is measured to the prism.

With the robotic total station, the unit with the transmitter and theodolite is connected through radio links and can be positioned by remote control from the target location. The transmitter continuously and automatically tracks the prism target and transmits data to the operator. Data entry can be made with a touch screen or keyboard which is mounted on the target pole where the single operator can enter notes about the measurements and the data logger stores the measurements for later download and use.

This method can measure the distances and angles to any object within a range of approximately 1,000 feet. At each increment of this range, the robotic total station must be manually repositioned by the data collector which takes about 15 minutes. Otherwise, it takes about one minute for data to be collected for each data element. This technique collects data on very specific and intended objects only since the operator indicates when and where to take a measurement. The resulting data collection time is high, and the effort is physically demanding but the amount of data processing needed is minimal due to the electronic nature of the instrument.

The equipment required for collecting data with this method is relatively expensive and requires training to operate correctly. A robotic total station costs from $10,000 to $30,000 depending on the features of the specific model. These systems are relatively complex, and their operation does require specialized training. Even though the financial investment for equipment and technology is relatively high, the most substantial cost to an agency implementing this method remains the cost of labor for data collectors to visit each survey location and acquire the required data elements. Data collection with a robotic total station exposes the data collection crew to operational traffic so safety measures appropriate to the transportation agency for other, similar road work should be used.

4.3.2 Remote Data Collection Methods

4.3.2.1 Mobile Imaging

Mobile imaging, also called photo or video logging, is a data collection method which employs the use of photography or videography equipment mounted on a vehicle for collecting high quality images along a roadway that may include the roadside. Mobile imaging has been widely used over the past three decades by transportation agencies for monitoring pavement conditions. [35] These mobile units are equipped with GPS sensors and distance travelled devices so that location data such as latitude, longitude, and milepost can be automatically associated with each collected image.

Figure 19. The first imaging van used by Connecticut DOT (left) and the current imaging van used by Ohio DOT. [36, 37]

Mobile imaging reduces data collector exposure to live traffic since the data is collected from within a moving vehicle at near traffic speed. This type of system is reported to acquire one mile of data in about nine minutes. In this method, data reduction and feature extraction take the form of a manual review of acquired imagery by a technician at a later time in an office setting. [38] Photogrammetry is the process of obtaining information about objects and environment by analyzing photographic images. This can be partially automated through on-screen digitizing to recognize shapes such as lines, points, and polygons. A significant manual effort (e.g., 50 minutes per mile or 1 minute per object), however, is still required to extract data elements on the features of interest from the acquired images. [38]

Mobile imaging data can serve the needs of multiple units of a transportation agency since it consists of all the observable features of the roadway. ConnDOT, for example, used mobile imaging for assessing pavement conditions starting in the mid-1990s. [35, 39] Fitzpatrick used the ConnDOT mobile images from pavement condition surveys to periodically inventory tire scuff marks on concrete median barriers in a high-volume expressway to determine the frequency of collisions with concrete median barriers. [39] Using this method, Fitzpatrick was able to assess the concrete barriers in an area that would have been impossible to make a site visit without closing lanes and disrupting traffic. Alaska DOT&PF provides another example in their Transportation Asset Management Synthesis (TAMS) where they reported that "certain roadside features such as guardrails and barriers are often inventoried as a part of a photo logging process using pavement survey equipment. However, this process seldom provides the performance and condition data necessary for asset management." [40] In another instance, Michigan DOT concluded in its validation study of inventory methods that mobile imaging stood out as the most effective approach. It provided the broadest coverage of assets, minimized worker exposure, and provided a means to collect the data at a much faster rate than manual processes. [41]

The equipment required for collecting data with this method is very expensive and requires specialized training. For these reasons, data collection using this method is typically made by dedicated crews or contracted out to third party service providers who specialize in using this method. For example, Ohio uses a company for road and pavement data collection and asset inventories that provides an online portal for storing and making data available. An image of the interface is show in Figure 20.

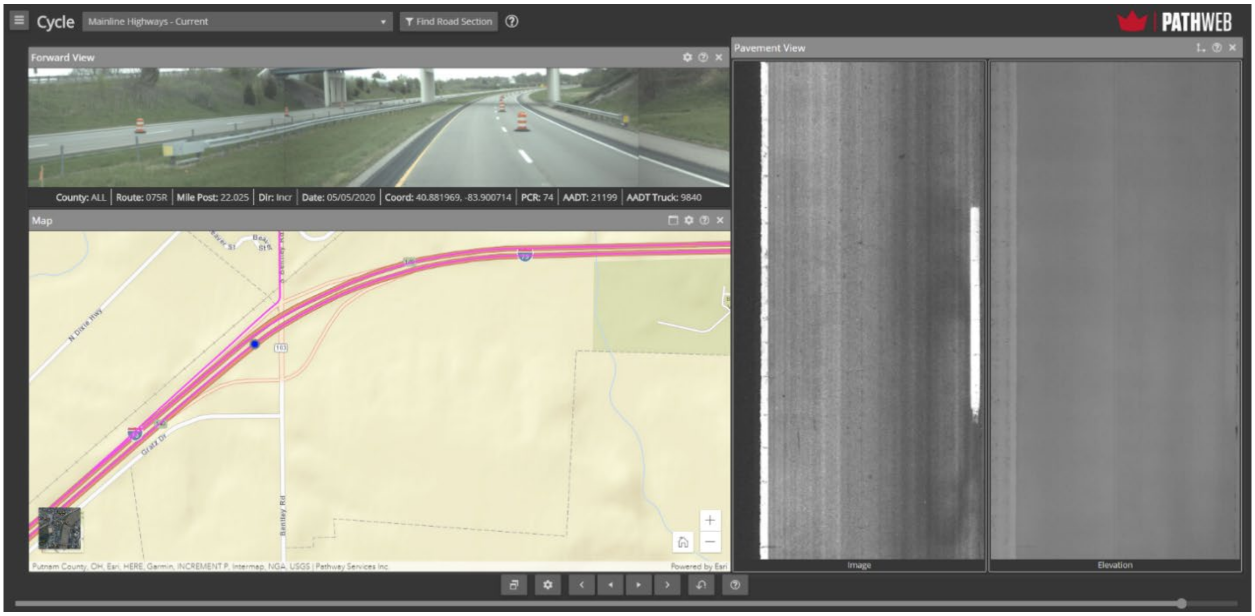


Figure 20. Ohio DOT Pathweb photolog portal.[42]

Mobile imaging data collection captures many images or continuous video along the data collection route. The location and identification of features can be extracted and documented at a later time by reviewing the captured images. Since this method scans all the roadway and roadside that is in view from the roadway, the end user can filter, and extract data based on the unique needs of the data collection task. As a result, multiple units within a transportation agency can use the same mobile imaging data for their own purposes. Images are acquired very quickly but extracting the inventory data is time consuming and usually involves a manual review. The roadside features which can be collected are limited to what can be seen visually from the roadway such as signs and barriers. Some features located on fill slopes may not be visible from the roadway and, therefore, would not be observable by the mobile imaging system and could not be inventoried using this method. Similarly, brush and tall grass can sometimes hide or obscure roadside features within the imagery.

Many transportation agencies periodically use mobile imaging to inventory assets and pavement conditions on their road network. In these cases, a virtual site history is available that shows visually how the roadside has changed through time. A historical review can sometimes indicate approximately when roadside hardware was installed, repaired, and/or replaced and how vegetation changes visibility and clear zone characteristics.

An extension of mobile imaging which is widely available and often free through the internet and cellular applications are services such as Google Earth and Google Maps. [43] Both of these software platforms provide access to Google Street View images which are much like transportation agency photologs. Street View images have the advantage that they are free, publicly available, and have no data collection cost. Disadvantages include a lack of control over the imaging period and quality. Images are collected by a mobile imaging van similar to what many transportation agencies use but the frequency of surveying usually depends on the importance of the routes such that rural, lower volume roads are seldom surveyed if at all.

4.3.2.2 LIDAR

Laser Imaging Detection and Ranging (LIDAR) is a technology that detects and locates objects using many laser-transmitted pulses of light which reflect off objects and return to the LIDAR receiver. The time it takes the laser light to return after transmission is the time of flight. This time of flight is multiplied by the speed of light and divided by two to calculate the distance or range to the objects being scanned. Using this method, many objects can be detected and the distance to those objects can be determined and mapped as a point cloud which can be used to create a three-dimensional (3D) representation of the scanned area.

LIDAR equipment can be handheld, tripod mounted, or mounted on a mobile unit such as a vehicle, airplane, or drone. Airborne LIDAR systems are commonly used to gather topographic data but are less useful for roadway and roadside asset data collection since it is difficult to identify small objects from such a great distance. [38] LIDAR systems mounted in specially equipped vans are used to collected data on highways as the vehicle proceeds along the highway with normal traffic.

Mobile LIDAR systems are mounted to a vehicle and driven along a highway corridor to create a 3D representation of the roadway, its surrounding terrain, and features on the roadside including roadside hardware assets. Mobile LIDAR produces survey grade data with accuracy that can only be matched by the robotic total station method, but with no risk of exposing data collection crew to traffic or the need for lane closures. [34] Mobile LIDAR vehicles are equipped with Global Navigation Satellite Systems (GNSS), GPS, and other sensors to capture accurate geospatial location references to the collected data. This type of system is reported to be able to collect one mile of data in about 30 minutes. [38] LIDAR can detect and measure slopes and terrain features. There are, however, limitations to the ability of mobile LIDAR to detect small objects such as signs and fences. Tall grass or heavy brush can also obscure some roadside features. [41] It is also difficult to make detailed assessments of roadside hardware installations.

The time that it takes to refine LIDAR data to isolate the data elements needed is called the data reduction time and can be significant. LIDAR data is reported to require a processing time of five hours per mile of data. [38] The significance of the data reduction effort is not only due to the time it takes to process the data but also to the inherently high cost of processing software as well as the need for highly specialized software operators. [38]

LIDAR is an effective data collection method for gathering large amounts of geospatial inventory data, especially when terrain and slope measurements are among the required data elements. Since this method scans all the roadway and roadside that is in view from the roadway, the end user can filter, and extract data based on their unique needs. As a result, multiple departments within a transportation agency can use the same LIDAR data for their own individual applications. The resolution of LIDAR data is generally insufficient for determining the condition of an installation or precisely measuring the presence or quality of individual parts. LIDAR is most useful for rapid collection of basic roadside inventory data but not for determining asset condition.

4.3.3 Comparing Data Collection Techniques

Manual data collection, cellular applications, and GPS data logging are the methods best suited to collect detailed scene information. Remote data collection techniques can be used to collect information which is independent of a crash occurring (e.g., OFFSET, HEIGHT, CURB, etc.) On-site techniques expose the data collectors to traffic and weather conditions. The disadvantage of data collector exposure is balanced by the increased detail available due to the data collector's physical proximity.

In terms of the time required for the acquisition of data using the various data collection techniques, remote techniques obtain the data faster since data is collected as the mobile unit drives past at near traffic speed. One mile of data can be collected in about 30 minutes using LIDAR and nine minutes for mobile imaging. On-site methods require extensive time in the field to facilitate being physically present at each feature for the time required to acquire the desired data. The GPS data logger is reported to collect 0.25 miles of data per hour. The robotic total station is reported to collect 0.10 miles of data per hour. Both the manual data collection techniques and cellular applications require about 1 minute per data element being collected and are likely comparable to GPS data logger and robotic total station.

In terms of precision and location accuracy, robotic total station and LIDAR are superior to all other methods due to the precision of the technology. The increased accuracy of LIDAR over mobile imaging has been found to not necessarily be cost beneficial. [41] Therefore, mobile imaging is preferred to collect large scale roadside inventory data. The precision of LIDAR and the robotic total station techniques are not always required and, therefore, is often employed only when high accuracy location information is needed. [34] The location accuracy of GPS data logging and cellular applications is usually sufficient for ISPE data collection.

Chapter 5. Data Management, Documentation, Extraction, and Linking

5.1 Data Management and Integrity

This section has been adapted from the FHWA ISPE Practice-Ready Guide. [23] Prior to the start of data collection, procedures for transmitting, organizing, and storing the data should be developed. Ultimately, a database of the collected data elements will be used for the data analysis. For this reason, an electronic database (e.g., Access database) is suggested. The source data gathered by the data collectors may be stored in multiple ways. For example, when hardcopies of forms, law enforcement crash reports or administrative summaries, etc. are collected, these hard copies may be scanned and added to the electronic database or may be stored in a traditional file organized by interaction with the safety feature. When data collection is limited to electronic sources (e.g., mobile device application, crash database, etc.), the collected data may only require storage in an electronic database.

It is effective to dedicate a single point of contact for data management so that data are not lost or mis-filed by being sent to the wrong person. The data collectors should know how to forward the collected data to the data manager. The collected data may, for example, be forwarded automatically (e.g., via mobile device application) or by email or hand delivered for each crash event.

Similarly, it is necessary for the data manager to establish an electronic folder and/or hardcopy file with a naming structure which can be referenced in the electronic database. One example would be to use the law enforcement crash report number as the file or folder name. Another method would be to use the crash date or the date and crash location. The data manager may find it helpful to maintain a check list or tracking form to ensure the information requested for each crash is obtained. This is especially helpful if information is coming from a variety of sources (e.g., data collector, law enforcement, loss recovery, maintenance).

Spreadsheet applications like Microsoft Excel can be used to store the extracted data elements electronically. Reference within the electronic file can be made to the storage of the backup information through the established folder/file naming convention.

Data completeness and integrity are important, so it is useful to have procedures that can check the accuracy and completeness of the data as they are received from the field. For example, a member of the team may use the photographs to ensure the hardware identifications made by the data collectors are correct.

In the case of a routine ISPE, there is no new data collection, but rather existing data sources are assembled. It is suggested that copies of the assembled data sources be maintained in a similar manner. For example, one may obtain an electronic database of five years of crash data from a jurisdiction. The database likely has three spreadsheet-style files for each year (i.e., crash event, units involved in each crash event, and persons within each vehicle). Five years of data, therefore, likely includes 15 individual files. Maintain a copy of the original, unaltered files prior to extracting the crash data into an ISPE dataset.

5.2 Data Extraction and Documentation Techniques

Once existing data has been assembled and new data has been collected, the information relevant to the ISPE must be extracted and documented such that it can be incorporated into an ISPE dataset. Extraction and documentation can be as simple as transcribing the observations recorded on a hard copy form into an electronic spreadsheet. When more automated cellular applications are used to collect the data, a structured and systematic method for data extraction, documentation, and submission to a central database can also be programed.

5.2.1 Cellular Applications

While paper forms are easily developed, reproduced, and distributed, data collection using mobile device applications (i.e., cell phone or tablet apps) or fillable Adobe PDF files have become routine in many agencies. Electronic data collection using mobile devices or interactive PDFs reduce database transcription or interpretation time and errors. Additionally, most mobile devices can easily collect photographs and GPS locations, thus making transmitting information not only faster and easier but more accurate and reliable.

Cellular applications are not only a data collection technique, but also an extraction and documentation technique. The types of data that can be documented using cellular applications include text and number input, date and time data, radio button selections, dropdown list selections, image files, and QR code data. Data elements that are not automatically acquired during the survey (e.g., date, time, GPS location, etc.) can be entered manually by the user based on their direct observations in the field.

Well-designed cellular applications use data validation to standardize observations and screen out incorrect or ambiguous data. Some of the ways that validation can be accomplished are to present a list or dropdown menu where only the acceptable responses are presented. Additionally, those acceptable responses which are presented to the user may be determined programmatically based on responses to earlier questions, only presenting the user with valid options or options that are applicable. Figure 21 shows the Guardrail Condition Assessment (GCA), developed by Plaxico *et al* and documented under NCHRP Web-Only Document 304: "Criteria for Restoration of Longitudinal Barriers" This cellular application dynamically provides the user with prompts based on the users responses. [44] Navigation logic and validation within the application can ensure that the user cannot move on until certain conditions are met. For example, all fields must be complete prior to submitting an entry to the database. Validation is a key part of application logic and works to improve the accuracy, consistency, and quality of the data.

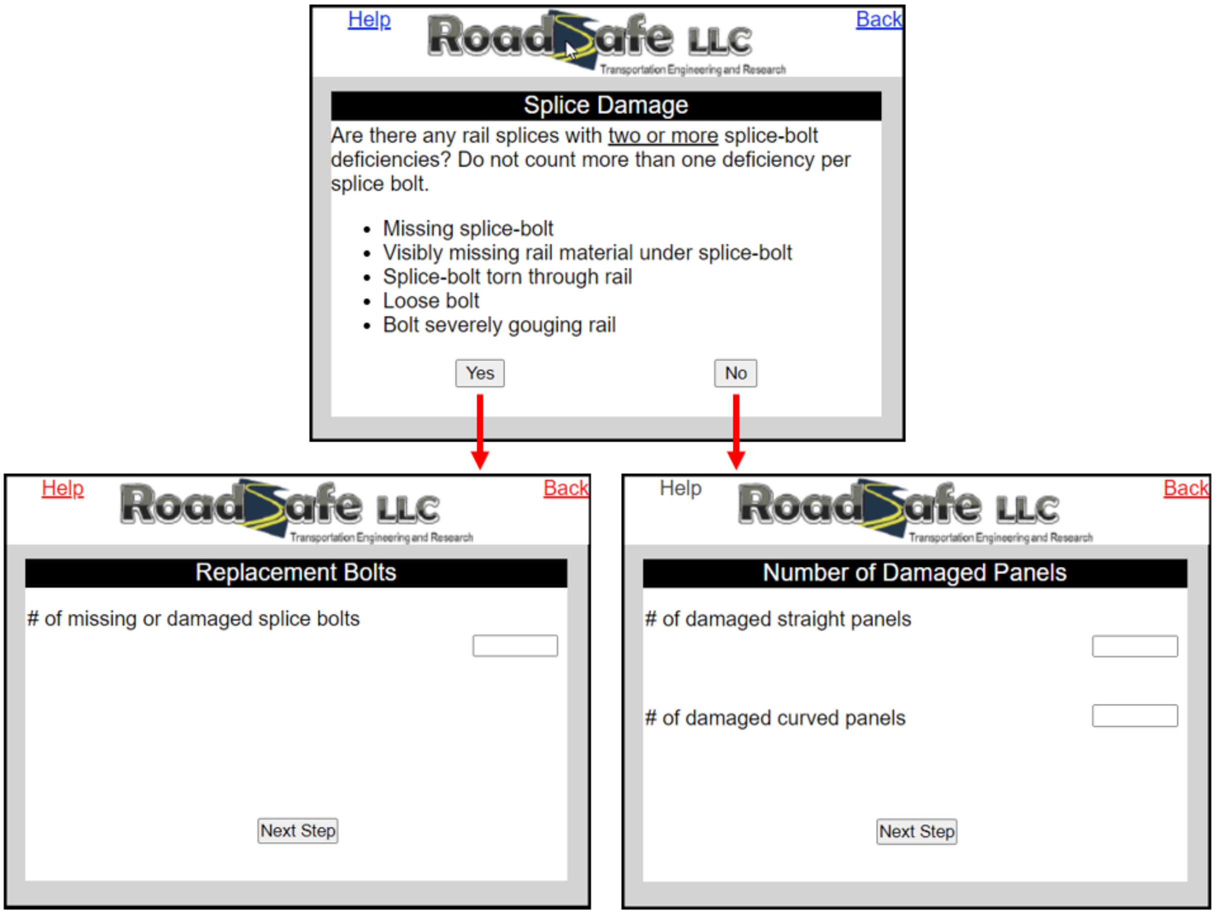


Figure 21. Dynamic selection of user prompts in the Guardrail Condition Assessment Application (GCA). [44]

Cellular applications can also provide open text fields for the data collector to describe the condition of an asset in their own words in cases where unusual conditions or situations occur. Well-designed cellular applications will focus on observable quantitative data rather than qualitative data thereby limiting interpretation errors during data processing.

When employing the use of cellular applications, data reduction, and processing are built into the application eliminating the need for data transcription labor. Furthermore, the data from a cellular application can be automatically deposited into a database such as Excel, Microsoft Access, MySQL, or MariaDB. Backend computer programs can be built to automatically perform archival, analytical, or organizational operations on the data in real time. Backend features are those which act on the content of the database without any action by the data collector. These features can include automatic analysis, reporting, email notifications and damage alerts.

Cellular applications are not necessarily dependent on cellular service. In such a case, extracted data is stored locally on the device and then uploaded to a database once a connection is restored.

Capturing the various data elements in a cellular application requires unique coding methods for each desired data type. The overall application logic will involve any combination of these methods along with validation to address the specific data elements desired. Cellular applications are most effective when they are uniquely programmed for the specific data collection task. A single cellular application could be developed with separate modules built specifically for the extraction of inspection data for a multitude of different hardware assets thus being one application that could provide tailored extraction sequences for many different asset types.

It is also possible for multiple cellular applications to be developed for differing purposes such as for different asset types, different agencies, or for the different data collection tasks. For example, one cellular app may be developed for asset inventory, one for inspection, and one for crash scene data collection. These applications could be programmed to communicate with one another or programmed to remain separate but deposit and read from the same database. It may be ideal to have all such functions in one cellular application or it may be preferable to design separate applications that can be deployed independent of one another and between multiple agencies or jurisdictions. Cellular applications are versatile and can facilitate effective documentation of inventory and in-service inspections of various types of features.

5.2.2 Comparing Extraction and Documentation Techniques

In comparison to cellular applications and fillable PDF forms, hardcopy forms are more easily and quickly developed and deployed since they only need to be typed and printed then distributed. However, hardcopy forms lack the ability to incorporate the use of typed data entries, dropdown selections, validation, and automatic submittal, making them more prone to errors. Furthermore, hardcopy forms are cumbersome compared to fillable forms and cellular applications due to organizational difficulties which are caused by weather, multiple data sources, and transport of the physical forms. Weather can hinder efforts to record data with a paper form since rain can ruin paper copies and wind can blow them away. Multiple data sources are difficult to manage because some method must exist to reliably correlate the paper form data to the data on cameras and GPS devices, leaving room for confusion, omissions, and errors. Transporting paper forms from the field to the office introduces an increased chance that forms may get lost or damaged. Similarly, translating written text from the printed form to typed entries in a database introduces the possibility for interpretation errors. In addition, transcription labor will be required to enter the data from the form into the ISPE database.

There is a hierarchy of structure and control when comparing these documentation methods. In a hardcopy form, fields are not structured beyond providing all possible fields that may be requested. Furthermore, there is little control over the user's input which can result in inconsistencies in data especially when multiple data collectors are using the form independently. Fillable PDFs provide additional structure to the process since some fields can be validated using drop-down menus, which provides the user with a list of choices that are acceptable, increasing the likelihood of consistency between collected forms. Cellular applications provide additional structure to the process by prompting the user for input based on data from previous entries. This introduces the highest level of efficiency since the user will only be prompted for relevant data and will be given relevant choices for selection instead of free-form input.

Cellular applications are in some ways similar to fillable PDF forms, but the useability and functionality of the cellular application is superior although this comes at the relatively high up-front cost to build and program the application. Cellular applications are installed on the data collector's phone and if updates are made, they are automatically incorporated into the installed version of the application. In contrast, PDF forms must be downloaded from an email attachment or web page any time there is an update to the form.

A comparison of the advantages and disadvantages of the extraction and documentation techniques is provided in Table 2.

Table 2. Comparison of Data Extraction and Documentation Techniques.

Method	Data entry	Advantages	Disadvantages
Hardcopy forms	• Printed text • Check boxes	• Quick to build and deploy.	• Weather can ruin paper. • Potential for loss or damage in transport. • Potential for interpretation errors.
Fillable PDF forms	• Typed text • Dropdowns • Photo attachments	• Quick to build and deploy. • Can be used on mobile devices or internet.	• User interface difficulties (e.g., panning, zooming, scrolling often required.) • Updates not automatically received.
Cellular applications	• Typed text • Dropdowns • Photographs • Video • QR data • RFID data	• Used on mobile device. • Form fits on screen. • Automatic updates. • Automated submission to database.	• Cost to develop app.

5.3 LINKING DATA SOURCES AND SURVEYS

There is no single best approach to extracting and linking the data required to perform an ISPE. Each jurisdiction should develop an approach that best fits with their needs through consideration of the agency's current technology environment and staff resources. Advanced analytical capabilities are not needed for the conduct of ISPEs, however, integration across databases will increase the data available and decrease the need to duplicate data collection.

The foundation for data integration is a linear referencing system. A linear referencing system refers "to a method of spatial referencing of the locations of physical features along a linear element. [The] features are described in terms of measurements from a fixed point, such as a mile marker or station along a road. … A well governed [linear referencing system] helps ensure that the spatial relationships between assets held in different databases can be viewed and analyzed." [45] NCHRP Report 08-115 also explains "asset identification and linear referencing schemes are vital to agency database integration. It is beneficial to structure new and existing [asset management] databases to provide these standardized data linkages. This practice will enable integration of asset and non-asset data for analysis and decision-making." [45] The SFLOC_B, SFLOC_E, SFID, and CRASH_LOC data elements are suggested to facilitate the linking of the safety feature information in an asset management plan with the crash data.

Given that SFLOC_B and SFLOC_E are collected in the asset management database, establishing data linkages "typically requires programming; however, more and more commercial software tools are providing end-user utilities to help automate development, decreasing reliance on staff with specialized skillsets." [45].

When GPS is used, steps can be taken to facilitate the linkage of crash data. To link a GPS crash location with a safety feature it is sometimes helpful to assume the crash location as a radius or poly line with the discreet crash location as the center. Then if the radius or poly line overlap with the safety feature's GPS location it can be assumed the crash interacted with the safety feature, especially if the sequence of events contained a safety feature interaction field. In the case of distinct safety features such as terminals, crash cushions, and support structures the CRASH_LOC will likely be very close to SFLOC_B and SFLOC_E so the radius or poly line can be somewhat small. In the case of longitudinal barriers there is a possibility that the CRASH_LOC will be mid-span (i.e., on a long run between SFLOC_B and SFLOC_E); this approach coupled with consideration of the road where the crash occurred and the safety feature is installed would be most effective.

The data element CRN is collected to facilitate linking of the crashes listed in the ISPE dataset with the electronic crash database, crash reports, crash photos, and/or insurance recovery databases. For individual ISPEs, this simple approach is most effective.

Different users and stakeholders may store existing, valuable ISPE data in a variety of ways. Data transformation is the process of converting data from one format to another. [45] Data transformation is often required to support the integration of this existing data. Batch processing facilitates the data transformation task. In any event, the steps taken to link, transform, convert, and/or reduce should be documented such that the process can be repeated by others and reviewed when coordination between different jurisdictions is desirable.

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Appendix A On-Site Data Collection Forms

The example form discussed herein may be adapted to the appropriate media, such as paper, cellular applications, PDF fillable forms, etc. The advantages and disadvantages of the media used are discussed in Section 4.3

These forms are specific to on-site data collection of crashes with safety features. Most of the data recorded on these forms are not available from other sources and are based on the data collectors' direct observations and/or measurements at the crash scene. The sample forms in Table A-1 identify key crash details that are typically relevant to an ISPE, but specific forms may vary in accordance with each agency's circumstances. Note that the crash report number and date are requested on each subsequent page to permit later compilation of the data should the individual sheets be separated.

In the cases where one or many of the data fields in the example shown already exist in the agency's crash report form or database, it is not necessary to collect the data in the field, rather the agency collected data can be relied upon.

The forms in Table A-1 are comprised of three sections, including (1) Crash Date and Location, (2) Crash Information, and (3) Site Characteristics. When these forms are used at the scene of a motor vehicle crash, the fields can generally be determined by the data collector, while in the field, in cooperation with on-scene law enforcement. The crash report number that is contained on the form should match the law enforcement recorded crash number. In instances where the crash is unreported, check the box in the upper left corner and any unknown data fields in the remainder of the data collection form will be left blank.

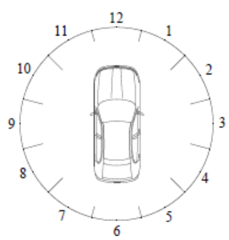
Further details regarding the appropriate data entry codes, inputs, and description of data fields can be found in Section 4.2.

Table A-1. Example on-site crash data collection form.

<table>
<tr><th colspan="4">On-Site Crash Data Collection Form</th></tr>
<tr><th colspan="4">Crash Date and Location</th></tr>
<tr><td>☐ Check here if the crash is unreported</td><td colspan="2"><u>Crash Date</u></td><td><u>Crash Report Number</u></td></tr>
<tr><td colspan="2"><u>Traffic Route</u> or <u>Latitude</u></td><td colspan="2"><u>Mile Marker</u> or <u>Longitude</u></td></tr>
<tr><td colspan="3"><u>What Harmful Event Directly Followed SFUE Crash?</u>
☐NONE - No Secondary Harmful Event
☐RFS - Rolled Over Field Side
☐RSS - Rolled Over Traffic Side
☐ROLL - Rolled Over, Side Unknown
☐TER - Interacted with Roadside Terrain Feature
☐VEH - Crash with Motor Vehicle in Transport
☐PED - Crash with Non-Motorized Vehicle
☐FO - Crash with Fixed Object
☐BA - Crash with Same or Another Breakaway Object
☐BAR - Crash with Same or Another Longitudinal Barrier
☐TCC - Crash with Same or Another Terminal or Crash Cushion
☐OTR - Other Harmful Event Not Listed
☐UNK - Unknown Harmful Event</td><td><u>Was the SFUE Crash:</u>

<u>The First Harmful Event</u>
☐YES ☐NO ☐UNK

<u>Any Harmful Event</u>
☐YES ☐NO ☐UNK

<u>The First and Only Harmful Event</u>
☐YES ☐NO ☐UNK</td></tr>
<tr><td colspan="3"><u>What was the Initial Contact Point with the SFUE?</u>


☐13 - Vehicle Roof
☐14 - Undercarriage
☐15 - Cargo Loss
☐16 - Vehicle Not at Scene
☐99 - Unknown</td><td><u>Did SFUE Penetrate Occupant Compartment?</u>

☐YES ☐NO ☐UNK</td></tr>
<tr><th colspan="4">Crash Information [include the appropriate box for the SFUE]</th></tr>
<tr><td>SFUE 1</td><td colspan="3"><u>Did Vehicle Breach the SFUE1?</u>
☐YES - Yes but Unknown
☐UNK - Unknown Breach
☐BUNK – Breach, unknown how
☐CNTD - Barrier not Breached
☐RFS - Roll Over
☐VLT - Vault
☐STR - Structurally Fail
☐UND - Underride</td></tr>
<tr><td>SFUE 2 or 3</td><td colspan="3"><u>What Happened when the Vehicle Impacted the SFUE2/3?</u>
☐ REDR - Redirected
☐ CPEN - Controlled Penetration of the TCC
☐ CNTL - Controlled Stop
☐ NONE - No Redirection or Controlled Pen/Stop
☐ UNK – Unknown</td></tr>
<tr><td>SFUE 4</td><td colspan="3"><u>What Happened when the Vehicle Impacted the SFUE4?</u>
☐BREAK - Device did Breakaway or Yielded
☐NOBREAK - Device did not Breakaway or Yield
☐UNK – Unknown</td></tr>
</table>

Table A-1 (Continued). Example on-site crash data collection form.

<table>
<tr><th colspan="3">On-Site Crash Data Collection Form</th></tr>
<tr><th colspan="3">Crash Date and Location</th></tr>
<tr><td>☐ Check here if the crash is unreported</td><td>Crash Date</td><td>Crash Report Number</td></tr>
<tr><th colspan="3">Site Characteristics</th></tr>
</table>

<table>
<tr><td>NAME</td><td>SFID</td></tr>
<tr><td>Roadway-SFUE Offset (ft.)

☐UNK - Unknown</td><td>Tapered Edge

☐YES
☐NO
☐UNK - Unknown</td></tr>
</table>

<table>
<tr><td>Roadway Condition
☐DRY -Surface is Dry
☐ICE - Surface is Icy or Frosty
☐MUD - Surface is Muddy
☐DIRT - Surface is Dirt
☐GRAV - Surface is Gravel
☐OIL - Surface is Oil Covered
☐SAND - Loose Sand on Roadway Surface
☐SLUSH - Surface is Slushy
☐SNOW - Surface is Covered in Snow
☐WATER - Surface is has Standing or Moving Water
☐WET - Surface is Wet
☐OTR - Other Condition not Covered Above
☐UNK - Unknown</td><td>Curb Present

☐YES
☐NO
☐UNK - Unknown

Curb Type

☐1 - No Curb
☐2 - Sloping Curb (> 4” height for > 1:1 or 6” for ≤ 1:1)
☐3 - Vertical Curb
☐UNK - Unknown</td></tr>
<tr><td>Ground Condition
☐FZN - Frozen Ground
☐SAND - Loose Sand/Uncompacted Borrow
☐WET - Muddy, Waterlogged, Saturated, etc.
☐NORM - Dry/Normal Conditions
☐UNK - Unknown</td><td>Curb-SFUE Offset (in.)

☐UNK - Unknown</td></tr>
</table>