Source: FHWA

Development of Safety and Traffic Data Collection System and Analysis Framework for Federal Lands

FINAL REPORT – DECEMBER 2022

U.S. Department of Transportation
Federal Highway Administration

FOREWARD

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Technical Report Documentation Page

1. Report No. FHWA-FLH-23-006	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Development of Safety and Traffic Data Collection System and Analysis Framework for Federal Lands: Final Report		5. Report Date December 2022
		6. Performing Organization Code
7. Author(s) Ian Hamilton, Tal Cohen, Michael Amoabeng, Michael Spear, and Catherine Chestnutt		8. Performing Organization Report No.
9. Performing Organization Name and Address Vanasse Hangen Brustlin 940 Main Campus Drive Suite 500 Raleigh, NC 27606		10. Work Unit No.
		11. Contract or Grant No. DTFH6116D00040L
12. Sponsoring Agency Name and Address Federal Highway Administration Office of Safety Research and Development 6300 Georgetown Pike, HRDS-20 McLean, VA 22101		13. Type of Report and Period Safety Evaluation (August 2020 – December 2022)
		14. Sponsoring Agency Code: FHWA

15. Supplementary Notes.
This report is a research product of the Federal Lands Highway's Innovation and Research Program. It was produced under the direction of Amit Armstrong and Matthew Hinshaw of the Western Federal Lands Highway Division, as well as technical contributions from a multi-agency technical advisory committee.

16. Abstract
The use of Geographic Information Systems (GIS) to assist with the development of planning documents is well known and practiced. This research effort investigated the use of GIS for safety and traffic assessments, current and best practices, for use in the Federal lands and rural areas. This research report documents the research process, findings, and recommended methods for use in primarily rural and limited data contexts. This consists of a preliminary literature review, data development framework, example case studies illustrating the framework in practice, and series of implementation steps that can help Federal Lands Highway (FLH) deploy the framework and improve safety data on Federally managed roads. The Appendix contains data schemas to help FLH obtain relevant safety data through custom data collection applications, field and desktop reviews, or other data collection initiatives.

17. Key Words: Safety, Federal, Lands, Systemic, Data, Framework	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages: 239	22. Price

Form DOT F 1700.7 (8-72) **Reproduction of form and completed page is authorized**

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

Table of Contents

List of Tables

List of Figures

List of Acronyms

Acronym	Description
AASHTO	American Association of State Highway and Transportation Officials
AADT	annual average daily traffic
AEGIST	Applications of Enterprise GIS for Transportation
AGOL	ArcGIS Online
BCR	benefit-cost ratio
BIL	Bipartisan Infrastructure Law
BLM	Bureau of Land Management
BOR	Bureau of Reclamation
CFLHD	Central Federal Lands Highway Division
CVTS	Collaborative Visitor Transportation Survey
CEFMS	Corps of Engineers Financial Management System
DCV	Data Collection Vehicle
DDSA	data-driven safety analysis
DOD	Department of Defense
DOI	Department of Interior
DMI	Distance Measuring Instrument
EFLHD	Eastern Federal Lands Highway Division
ETIC	Electronic Technical Information Center
EDW	Enterprise Data Warehouse
EDC	Every Day Counts
FAMS	Facility Asset Management System
FMSS	Facility Management Software System
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FLMA	Federal Land Management Agency
FLAP	Federal Lands Access Program
FLH	Federal Lands Highway
FLPP	Federal Lands Planning Program
FLTP	Federal Lands Transportation Program
FoRRRwD	Focus on Reducing Rural Roadway Departures
FRSP	Forest Road Safety Plan
FDE	Fundamental Data Elements
GTFS	General Transit Feed Specification
GIS	geographic information systems
GPS	Global positioning systems
GTFL	ground transportation linear feature

GIP	Guardrail Inventory Program
HPMA	Highway Pavement Management Application
HPMS	Highway Performance Monitoring System
HSIP	Highway Safety Improvement Program
HSM	Highway Safety Manual
IMARS	Incident Management Analysis and Reporting System
IPAC	Information in Planning and Consultation
IT	information technology
IIJA	Infrastructure Investment and Jobs Act
IRC	Innovation and Research Council
IRMA	Integrated Resource Management Application
IHSDM	Interactive Highway Safety Design Model
iRAP	international Road Assessment Program
ICE	intersection control evaluation
LOSS	Level of Service of Safety
LiDAR	Light Detection and Ranging
LRS	linear referencing system
LRSP	local road safety plan
LTAP	Local Technical Assistance Program
LBS	Location based services
MOU	memoranda of understanding
MPO	metropolitan planning organization
MIRE	Model Inventory of Roadway Elements
NAIP	National Agriculture Imagery Program
NCHRP	National Cooperative Highway Research Program
NPS	National Park Service
NRRS	National Recreation Reservation Service
NRM	National Resource Manager
NRSS	National Roadway Safety Strategy
NTAD	National Transportation Atlas Database
NVUM	National Visitor Use Monitoring
NWRS	National Wildlife Refuge System
NOFO	Notice of Funding Opportunity
OMB	Office of Management and Budget
PFS	Pooled Fund Study
PS&E	plans, specifications, and estimate
PSA	Project Site Area
PSCi	Proven Safety Countermeasures initiative
RISE	Reclamation Information Sharing Environment
RMIS	Recreation Management Information System
RITIS	Regional Integrated Transportation Information System

ROI	return on investment
RSA	Road safety audit
ROaDS	Roadkill Observation and Data System
RIP	Roadway Inventory Program
SRIP	Safer Roads Investment Plan
SMS	safety management system
SPF	safety performance function
SJNF	San Juan National Forest
STEAP	Screening Tool for Equity Analysis of Projects
SHSP	Strategic Highway Safety Plan
SMEs	subject matter experts
TAC	technical advisory committee
TOPS	Traffic Operations and Safety
TRB	Transportation Research Board
TTPSF	Tribal Transportation Program Safety Funds
usRAP	U.S. Road Assessment Program
USACE	United States Army Corps of Engineers
USDOT	United States Department of Transportation
USFWS	United States Fish and Wildlife Service
USFS	United States Forest Service
UTM	Universal Transverse Mercator
VA	Value Analysis
VERS	Visitation Estimation & Reporting System
WIP	Wall Inventory Program
WAPDD	Western Arkansas Planning and Development District
WFLHD	Western Federal Lands Highway Division
WTI	Western Transportation Institute

1

Introduction

The use of Geographic Information Systems (GIS) to assist with the development of planning documents is well known and practiced. This research effort investigated the use of GIS for safety and traffic assessments, current and best practices, for use in the Federal lands and rural areas. This research report documents the research process, findings, and recommended methods for use in primarily rural and limited data contexts. Western Federal Lands Highway Division (WFLHD) of the Federal Highway Administration (FHWA) led the development of this framework with key input from Federal Land Management Agencies (FLMA), FHWA's Office of Tribal Transportation, and a technical advisory committee (TAC). Representatives and agencies involved in the TAC included:

- WFLHD.
- Eastern Federal Lands Highway Division (EFLHD).
- Central Federal Lands Highway Division (CFLHD).
- FHWA Office of Safety.
- Volpe National Transportation Systems Center.
- National Park Service (NPS).
- United States Bureau of Reclamation (BOR).
- United States Bureau of Land Management (BLM).
- United States Forest Service (USFS).
- United States Fish and Wildlife Service (USFWS).
- United States Army Corps of Engineers (USACE).
- Western Transportation Institute (WTI) – Rural Road Safety Center.
- Gila River Indian Community.
- Acadiana Planning Commission.
- Washington State Department of Transportation (DOT).
- Louisiana State University – Center for Analytics & Research in Transportation Safety.
- University of Kentucky.
- Texas A&M University Transportation Institute.

Research Purpose and Objectives

This research effort had two principal goals:

1. Enhance the FHWA GIS application, developed as part of a separate ongoing effort within Federal Lands Highway (FLH), to aid in the continual collection of safety and traffic data. This will address a gap in available transportation agency data needed to support planning, programming, and project-related data-driven solutions.
2. Complement the first goal by building an analysis framework to use the safety and traffic data collection system to facilitate direct input into safety analysis software and other methodologies for both site-specific and systemic safety solutions.

This research supports several Federal initiatives and policies with respect to improving safety on the nation's public roads:

- The 2021 Infrastructure Investment and Jobs Act (IIJA)/Bipartisan Infrastructure Law (BIL) and the need for data-driven decision-making with respect to funding and project prioritization.(1)
- Components of the United States Department of Transportation's (USDOT's) 2022 National Roadway Safety Strategy (NRSS), including safer people, safer roads, safer speeds, and equity.(2)
- Interagency GIS data standardization across FLMAs as required by the 2022 Modernizing Access to Our Public Land (MAPLand) Act.(3)
- Support for a safety management system (SMS) for NPS as required by 23 CFR § 970.212.(4)
- Promotion of systemic safety and proven safety countermeasures as a means of addressing risk on public roads.

The framework is tailored and tiered to apply to diverse FLMA data capabilities, as well as rural-centric conditions and risk factors. The framework will help FLH prioritize data collection, management, and analysis procedures for assessing safety needs on Federally-managed roads, including:

- Supporting the FLH American Association of State Highway and Transportation Officials (AASHTO) Safety Analyst™ project (or other future SMS development and support).
- Enhancing local road safety plans (LRSPs) and safety action plans (SAPs).
- Refining road safety audits (RSAs).
- Improving design, safety analysis, and components of plans, specifications, and estimate (PS&E) packages during typical FLH project development.
- Supplementing gaps in existing safety data, including crash data.
- Identifying the role of specific FLMA tools in the broader framework.

An additional goal of the data collection framework is the coordination of data collection activities across Federal agencies, as well as the development of memoranda of understanding (MOUs) between Federal transportation agencies and external partners. These could include Tribal, State, and local governments. The deployment of the framework will include activities that foster coordination and collaboration between data stakeholders that build analytical capacity for Federal lands.

2

Literature Review

As a first step, the research team gathered information about existing practices and guidance to promote the use of GIS data and tools to support systemic roadway safety analysis on Federal lands. Rather than taking a reactive view of safety issues (such as targeting crashes that have already occurred), the systemic approach is a data-driven safety assessment that identifies risk factors across a road network and addresses them proactively. This technique is especially applicable to rural or local roads where crash data may be sparse or unavailable. The Federal lands context covers a broad spectrum of political, administrative, geographic, and climatological environments across the United States. As a result, there is a critical need to identify best practices associated with data collection, integration, and analysis from agencies throughout the country and flexibly apply them on roads owned and maintained by FLMAs, as well as other State and local governments.

The research team considered the following areas of practice as part of the literature review:

- Plan Development and Partner Engagement.
- Data Collection and Aggregation.
- Data Analysis.
- Enterprise Data Management and Approach.

Plan Development

A systemic approach to safety is the result of a plan that identifies local risk factors and identifies locations for potential improvement. LRSPs, which can also be referred to as local road SAPs more generally, are an FHWA proven safety countermeasure that can support systemic safety analysis and provide a repeatable framework for identifying, analyzing, and prioritizing roadway safety improvements on local roads, especially those with limited data availability.[5] FHWA supports local agencies as they develop their own LRSPs through the FHWA's Do-It-Yourself resource page.[6]

Partner Engagement

Many of the agencies that collaborate with FLH do not have, or are not familiar with, dedicated safety improvement programs such as the Highway Safety Improvement Program (HSIP). These are typically administered by State DOTs and local agencies. There are opportunities to collect relevant data, analyze existing conditions, and develop plans with cost-effective safety countermeasures to pursue available funding opportunities to implement improvements; these programs include HSIP, Federal Lands Transportation Program (FLTP), Federal Lands Access Program (FLAP), and other BIL-related programs. Identifying plan champions at the applicable agency level(s) (i.e., Federal, Tribal, county, or municipal agencies) is critical for a successful SAP. FHWA and other programs, such as Local Technical Assistance Programs (LTAPs) and other State DOT resources, are available to provide guidance and technical assistance for some plans, but the majority of effort and leadership to complete SAPs must come from the agencies whose jurisdiction would be affected.

FHWA's *Implementing a Local Road Safety Plan (*LRSP guide*)*[7] proposes a six-step process to achieve a successful and implementable LRSP:

1. Maintain buy-in and support.
2. Identify funding mechanisms.
3. Identify and prioritize projects.
4. Determine project delivery methods.
5. Evaluate the plan's effectiveness.
6. Continue active communications and coordination.

Partner engagement is explicitly the first and last step, as it guides many of the activities in the remaining four steps. Although the FLH-proposed framework has data collection and analysis in a GIS platform as a primary objective, this data management effort can be placed in the context of the broader systemic analysis and LRSP framework. The FHWA LRSP guide notes that identifying plan champions at a State or local level are critical to collect data and pursue plan goals. Furthermore, continued coordination during and after the plan promotes implementation and can be used as a method to continue data collection and sharing across agencies.

The need for a champion is supported in FHWA's *Developing Safety Plans: A Manual for Local Rural Road Owners*[8] and *Developing a Transportation Safety Plan: Information Tools for Tribal Governments Plan*[9] proponents should identify leaders of the plan development effort and assemble a working group of relevant stakeholders. Core responsibilities of this group over the course of LRSP development include:

- Establishing a charter or MOU to clarify each working group member's role.
- Analyzing data (crash, traffic, etc.) to look for trends or potential problem areas.
- Recommending and prioritizing emphasis areas to include in the LRSP.
- Engaging relevant safety stakeholders.
- Identifying public, private, and non-profit funding sources to implement the LRSP.
- Writing the LRSP.
- Marketing the LRSP through a communication plan with key messages for active public involvement.
- Encouraging local groups (civic organizations or business improvement districts) to adopt common safety goals as part of their plans.
- Participating in LRSP implementation efforts and tracking progress after the initial plan is developed.

The working group should be multi-disciplinary, including stakeholders representing engineering, enforcement, education, emergency services, and other related disciplines and groups (e.g., political and administrative organizations, transit agencies, railroad managers, and advocacy groups). Regular meetings can demonstrate progress and encourage participation from different agencies.

Data Development

In addition to partner and stakeholder engagement, there are several examples of Federal- and State-level guidance that outlines the types and sources of data that can support systemic analyses. FHWA's *Roadway Safety Information Analysis: A Manual for Local Rural Road Owners*(10) guide provides a framework for basic data collection necessary for rudimentary systemic analysis, as well as several case studies of safety analyses on local roads with limited data. FHWA's *Improving Safety on Rural Local and Tribal Roads Safety Toolkit*(11) guide provides a primer on the types of data and analysis that can support an LRSP. Like similar FHWA guides, it offers guidance and potential troubleshooting solutions in a step-by-step format. Steps 1 and 2 are most relevant to data development:

- **Step 1 involves compiling data**: anecdotal data, quantitative data, and data from existing resources and documents. This includes organizations and agencies that can provide additional safety analysis support.
- **Step 2 discusses five types of network screening**: with maintenance staff, with crash data (frequency alone), with crash data and traffic volume data (for a crash rate), utilizing software (e.g., usRAP, Safety Analyst™), and with systemic analysis. These approaches require data, and a framework for data development is an important foundation for plan development.

As a State example, the California DOT (Caltrans) produces a *Local Road Safety Manual*(12) California now makes LRSPs (or a now superseded Systemic Safety Analysis Report) a prerequisite to HSIP funding, and this document details many of the elements needed to support plan development:

- Relevant data sources to highway safety in the State (e.g., crash data portals).
- Methods for collecting and developing quantitative and qualitative data, including field reviews, as well as aerial or street-level photo logs.
- Analysis methods and countermeasure selection.
- The State's HSIP application process and recommendations for project delivery.

Data Collection and Aggregation

This section describes guidance and practical examples of methods for developing 1) roadway, 2) traffic and exposure, and 3) qualitative data in rural locations and areas with limited available data.

Roadway Characteristics and Alignment

FHWA's *Model Inventory of Roadway Elements (MIRE) 2.0*(13) documents a comprehensive list of roadway and infrastructure asset data elements that can help support robust safety analyses. While agencies are not obligated to collect all 205 MIRE data elements, the data definitions and concepts in this document can serve as the foundation for a data dictionary of public roadway information for paved and unpaved roads. Furthermore, the MIRE Fundamental Data Elements (FDE) are a smaller subset of core data elements that can support most analyses detailed in the First Edition of the AASHTO Highway Safety Manual (HSM).

These are organized by the following categories:

- Non-Local Paved Roads Based on Functional Classification.
  - Segments.
  - Intersections.
  - Interchanges/Ramps.
- Local Paved Roads Based on Functional Classification.
  - Segments only.
- Unpaved roads
  - Segments only.

The accompanying *MIRE Data Collection Guidebook*(14) provides a general overview of several data collection techniques applicable to MIRE, including:

- Data mining from Highway Performance Monitoring System (HPMS) databases, construction records, as-built plans, pavement monitoring systems, and video logs. Although not specified in the guidance, machine learning techniques are increasingly being used to extract data elements from aerial- and street-level imagery.
- Mobile data collection through network-enabled and standalone applications and devices.
- Aerial imagery.
- Light Detection and Ranging (LiDAR) and video log collection through ground-based mobile units or aerial platforms.

Horizontal curvature is a common risk factor for roadway departure crashes, and there are several methods for obtaining curve locations. Highly accurate, but costly, methods involve mobile LiDAR and other remote sensing techniques; however, several applications derive sufficiently reliable results based on existing GIS centerline work. The University of Wisconsin recently published a paper and developed a companion tool that extracts horizontal curvature from road centerline geometry in GIS.(15, 16) *Curve Finder* is a GIS-based tool developed by the University of Wisconsin's Traffic Operations and Safety (TOPS) Laboratory that produces curvature definitions in line with MIRE standards. Previous research has indicated reliable effectiveness at identifying existing curvature and "false identification" (p. 172; i.e., flagging a curve where no curve exists on the ground) tends to be acceptably low.(17) However, the most important caveat associated with *Curve Finder*, as well as other automated techniques, involves poor quality GIS data and centerline digitization; manual quality control may be necessary if the GIS centerline does not accurately reflect the ground alignment or the spacing and number of GIS vertices leads to low-resolution curvature (the directional bearing between vertices is the key input interpreted by the tool). The level of effort associated with this quality control will vary according to the quality of the input centerline dataset.

Traffic and Exposure

FLMAs often collect and manage traffic count datasets in an ad-hoc fashion (i.e., the specific program will vary by location, agency, and context). These can be collected at the park, site, or refuge level, and they may not be aggregated to a national office or dataset.

FLH could consider the following when selecting the most appropriate data source for each FLMA and location:

- There are notable national traffic count programs in certain agencies, including the NPS's Integrated Resource Management Application (IRMA) and Continuous Counter System, as well as the USACE's metering program with load factors to estimate total visitation.
- There are several visitor count and estimation methods (with surrogates) that could compensate for a lack of local road traffic data. These include NPS's IRMA, USFS's National Visitor Use Monitoring (NVUM) program, and BLM's Recreation Management Information System (RMIS).
- Across all FLMAs, the National Recreation Reservation Service (NRRS; informally referred to as recreation.gov) tracks reservations and other transaction information at specific locations (e.g., campgrounds). Although these data may not reflect visitation that did not involve a reservation or transaction (e.g., day trips or through traffic), they do indicate travel demand at specific locations in a park, unit, or site by day of the week and month.

Although traffic counts and annual average daily traffic (AADT) are often the most appropriate exposure metrics for the purpose of safety analysis, there are several indicators of exposure available to FLMAs. These resources can help define when and where vehicles and other users may travel on Federal lands, including:

- Trip generators and attractors on certain routes.
- Peak travel seasons and months.
- Locations where vehicle, non-motorist, and wildlife conflicts may be most heavily traveled.

Leggett et al. (2017)[18] provides a comprehensive overview of visitation estimation practices throughout FLMAs, as well as the official definition of "visit" by agency.

Table 1 summarizes each FLMA's methods according to these findings.

Table 1. Existing visitation estimation methods by FLMA.[18]

FLMA	Methods used
NPS	**Direct counts:** These include counts of people at visitor centers or on the grounds, tickets sold for specific attractions, backcountry permits issued, and other similar counts. **Proxy counts:** These are counts that are correlated with the total number of visits, such as counts of occupied campsites or traffic counts. **Statistical correlation estimates:** Some visitation estimates are based on estimates for other areas. For example, at Fort Scott National Historic Site, visitors entering the visitor center are counted by hand, and a regression-based estimate is produced for the additional visitors that enter the park but are not counted at the visitor center. **Flat estimates:** A flat, or constant, estimate of visitation is used for some resources that cannot be monitored in a cost-effective way. These estimates are based on historical information and/or professional judgment.
USFS	The NVUM program is the institutional method for estimating visitation in National Forests. This relies on a sampling of "site days," or a continuous 24-hour period at a single site. These sites are categorized by three characteristics: site type, existence of proxy data, and expected use level: **Site type**: All sites are classified as either day-use developed sites (e.g., picnic areas), overnight use developed sites (e.g., campgrounds), wilderness sites (e.g., trailhead providing hiking access to a wilderness area), general sites not in the previous three categories (e.g., trailhead providing hiking or hunting access to a national forest), and viewing corridor sites (e.g., public road providing views of a National Forest). **Proxy data**: All sites are classified as either having "proxy" information or not having proxy information. Sites with proxy information have information available that is expected to be closely related to the volume of recreation visits. Examples include data from fee envelopes at campgrounds, permanent traffic counters, and lift ticket sales at ski areas. When this type of proxy data covers all recreation visits at the site and is available year-round, it can be used to improve the accuracy of estimates of recreation site visits. **Expected use level**: All site days in the calendar year are assigned to one of five use levels (very high, high, medium, low, or none) based on site managers' expectations regarding the flow of last-exiting recreation visitors. Site days with higher expected exiting visitor flows are sampled at higher rates. Field personnel, including USFS employees, contractors, and university personnel, are deployed on selected site days to gather data that allows one to estimate the number of last-exiting visitors leaving the site on that day. Specifically, with the exception of viewing corridor sites and sites with proxy data, field personnel gather three types of data for every sampled site day: **Automated counts:** Automated counts of all people or vehicles entering and departing the site throughout the entire 24-hour period. These counts are obtained by installing a temporary vehicle counter, such as a pneumatic tube, at a point near the entrance to the site that all (or nearly all) vehicles must pass by in order to enter.

FLMA	Methods used
	Manual counts: Manual counts of all people or vehicles leaving the site during a randomly selected six-hour shift (either 8 AM to 2 PM or 2 PM to 8 PM). Two-thirds of the sampled site days are assigned to the shift that is expected to have the heaviest flow of last-exiting recreational visitors; the remaining one-third are assigned to the other shift. These manual counts are used, together with readings from the automated counter at the beginning and end of the six-hour shift, to convert the 24-hour automated count to an estimate of exiting vehicles. **Interviews:** Interviews with vehicle occupants during the randomly selected six-hour shift. Field personnel attempt to intercept **all** exiting vehicles for interviews (i.e., there is no sampling of vehicles), provided that they are not busy conducting an interview with another visitor when the vehicle passes by. The interview begins with screening questions to identify vehicles with last-exiting recreation visitors. For these vehicles, a randomly selected occupant (age 16 or over) is asked additional questions to obtain general data on trip characteristics, including persons per vehicle and number of sites visited. Data on persons per vehicle are used to convert the 24-hour vehicle count into a visitation estimate for the sampled site day. Data on the number of sites visited within each national forest are used to convert estimates of site visits to estimates of national forest visits.
USFWS	**Direct observation:** Visits are counted either directly or indirectly (e.g., using video cameras). **Traffic counters:** Automated traffic counters are placed on entrance roads or near visitor centers to record vehicles entering sites. The traffic counts are combined with information from direct observation or surveys to estimate total visitation (e.g., number of visitors per vehicle, percentage of vehicles engaging in recreation, etc.) **Patrols:** Public use areas (e.g., boat ramps or parking lots) are patrolled and the number of recreational visits is counted over a set period of time. This sample is used to estimate the total number of visits in that area. For wetland management districts and refuges with diffuse access or dispersed recreation sites, the patrols method offers a useful alternative to traffic counters. **Self-registration:** Self-reported information is collected from visitors via guest books, trail registers, and voluntary hunting or fishing permits in cases where fees are not collected. **Entrance fee stations and permits:** About 35 refuges charge an entrance fee, and about 106 refuges charge fees for activities such as overnight camping, hunting, and boating. **Surveys:** Visitation information is collected via surveys (e.g., mail, telephone, and traffic-stop surveys), which provide information about visitation and visit characteristics like group size, length of stay, recreational activities, visitor satisfaction, and more. **Indirect estimation based on professional judgment:** In some cases, professional judgment is used to estimate visitation.
BOR	**Automated or manual traffic counts:** These counts are usually combined with an assumed number of persons per vehicle to estimate visitation. **On-site camp hosts:** Some project areas rely on on-site camp hosts to generate and log visitation counts.

FLMA	Methods used
	Fee collection: At some project areas, overnight camping fees, parking fees, and managing partner entrance fees are used to estimate visitation.
BLM	**Automated traffic and trail counters:** At some sites, automated counters are used to measure traffic volume or foot traffic on trails. These counts are converted into visitation estimates using information about the percentage of vehicles associated with recreation, number of visitors per vehicle, length of time on site, and other visit characteristics. This information is based on a mixture of on-site observations and professional judgment. **Counts based on fee data:** Visitation is tracked at some sites using fee data, including permits (e.g., overnight camping), registrations, and fee envelopes. **Other counts based on observation and professional judgment:** BLM staff also use a combination of observation and professional judgment to estimate visitation at some sites. For example, BLM staff might record the number of observed visitors for a period of time at a site in their patrol logs.
USACE	**Automated counters**: These include traffic and trail counters, which are combined with on-site surveys to estimate visitation. **Transaction data:** Camping and shelter transaction data from the NRRS. **Revenue data:** Overnight use revenue data from the Corps of Engineers Financial Management System (CEFMS). **Ratio estimates:** Estimates based on the number of parking spaces or campsites combined with an assumed occupancy rate. **Third-party estimates:** Independent estimates from leased areas managed by State/local parks, nonprofit parks, and private.

Qualitative and Anecdotal Information

Low-volume roads, both paved and unpaved, have several challenges that limit the applicability of traditional data analysis. Although a high proportion of fatal and serious injury crashes occur on rural and local roads, these events are often dispersed over a large amount of centerline mileage. As a primary owner and maintainer of local, rural, two-lane roads, Federal and Tribal agencies may not have access to the crash, roadway, and traffic data for these roads recommended by most safety analysis methods. This information can be supplemented through the collection and aggregation of qualitative data (e.g., local, or institutional knowledge) or field assessments.

FHWA's *Road Safety Audit Toolkit for Federal Land Management Agencies and Tribal Governments* suggests that when reliable crash data are not available, anecdotal information (e.g., from maintenance, enforcement call logs, landowners) and evidence of conflicts and crashes (e.g., skid marks, and fence strikes) can be used to assess potential safety risks.(19) Practitioners can passively observe these data in the field or actively collected during an RSA.

Additionally, expected crash frequency can be qualitatively estimated on the basis of exposure and probability, including, but not limited to, the following factors:

- Frequency of driveways.
- Presence of popular tourist locations.
- Seasonal variation in park, forest, or recreational area use.
- Expected pedestrian, bicycle, or recreational vehicle use.
- VMT.
- Segment length.
- Centerline mileage.

Furthermore, expected crash severity can be qualitatively estimated on the basis of factors such as anticipated speeds, posted speed limits, expected collision types, and the likelihood that vulnerable road users would be exposed.

FHWA's *Low-Volume Roads and Road Safety Audits: Lessons Learned*(20) focuses on the list of common issues associated with rural and local roads, including environmental and enforcement concerns, as well as seasonal variation in use and road conditions. The guide also notes that a comparison of issues on paved and unpaved roads could lead to significant differences in design criteria and safety performance that reviewers should consider. Furthermore, non-motorized users may be more vulnerable in these contexts, as local roads often lack bicycle and pedestrian infrastructure, and drivers may not expect these users.

FHWA's *Vegetation Control for Safety, A Guide for Local Highway and Street Maintenance Personnel*(21) offers considerations for systemically managing the visibility, conspicuity, and hazard issues associated with roadside vegetation. This includes a checklist of specific criteria that would be incorporated in a vegetation management strategy:

- Sign visibility.
- Clear sight lines.
- Drainage.
- Intersection/Cross-street visibility.
- Roadside trees.
- Winter maintenance.
- Pedestrian paths.

Agencies can incorporate vegetation maintenance cycles and issue tracking in a systemic or systematic approach.

FHWA's *Improving Safety on Rural Local and Tribal Roads Safety Toolkit* also notes that public and stakeholder sentiment can be used as a data source.(11) Crowd-sourced input can provide insights into issues that may present challenges to visitors and tourists on Federal lands that may not be readily recognizable to staff that live and work near the site year-round. This information can be used to assess the public's perception of recent improvements.

A **systematic** approach is based on a policy to install countermeasures wherever they might be applicable, regardless of risk. The **systemic** approach prioritizes treatment locations based on data-driven analysis and the presence of risk factors.

The *Collaborative Visitor Transportation Survey* (CVTS)[22] is an ongoing effort to streamline visitor survey data collection from several FLMA's, including:

- BLM.
- USFWS.
- USACE.
- USFS.
- NPS.

Data Analysis

This section describes different approaches to safety analysis, particularly those presented in the First Edition of the HSM[23], as well as different approaches to systemic safety analysis. The former focuses on network screening through observed or predicted crashes, diagnosing relevant issues at high crash sites, and addressing those issues with countermeasures. The latter focuses on risk associated with crashes, although crashes need not have occurred to proactively address safety concerns.

Predictive Analysis

AADT-only SPFs are the simplest crash prediction models, and "the primary purpose of this SPF…is to assist an agency in their network screening process, i.e., to identify sites that may benefit from a safety treatment" (p. 8).[24] These models only require a few data elements (figure 1):

$$P = L \times e^{-5.05} \times (AADT)^{0.66}$$

Figure 1. Equation. Example of an AADT-only SPF.[24]

Where:

P is the total number of crashes in 1 year on a segment of length *L*.

These models could also be developed for specific facility types (e.g., urban or rural, median-divided or undivided, etc.) so that individual locations can be compared to a peer group of similar locations. The performance of the peer group would represent the typical safety performance of that facility type. FHWA's *Safety Performance Function (SPF) Development Guide: Developing Jurisdiction-Specific SPFs*[24] provides guidance for agencies to develop their own SPFs.

Crash Modification Factors (CMFs)

SPFs predict a number of crashes for a site based on geometric and operational conditions (existing or future). CMFs allow practitioners to modify these predictions to account for site-specific conditions or contemplated changes to site conditions by applying a multiplier that indicates a potential reduction (or increase) in crashes. CMFs apply to both AADT-only and complex SPFs. A CMF of less than 1 indicates a predicted reduction in crashes based on the presence of that feature, and a CMF greater than 1 indicates predicted increases in crashes for that feature. The HSM contains several standard CMFs, but CMFs can vary according to context. Several States develop their own suite of CMF values applicable to that jurisdiction, and FHWA's *CMF Clearinghouse*[25] provides guidance on CMF development, as well as a comprehensive inventory of CMFs developed around the United States.

Systemic Analysis

The National Cooperative Highway Research Program (NCHRP) Research Report 955, *Guide for Quantitative Approaches to Systemic Safety Analysis*, summarizes three different approaches to applying quantitative methods to systemic safety analysis (figure 2):[(26)]

1. **If your agency lacks both reliable crash and traffic data across the entire network:** Consider implementing the methods described in FHWA's *Systemic Safety Project Selection Tool*[(27)]. The FHWA report suggests identifying 1) focus crash types, 2) focus facility types, and 3) specific risk factors to be addressed. This would involve an agency establishing a crash type and facility type to be addressed (e.g., roadway departure on two-lane, two-way rural roads) and identifying sites that meet certain risk criteria. These focus crash types could also be based on existing strategic plans, such as a Strategic Highway Safety Plan (SHSP) or other action plan. Even without crash or traffic information, risk factors can be borrowed from another (similar) agency's SAP or from the inputs in Part C of the First Edition of the HSM. Furthermore, relevant cost-effective countermeasures can be used to prioritize sites with risk factors that could be addressed by that suite of countermeasures (e.g., curve delineation and rumble strips to address roadway departure risk).
2. **If your agency lacks crash data, but it has access to reasonably reliable traffic volumes across the entire network:** Consider implementing the methods prescribed by the U.S. Road Assessment Program (usRAP)[(28)], the International Road Assessment Program (iRAP)[(29)], and the supporting ViDA software[(30)]. This software rates segments in 100-meter intervals according to a star rating (1 being highest safety risk and 5 being lowest safety risk). Although crash data are not required to support usRAP and ViDA, many of the scoring criteria include road geometric and cross-section data, roadside conditions, and traffic volume and flow characteristics. Based on these ratings, the software allows users to generate a safer roads investment plan. This is a ranked list of locations and countermeasures that meet users' predefined cost/benefit targets.
3. **If your agency has both crash and traffic data across the entire network:** Consider implementing a robust SMS. This could be developed in-house or it could involve third-party software such as AASHTOWare Safety™ (formerly AASHTOWare Safety Analyst™).[(31)] This approach would necessitate the implementation of SPFs and CMFs to apply the predictive method and perform network screening. Predicted and expected crash estimates also allow agencies to conduct more reliable benefit/cost assessments with respect to potential treatments based on estimated future crashes reduced and countermeasure life-cycle costs.

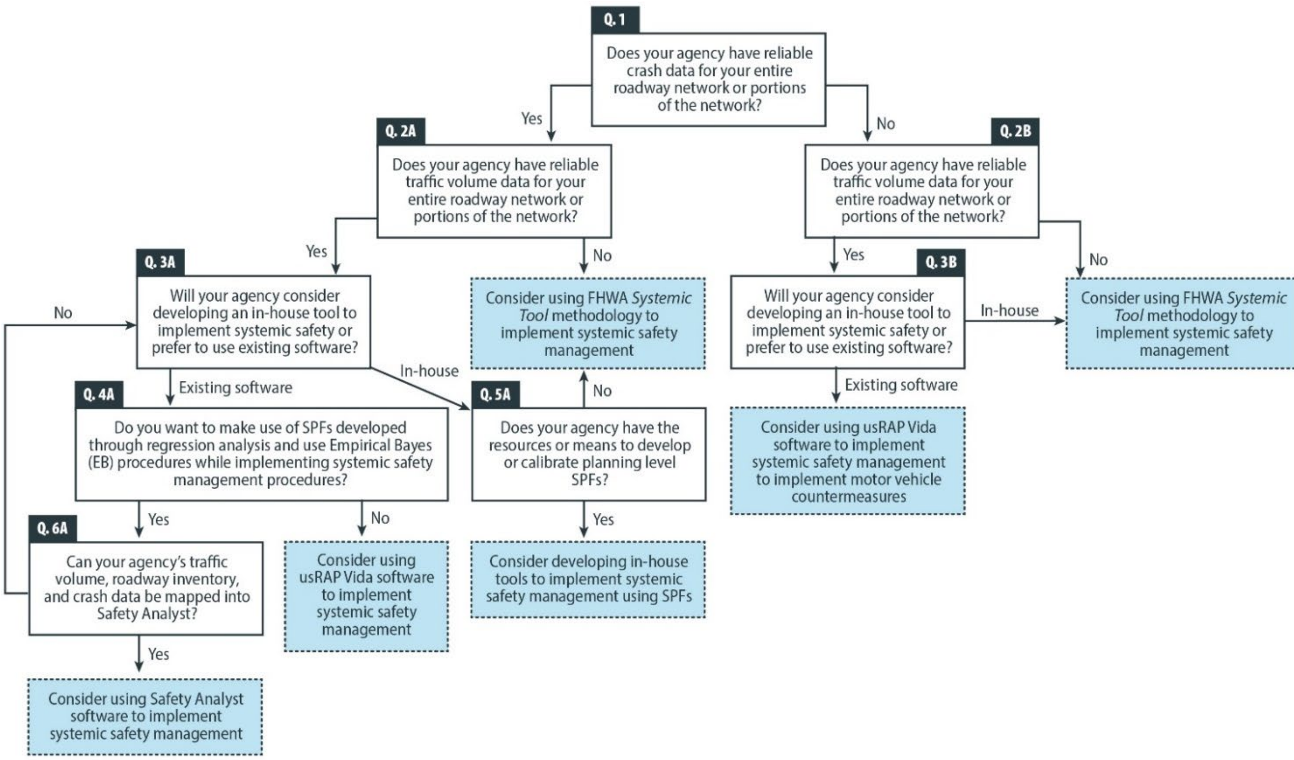

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Figure 2. Graphic. NCHRP 955: Logic and framework geared toward helping an agency select a preferred systemic safety management approach and/or software tool for implementation.[26]

If crash data are available, FHWA's *Crash Tree Diagram Tool* provides a user-friendly way for agencies to quickly assess trends, risk factors, and contributing circumstances.[32] The Microsoft Excel™-based tool filters crashes based on crash-level attributes and displays the results in a graphic output. The FHWA *Crash Data Summary Template* is another systemic analysis support tool that uses crash data to assess local trends.[33] While the graphic interface is less robust than the Crash Tree Tool, this tool helps isolate patterns unique to a local jurisdiction by comparing local crashes to crashes from a reference region. For instance, a county can compare the distribution of contributing circumstances on county roads relative to the State as a whole. Furthermore, a county can compare the distribution of contributing circumstances between severity levels (i.e., fatal and serious injury crashes relative to total crashes).

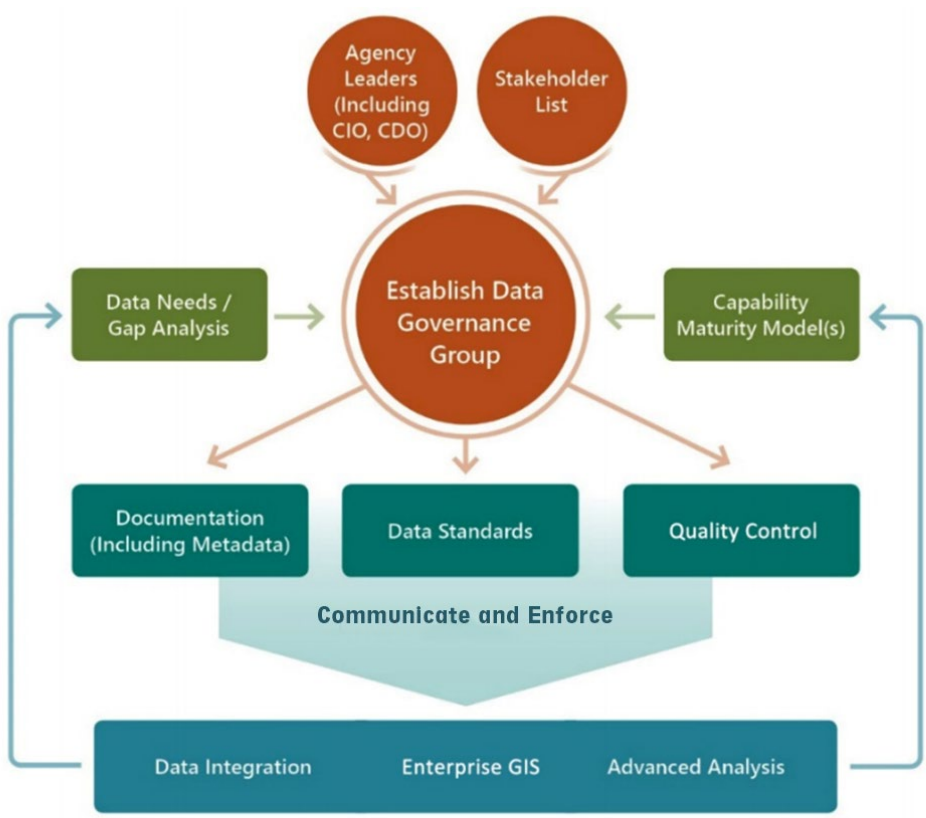
If crash data are not a reliable data source (either because data are unavailable or because crashes are so infrequent that reliable patterns do not emerge), usRAP and the accompanying software, Vida, are tools that specialize in conducting data-driven safety assessments in areas where a proactive or systemic approach is desired.[28,30] The software tool takes roadway and traffic control inputs from existing highway agency databases (often developed from video or photo logs) to develop star ratings (1 through 5) that generally quantify safety risk at specific sites. A road safety score is assigned to each road segment based on the input roadway and traffic control characteristics and a star rating is assigned to a specific band of road safety scores. Risk maps are generated based on road safety scores and the star ratings. usRAP then develops a Safer Roads Investment Plan (SRIP) using the risk maps. SRIP evaluates a roadway's identified risks, engineering needs, and countermeasure options for safety improvements based on a specified minimum benefit-cost ratio.

Enterprise Data Management and Approach

FHWA's *Applications of Enterprise GIS for Transportation: Guidance for a National Transportation Framework*[34] provides advice for State agencies on how to apply enterprise data governance principles to standardize agency data models and the systems supporting GIS data development. According to this guidance,[34]

> "In transportation, data governance is a formal process of managing data and systems to meet the enterprise's needs for information to support decision-making. In practice, this enterprise approach must also look to the individual business unit's needs in defining needs at the organization-wide level. Data governance is specifically designed to be a joint exercise of executive-level managers (agency directors, the chief information officer, and chief data officer in particular), the many business units' subject matter experts (the practitioners), and the information technology (IT) experts supporting the enterprise and the business units." (p. 26)

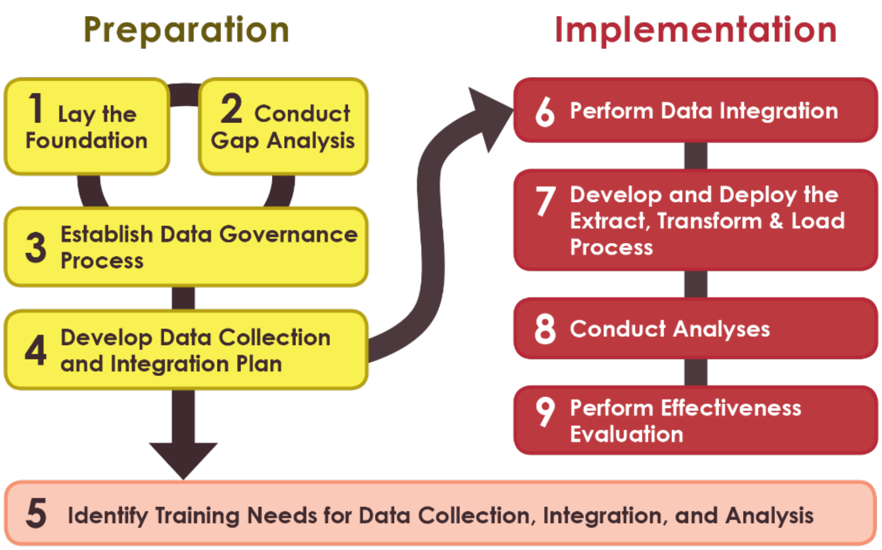
The purpose of data governance is to provide the authority and oversight necessary to adequately perform data management and enforce standards, quality, and documentation. This provides the institutional framework necessary to incorporate and integrate data from different business units within an organization, as well as external partners operating within that framework (figure 3).



Source: FHWA

Figure 3. Graphic. A flow diagram of data governance.[34]

The Federal and Tribal lands context covers a diverse range of geographies and jurisdictions; this often includes national parks, forests, and recreational areas that cross State and county boundaries. As a result, data collaboration and integration can support data analysis both in and around Federal and Tribal lands. FHWA's *Informational Guide for State, Tribal, and Local Safety Data Integration*[35] presents a nine-step process to help agencies of different organizational levels achieve data integration (figure 4).



Source: FHWA

Figure 4. Graphic. FHWA's nine-step process for safety data integration.[35]

While each step contains relevant guidance to the process, agencies can flexibly focus on specific steps according to their needs. The nine steps are:

- **Step 1- Lay the Foundation:** This step talks about a variety of partners and their roles in safety data integration. Important items in this step are:
  - Secure the commitment of executive management.
  - Forge partnerships.
  - Establish needed MOUs and Data Sharing Agreements to establish expectations.
  - Establish communication processes to inform and involve all stakeholders.
- **Step 2 – Conduct Gap Analysis:** This step includes the following important items:
  - Establish a team to perform the gap analysis.
  - Perform a survey of user needs and available data sources.
  - Plan to repeat the gap analysis periodically.
  - Recognize the interactions between forging partnerships, gap analysis, and data governance efforts.
- **Step 3 – Establish Data Governance Process:** This step involves the following key items:
  - Leadership: Identify leadership and establish a data governance committee to monitor data integration.
  - Quality: Establish a data quality assurance program including data standards and measures of data quality.
  - Prioritization: Establish clear priorities to address data gaps and needs.

- » Cooperation: Identify opportunities for cross-organizational collaboration and data sharing and integration; establish MOUs.
- » Flexibility: Communicate innovative solutions among stakeholders.
- » Utilization: Promote appropriate data usage among stakeholders.

- **Step 4 – Develop Data Collection and Integration Plan:** The plan should acknowledge and cover each of the nine steps in the integration process. It should also document each action in the process, as well as the responsible offices or agencies for each action.
- **Step 5 – Identify Training Needs for Data Collection, Integration, and Analysis:** Anyone who operates with integrated data should be assessed for potential training needs. Training may need to be a continuous process, and it may involve stakeholders at partner or subsidiary (i.e., local) agencies.
- **Step 6 – Perform Data Integration:** This step lists common issues and recommended solutions:
  - » Issues:
    - Missing, inaccurate, or poor-quality data.
    - Data stored in legacy systems may not be compatible with new or modern data systems.
    - Lack of storage capacity.
  - » Solutions:
    - Plan for future data needs.
    - Develop forums for developers and users to collaborate and identify quality controls.
    - Apply automation as much as possible.

A pilot study between the Indiana (IN) LTAP and Putnam County (IN) documented four phases:

1. *GIS assessment* – Assessed current conditions, practices, and needs.
2. *GIS data development and integration* – Collected GIS data and prepared local data for inclusion in the integrated database.
3. *GIS website development* – Developed and implemented a website to provide information to internal and external stakeholders.
4. *Asset data collection* – Developed an outline-level plan for future asset data collection.

- **Step 7 – Develop and Deploy the Extract, Transform, and Load Process:** This step talks about GIS-based data integration and spatial data analysis, filters, and extraction.
- **Step 8 – Conduct Analyses:** This section talks about types of safety analyses for different purposes.
- **Step 9 – Perform Effectiveness Evaluation:** This step emphasizes the need to provide evidence of program effectiveness. It offers several indicators of success:
  - » Use of predictive (i.e., HSM) methods of all public roads.
  - » Number of agencies included in data sharing agreements.
  - » Implementation of data governance to formalize data integration.

In addition to these nine steps to promote interagency data integration, the guidance also notes the importance of metadata, or data about data, in building a data collection and integration program. Key metadata elements include:

- **Data dictionaries** that list and describe all elements in a database.
- **Data flows** that textually describe (or graphically illustrate) the data management steps from collection to final storage and sharing.
- **Data access rights** that document the access permissions of specific user bases (owners, custodians, contributors, etc.).
- **Data quality and standards** documentation that sets institutional requirements for the format, precision, and accuracy of each data element.
- **Data retention** guidelines that house past conditions along with the latest existing conditions (e.g., annual "snapshots" of conditions.[35]
- **User support** mechanisms and agencies responsible for disseminating data collection and management training and guidance.

Agency Interviews

As part of the literature and background review, the research team conducted a series of interviews with FLMA representatives and USDOT data managers:

- BLM.
- BOR.
- CVTS managed by the Volpe Center.
- Roadkill Observation and Data System (ROaDS) managed by the Department of Interior (DOI).
- USFWS.
- NPS.
- Roadway Inventory Program (RIP) managed by EFLHD.
- USACE.
- USFS.

Appendix A: Interview Summaries contains summary memorandums discussing the outcomes and findings of these interviews.

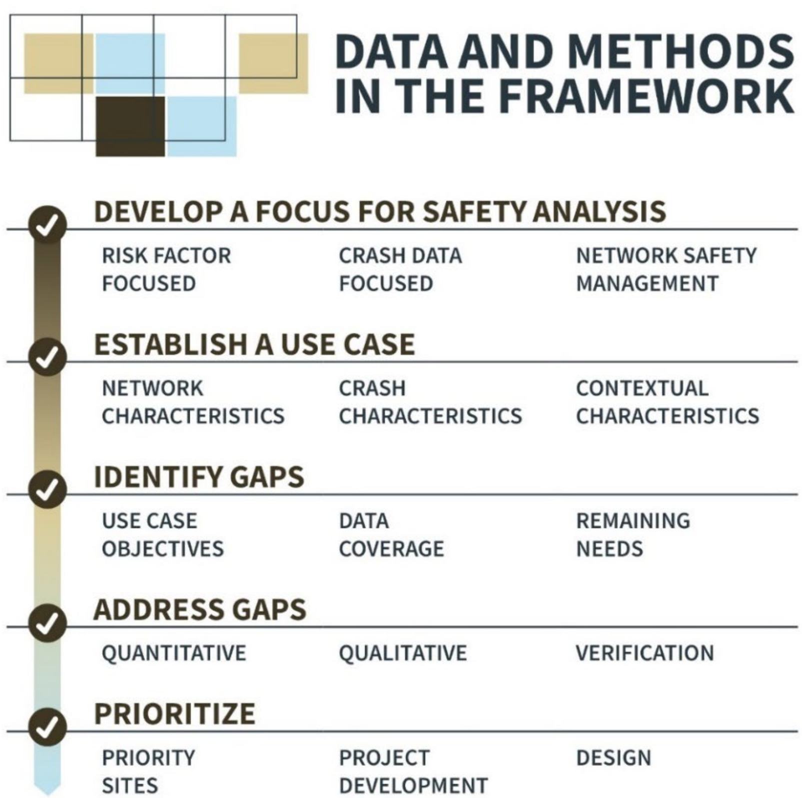
3

Data Development Framework

The project team applied the lessons learned during the literature review to develop a data collection framework to support data-driven safety analysis (DDSA) on FLMA roads. Key components of the research that informed the framework include:

- Data sources that can potentially contribute to safety analysis in rural settings.
- Noteworthy practices for integrating and managing data to build analytical capacity.
- Analysis methods that can be applied by stakeholders with varying resource availability and capacity.
- Risk factors for rural and low traffic volume roads (*Appendix B*).
- Approaches to coordination between stakeholders to aggregate data, evaluate project effectiveness, and track progress toward goals.

Figure 5 provides a concise overview of the proposed framework. Although the framework follows a generalized transportation planning process from long-range planning to individual project development, its flexibility allows practitioners at each stage to identify strategies for incorporating safety data into decision-making.



Source: FHWA

Figure 5. Graphic. FLH data collection framework.

The goal of the framework is to support decision-making. It provides methods for identifying minimum data requirements for specific types of analysis, priority safety risk factors to be addressed on FLMA roads, and data resources to address these risks. The following sections comprise the core pillars of the framework:

Develop a Focus for Safety Analysis: This section refers to long-range and strategic planning for safety. This includes assembling stakeholders, maintaining buy-in, and refining safety data analysis methods to develop priorities.

Establish a Use Case for Safety Data: This section scans existing data sources and their applicability to different components of traditional safety analysis. This includes systemic analysis techniques, as well as methods documented in the HSM.

Identify Gaps: This section evaluates existing safety data with respect to a potential use case and near-term needs. Data should support priorities and emphasis areas established by stakeholders and strategic planning.

Address Gaps: This section discusses criteria for evaluating remaining data needs to support the near-term use case. This includes programmatic and agency-wide data collection, as well as site-specific methods.

Prioritize: This section documents the application of safety data for site-specific risks and improvements. This research identified several risk factors for rural and low volume roads based on existing literature, including key thresholds for potential risk. This also includes project close-out and managing collected data long-term.

Systemic safety improvement means a proven safety countermeasure(s) that is widely implemented based on high-risk roadway features that are correlated with particular severe crash types.[36]

As part of the research process, the research team developed a suite of data elements that can support FLH and FLMA safety analysis efforts moving forward. This includes a complete list of data elements that could support various safety needs on road segments, curves, intersections, and intersection approaches. These data also apply to non-motorized modes, as well as supporting wildlife crossing analysis and related safety needs. The research team further refined this list of data elements into prioritized "Short Forms:"

- Risk Factor Thresholds.
  - Tangents.
  - Horizontal Curves.
  - Intersections.
  - Non-Motorized Modes.
- Qualitative Observations.
- Countermeasure Presence.

These Short Forms reflect risk factors or countermeasures that are most applicable to safety needs on Federally-managed roads. These data elements can be applied strategically throughout the framework, particularly at times where data are limited, and data collection efforts require focus.

Short Forms can be used as a "star" or "point" system for identifying high risk locations; tangents, curves, or intersections that have a high number of risk factors or "stars" can be prioritized for potential improvements. Likewise, locations without countermeasures present could be reviewed for future installation.

Table 2 lists data elements prioritized for each Short Form, and Appendix B: Short Form User Manual and Appendix C: Data Element User Manual contain user manuals for each Short Form and data element.

Table 2. Short form data elements.

SHORT FORM	DATA ELEMENTS
Tangent/Curve	› Average lane width › Shoulder type › Shoulder width › Radius *(Curve Only)* › Delineation › Grade › Driveway/access point density *(Tangent Only)* › Intersection, driveway, or other access point present *(Curve Only)* › Side slope › Horizontal sight distance *(Curve Only)* › Vertical sight distance › Presence of a visual trap *(Curve Only)* › Distance to fixed roadside objects › Type of fixed roadside objects › Unpaved road *(Tangent Only)* › Poor pavement condition *(Tangent Only)* › On-street parking *(Tangent Only)* › Crash history › Daily traffic count › Posted speed limit *(Tangent Only)*
Intersection	› Intersection angle › Traffic control › Lighting › Left turn lane (on uncontrolled approach) › Crash history › Daily traffic count (sum of major and minor approaches)
Non-Motorized	› Sidewalk/sidepath › Informal or “desire” path › Lighting › Crossing markings › Crossing signage › Crossing refuge › Crossing signal › Posted speed limit › Crash history

SHORT FORM	DATA ELEMENTS
Qualitative/Site Observation	› Sight distance limitation (Vertical/Horizontal) › Average lane width (Narrow roads; passing width) › Shoulder width (No or limited shoulders) › Side slope (steep slopes) › Pavement edge dropoff › Roadside objects (Distance) › Roadside objects (Type) › High use turnout/scenic view › Public events › Speeding issue (Anecdotal) › High crash location (Anecdotal) › Intermittent obstruction (e.g., Rock fall or flooding) › Pavement condition › Motorized mixed use › Informal or “desire” path › Frequent non-motorized crossings › Parking on shoulder › Seasonal closure › Large vehicles (e.g., trucks, RVs)
Countermeasure	› Traffic control type (e.g., all-way stop) › Lighting › Delineators › Warning signage › Regulatory signage › Wayfinding signage › Centerline markings › Edge-line markings › Number of approach exclusive left-turn lanes › Number of approach exclusive right-turn lanes › Centerline rumble strips › Shoulder rumble strips › Advisory pavement marking › Dynamic speed signage › Outside barrier › Median (type, width, and barrier) › SafetyEdge^{SM} › Sidewalk/Sidepath › Crosswalk › Bicycle markings (including wide paved shoulder) › High friction surface treatment

Develop a Focus for Safety Analysis

Federal policy stresses DDSA to support eligibility criteria for federal safety funds.[37] This includes strategic planning. Strategic safety planning identifies broad priorities for an entire agency or jurisdiction that can be targeted through spot (i.e., individual location) or systemic (i.e., multiple location) improvements.[37] Agencies can assess these priorities through a variety of methods and scale the efforts to meet the capacity of each FLMA, Tribe, or other local agency.

Relevant Plans

HSIP, the principal safety-specific Federal funding program, requires strategic planning prior to funding application. Specifically, HSIP requires States to develop and maintain a SHSP on a regular five-year (or fewer) cycle (23 CFR 924.9). Projects funded through HSIP must demonstrate their connection to the SHSP through prioritized focus or "emphasis" areas (23 CFR 924.9). Additional funding mechanisms available to FLMA agencies, as well as their Tribal and local partners, also emphasize applicability to existing plans:

- **FLAP:** This funding mechanism is intended to, "improve transportation facilities that provide access to, are adjacent to, or are located within Federal lands."[38] FLAP project selection criteria often explicitly refer to an, "FLMA plan, State or County Comprehensive Plan," as a favorable indicator in project scoring.[39] Furthermore, FLAP criteria also suggest that consensus agreement for project priority between the State DOT, FLMA, and the facility owner/applicant is a major consideration for funding. A documented plan improves an applicant's ability to demonstrate this consensus.
- **Tribal Transportation Program Safety Funds (TTPSF):** TTPSF eligibility covers, "strategies, activities, and projects on a public road that are consistent with a transportation safety plan and (i) correct or improve a hazardous road location or feature, or (ii) address a highway safety problem."[40]
- **Safe Streets for All (SS4A):** SS4A funds are available to metropolitan planning organizations (MPOs), counties, cities, towns, Tribes, and other agencies or subdivisions of a State. This funding mechanism covers both action planning and implementation activities. Eligibility for implementation funding requires that, "applicants must have an existing Action Plan to apply for Implementation Grants or have an existing plan that is substantially similar and meets the eligibility requirements of an Action Plan."[41]
- **Rural Surface Transportation Grant Program:** The Rural Surface Transportation Grant Program supports projects that improve and expand the surface transportation infrastructure in rural areas.[42] Like other BIL-related programs, this competitive funding source is intended to increase connectivity, improve the safety and reliability of the movement of people and freight, and generate regional economic growth and improve quality of life. This program will allocate $2 billion in funding over fiscal years 2022 through 2026.

Table 3 provides some framework questions and strategies to help develop a safety focus from existing or upcoming plans if one is not readily available.

Table 3. Questions and strategies for developing a safety focus from recent plans.

KEY QUESTIONS	RECOMMENDED ANALYSIS STRATEGIES
Is there an existing strategic plan or Needs Assessment for your jurisdiction?	› Consider the applicable State SHSP for potential emphasis areas. › Consider the most recent Needs Assessment for the applicable State for priority locations and frequent issues. › Consider past projects or field reviews for documented safety issues that can be systemically addressed.
Is there an upcoming Needs Assessment or strategic planning effort?	› Consider using the Qualitative Short Form to obtain feedback from a non-technical or non-safety specific audience. › Consider using web maps to convey existing conditions to stakeholders (e.g., funding eligible roads, traffic volumes, historic crashes, etc.). › Consider using Crowdsource applications or custom data collection tools to obtain digital feedback from stakeholders.

Focus Crash and Facility Types

FLMAs, Tribes, and local agencies will have varying data availability and analytical capability. The primary criterion for determining this capability relates to the availability and reliability of crash data (figure 2). In other words, agencies without reliable crash data must rely on roadway, traffic, and other contextual characteristics to determine crash risk. To support practitioners with varied or limited safety data available, this framework proposes three tiers of analysis for FLMAs assessing their strategic safety focus:

1. Risk Factor Focused.
2. Crash Data Focused.
3. Network Safety Management.

Risk Factor Focused

A Risk Factor Focused Approach could be considered in contexts where data, staff, and/or analysis capabilities are limited. This research identified several risk factors for tangents, curves, intersections, and non-motorized users (i.e., risk Short Forms) that could serve as baseline safety issues for FLMA plans to address. These risk factors can be supplemented by local stakeholder input, qualitative data, or support for other agency objectives (i.e., pedestrian mobility or transit stop access).

Crash Data Focused

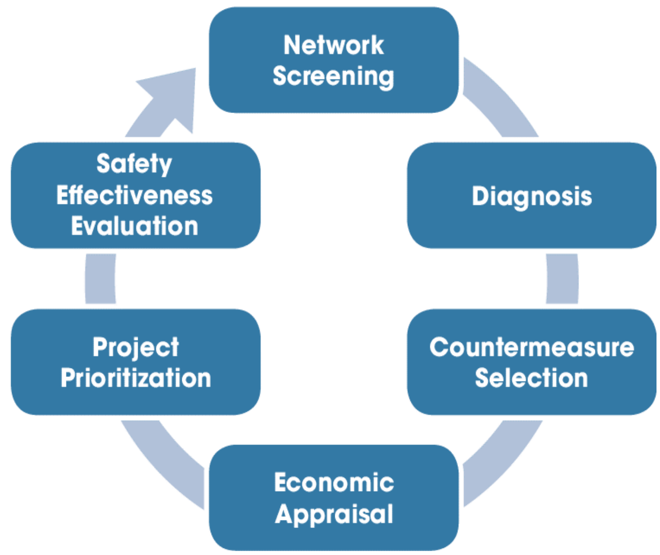
If crash data are available, even if these data are not spatially located, there are several tools available to practitioners that can help delineate risk factors. This approach also borrows from FHWA's *Systemic Safety Project Selection Tool*, as focus crash types can be used to identify focus facility types and associated risk factors. FHWA's Crash Tree Tool provides a user-friendly way for agencies to quickly assess trends, risk factors, and contributing circumstances. The Microsoft Excel™-based tool filters crashes based on crash-level attributes and displays the results in a graphic output.

The FHWA *Crash Data Summary Template* is another systemic analysis tool that uses crash data to assess local trends.[33] While the graphic interface is less robust than the *Crash Tree Tool*, this tool helps isolate patterns unique to a local jurisdiction by comparing local crash proportions to crash proportions from a reference region. For instance, a participating FLMA, Tribe, or local agency can compare the distribution of contributing circumstances on local roads relative to the region or State as a whole (or compare high severity crashes to all crashes or lower severity crashes on the agency's roads).

Finally, the Risk Factor and Crash Data Focused approaches can be combined. For instance, crash data can determine that roadway departure is a substantial issue in a particular FLMA jurisdiction, and Short Form curve-related risk factors can help prioritize where improvements are most critical.

Network Safety Management

The Network Safety Management approach is intended to provide a framework for collecting enterprise-wide safety data for more rigorous hot spot and systemic safety analysis, including the use of predictive methods. This approach directly adopts the six-step Roadway Safety Management Process in Part B of the First Edition of the HSM (figure 6).[23] Although the practical user base for this approach is anticipated to be small in the FLMA and Tribal community, NPS has collected data to support Safety Analyst™ at 24 parks in the continental U.S. The NPS's RIP, managed by EFLHD, can be leveraged to maintain these data long-term.



Source: FHWA

Figure 6. Graphic. Roadway safety management process.[43]

Even without Safety Analyst™ or a custom SMS, usRAP and the ViDA software could be an alternative for agencies with limited crash data. usRAP does not require crash data; however, it is still a data intensive approach that would require robust data collection across all roads within a study area. Since FLH is not the sole data steward for any individual FLMA or Tribe, this approach would require close coordination with each FLMA to collect data along all relevant routes, including standardization of data within a linear referencing system (LRS) framework.

Table 4 provides some framework questions and strategies to help develop a safety focus from available data.

Table 4. Questions and strategies for developing a safety focus with available data.

KEY QUESTIONS	RECOMMENDED ANALYSIS STRATEGIES
Do you have access to reliable roadway data?	› **No:** Consider using the risk factor Short Forms as a guide for identifying locations for safety improvements. › **Yes:** Consider using available roadway attributes to identify risk factors and to supplement the crash analysis (if applicable):
Do you have access to reliable geolocated crash data?	› **No:** Consider using road and roadside characteristics along with countermeasure presence and other contextual data (i.e., functional class and popular destinations) to map priority risk factors. The Short Forms can help inform critical needs in the absence of other data. › **Yes:** Consider using FHWA's Crash Tree Tool and Crash Data Summary Template to identify an emphasis area and associated focus crash types and facility types, for example: » Roadway departure. » Non-motorized users. » Wildlife collisions. » Time of day or year. » Needs of resident users or visitors.
Do you have access to comprehensive traffic count data?	› **No:** Consider using road and roadside characteristics along with countermeasure presence and other contextual data (i.e., functional class and popular destinations) to map priority risk factors. › **Yes:** Consider using traffic volumes to guide where risk factors should be prioritized (i.e., where exposure is highest or where factors are overrepresented relative to exposure).
Are you interested in pursuing a comprehensive safety strategy for your agency?	› Consider pursuing usRAP, Safety Analyst™, or similar HSM-based analytical tool to focus data collection that will support the tool.

Establish a Use Case for Safety Data

Local action plans and project development should reflect the strategic priorities of the stakeholders involved. The literature review demonstrated that documentation of priorities and agency collaboration increase the likelihood of funded and implemented improvements. This component of the data collection framework outlines considerations for practical application based on the intended use of the data.

Use Case Scope

The potential application or "use case" for safety data can help guide practitioners as they prioritize data needs. This includes LRSPs and SAPs, as well as location-specific project development.

Planning and Project Programming: Strategic plans inform high-level needs. Action plans explicitly prioritize where and how resources will be deployed to address these needs. As a result, relevant data should be available at a scale that supports network screening and site identification. Furthermore, data could support diagnosis and countermeasure identification by allowing practitioners to identify overrepresented characteristics and key threshold criteria for specific improvements in the network (figure 7).

Roadway Configuration	Posted Speed Limit and AADT																										
	Vehicle AADT <9,000									Vehicle AADT 9,000-15,000									Vehicle AADT >15,000								
	≤30 mph			35 mph			≥40 mph			≤30 mph			35 mph			≥40 mph			≤30 mph			35 mph			≥40 mph		
2 lanes (1 lane in each direction)	1*	2		1*			1+			1*			1*			1+			1*			1+			1+		
	4	5	6		5	6		5	6	4	5	6		5	6		5	6	4	5	6		5	6		5	6
				7		9	7*		9*				7		9	7*		9*	7		9	7		9			9*
3 lanes with raised median (1 lane in each direction)	1*	2	3	1*		3*	1+		3*	1+		3	1+		3*	1+		3*	1+		3*	1+		3*	1+		3*
	4	5			5			5		4	5			5			5		4	5			5			5	
				7		9	7*		9*	7		9	7*		9*	7*		9*	7		9	7*		9*			9*
3 lanes w/o raised median (1 lane in each direction with a two-way left-turn lane)	1*	2	3	1*		3*	1+		3*	1+		3	1+		3*	1+		3*	1+		3*	1+		3*	1+		3*
	4	5	6		5	6		5	6	4	5	6		5	6		5	6	4	5	6		5	6	5	6	
	7		9	7		9			9*	7		9	7*		9*			9*	7		9			9*			9*
4+ lanes with raised median (2 or more lanes in each direction)	1*		3*	1*		3*	1+		3*	1+		3*	1+		3*	1+		3*	1+		3*	1+		3*	1+		3*
		5			5			5			5			5			5			5			5			5	
	7	8	9	7	8	9		8	9*	7	8	9	7*	8	9*		8	9*	7*	8	9*		8	9*		8	9*
4+ lanes w/o raised median (2 or more lanes in each direction)	1*		3*	1+		3*	1+		3*	1+		3*	1+		3*	1+		3*	1+		3*	1+		3*	1+		3*
		5	6		5	6*		5	6*		5	6*		5	6*		5	6*		5	6*		5	6*		5	6*
	7	8	9	7	8	9		8	9*	7	8	9	7*	8	9*		8	9*	7*	8	9*		8	9*		8	9*

Given the set of conditions in a cell,

Signifies that the countermeasures is a candidate treatment at a marked uncontrolled crossing location.

* Signifies that the countermeasure should always be considered, but not mandated or required, based upon engineering judgement at a marked uncontrolled crossing location.

+ Signifies that crosswalk visibility enhancements should always occur in conjunction with other identified countermeasures.

The absence of a number signifies that the countermeasure is generally not an appropriate treatment, but exceptions may be considered following engineering judgement.

1 High-visibility crosswalk markings, parking restrictions on crosswalk approach, adequate nighttime lighting levels, and crossing warning signs.

2 Raised crosswalk

3 Advance Yield Here to (Stop Here For) Pedestrian sign and yield (stop) line

4 In-Street Pedestrian Crossing sign

5 Curb extension

6 Pedestrian refuge island

7 Rectangular Rapid-Flashing Beacon (RRFB)

8 Road Diet

9 Pedestrian Hybrid Beacon (PHB)

Source: FHWA

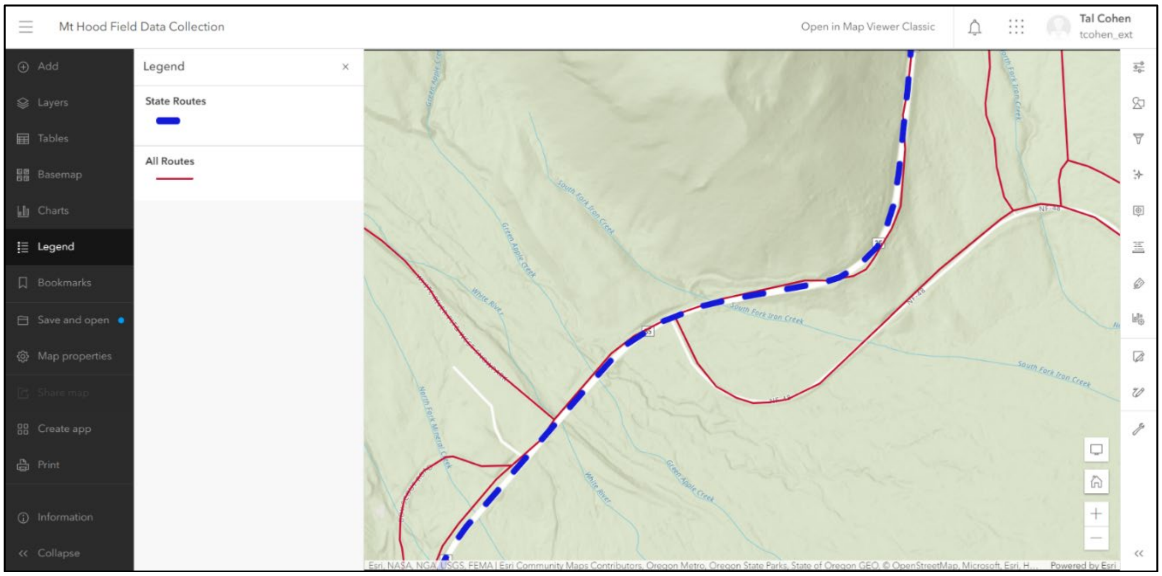
Figure 7. Graphic. FHWA's Guide for Improving Pedestrian Safety at Uncontrolled Crossing.[44]

For instance, if traffic volumes, number of lanes, median type, and posted speed limit data are available, systemic diagnosis can assess the level of risk associated with each factor. Network screening can then focus on locations with the highest risk and where countermeasures would be applicable for installation (e.g., raised crosswalks or pedestrian hybrid beacons).

Project Development: Once projects move from prioritization to implementation, safety data can be collected to support site-specific analyses. This includes support for safety analysis software such as the Interactive Highway Safety Design Model (IHSDM) that can help diagnose potential issues, as well as observational studies that can recommend specific improvements (e.g., RSAs). These data can also support the development of PS&E documents by identifying qualitative and quantitative risk factors and demonstrating safety as a project need. Quantitative metrics (i.e., number of curves or mileage of road) can also support planning-level cost estimates for potential projects.

Geographic Scale

FLH collaborates with many transportation safety stakeholders nationwide. These include FLMAs, Tribal agencies, State DOTs, and local governments. This diversity increases the complexity associated with safety planning and engineering, as well as the governance, management, and maintenance of safety data. For instance, a study may require road centerline data from two agencies (e.g., a State DOT and an FLMA) and the collected centerline network may comprise three separate schemas (e.g., State-maintained roads, locally maintained roads, and FLMA roads). Figure 8 provides an example from Mt. Hood National Forest in Oregon.



Source: FHWA

Figure 8. Graphic. Example of geographic mismatch between State and FLMA road data.

Table 5 provides some framework questions and strategies to assess data collection needs based on the analysis use case and the availability of data.

Table 5. Questions and strategies for understanding data required for a use case.

KEY QUESTIONS	RECOMMENDED ANALYSIS STRATEGIES
Do you require data for an entire jurisdiction or a smaller study area (i.e., corridor or intersection)?	› Consider obtaining planning-level roadway and contextual data at a jurisdictional level, for example: » Functional classification. » Surface type. » Traffic volume. » Number of lanes. » Road/lane width. » Posted speed limit. » Traffic control. › Consider obtaining design-level characteristic data for more granular studies, particularly data elements noted in the Short Form.
Does your analysis inform planning priorities or project scoping and design?	› Consider obtaining national or State-level data for planning priorities. › Consider data from local sources or field collection for project scoping and design.
Does your study area encompass more than one road owner or stakeholder agency?	› Consider engaging all participants for available data. › Use FLH's ArcGIS Online or Transportation GIS at FLH managed services portal to manage data sharing and appropriate access.

Identify Gaps

FLH does not "own" or actively maintain many of the datasets necessary for safety analysis. These data are owned by a series of stakeholders including FLMAs, Tribes, State DOTs, and local governments. Data gaps exist as a result of both uneven data collection (i.e., data may be collected for one FLMA, but not for another), as well as disparate responsibilities within the same agency (i.e., data may be selectively maintained by different units within the same agency). This component of the framework will help FLH identify gaps in safety data availability and coverage and evaluate approaches to address these gaps.

Furthermore, user access to safety datasets may vary by agency, and each agency may have disparate methods for sharing that data. Most FLMAs provide some degree of GIS data access through agency-specific open data portals. For instance, the NPS Navigator application is a geospatial map that enables the general public to visualize NPS data, including the RIP dataset.[45] The USFS Enterprise Data Warehouse (EDW) has individual applications that allow the general public to download individual USFS datasets locally.[46] Coordination between FLH and FLMAs on the location of existing data and a plan for long-term storage and access will be essential.

Existing Data

As practitioners refine the scope and scale of a safety analysis use case, they should be conscious of needed data inputs and potential sources for these data. Table 6 provides some framework questions and strategies to assess potential gaps in existing (or known) data.

Table 6. Questions and strategies to consider when assessing data gaps.

KEY TOPICS	RECOMMENDED QUESTIONS AND ANALYSIS STRATEGIES
Strategies by Potential Use Case	› **Plan Development:** Prioritize sites for improvement with supporting countermeasures across a broad geographic area. › **RSA/Site Evaluation:** Review site-specific risk factors and develop recommendations for improvements. › **Funding Application:** Develop costs for addressing a specific safety need associated with a suite of improvements (either systemically or at a single site). › **Project Development:** Refine project design and countermeasures for an individual project.
Questions for Dimensions of Available Data	› **Geographic Scale:** Are data available for the entire study area (i.e., agency, region, unit, corridor, or intersection)? › **Risk Factor Presence:** Are practitioners able to discern specific risk factors associated with safety focus areas (i.e., based on analysis results)? › **Countermeasure Presence:** Are practitioners able to discern the location of countermeasures that could indicate a reduced risk (i.e., present at a high-risk location) or an increased risk (i.e., not present at a location)?

Data Sources

Existing data vary in quality and completeness by geography and agency. Table 7 presents existing data sources that can support systemic analysis on FLMA roads. While this list may not be comprehensive, it provides a starting point for agencies to identify sources for data such as horizontal and vertical geometry, cross section and roadside features, traffic and operations characteristics, multimodal facilities, wildlife activity, and existing safety features. Agencies are encouraged to seek other custom datasets available to individual regions or units.

Table 7. Essential data types and resources for safety analysis on FLMA and Tribal roads.

DATA NEED	DATA TYPES	RESOURCES
Horizontal Geometry	› Centerline(s)	› RIP › EDW (USFS) › Highway Performance Monitoring System (HPMS) › Curve Finder (University of Wisconsin's Traffic Operations and Safety Laboratory)
Vertical Geometry	› Digital elevation models (DEMs) › Light detection and ranging (LiDAR) point cloud › Canopy heights	› National Map (United States Geological Survey; USGS) › ScienceBase Catalog (USGS)
Cross Sectional	› Road characteristics › Number of lanes › Surface/lane width › Median type/width › Surface type › Aerial imagery	› RIP › EDW › HPMS › National Agriculture Imagery Program
Roadside	› Centerline(s) › Digital elevation models (DEMs) › Light detection and ranging (LiDAR) point cloud › Street-level imagery	› RIP (including wall and guardrail inventories) › EDW › National Map
Traffic and Operations	› AADT or individual counts › Functional classification › Posted speed limit › Crowdsource data › Connected vehicle and probe data › Visitor counts › Campground occupancy › Other surrogates	› HPMS › National Transportation Atlas Database (NTAD; Bureau of Transportation Statistics) › Integrated Resource Management Applications (NPS) › Continuous Counter System (NPS) › Visitation Estimation & Reporting System (VERS; USACE) › National Visitor Use Monitoring Program (USFS) › Recreation Management Information System (BLM) › National Recreation Reservation Service › Waze (via USDOT) › Regional Integrated Transportation Information System (RITIS) › Third-party providers » Wejo » Inrix » StreetLight » HERE » Replica » TomTom » AirSage » TrafficCast

DATA NEED	DATA TYPES	RESOURCES
		» NAVTEQ
Multimodal	› Trail centerlines › National Transit Inventory	› FLMA open data portals › Trails Explorer Application (USGS) › NTAD › Census Bureau » American Community Survey » Longitudinal Employer-Household Dynamics › Third-party providers » StreetLight » Strava
Wildlife	› Carcass locations › Observations › Land cover	› Roadkill Observation and Data System (ROaDS) › National Land Cover Database
Existing Safety and Traffic Features	› Signage › Roadside/Median Barriers › Traffic control devices › Pavement markings	› RIP › EDW › National Wildlife Refuge System sign inventory (USFWS) › National Bridge Inventory (USDOT)

Address Gaps

This research investigated several methods for obtaining safety data on FLMA roads. These include quantitative and qualitative methods, as well as tools for verifying data in the field.

Quantitative Methods

Quantitative methods refer to those that produce measurable information about the performance of the transportation system. Quantitative data collection generally come in two forms, 1) data that can be derived from existing sources of information, and 2) data collected specifically for an intended analysis use case. FLH coordinated with the EFLHD's RIP Team during this research effort as an example of programmatic quantitative data collection. The research found noteworthy methods that include derived and custom, study-specific methods:

Derived Data

- Horizontal curvature estimated from existing digital road centerlines.
- Vertical grade and slopes estimated from DEMs.
- Surrogate data that could correlate with safety conditions:
  - Land cover and use.
  - Posted speed limits.
  - Functional classification.
  - Visitation and reservation counts.
  - Trail and destination locations.

Data Collected for a Specific Use Case

- Aerial imagery.
- Photologs.
- Traffic counts.
- LiDAR.
- Probe/Bluetooth.
- Location based services (LBS).
- Connected vehicles.

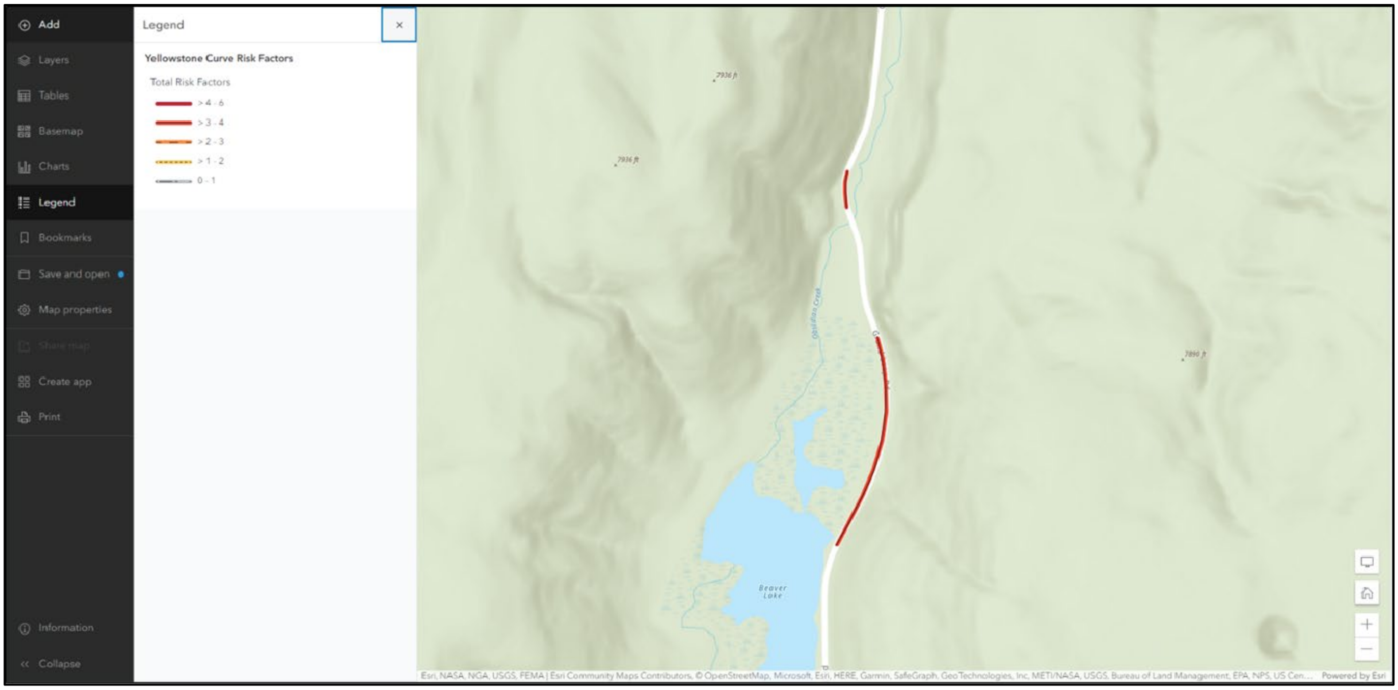
The following section details specific methods and data requirements for methods that can support the most critical analysis needs as defined by the Short Forms and framework.

Quantitative Analysis Methods

The research uncovered several methods of addressing key risk factors on FLMA roads, particularly in locations where crash data are limited or unavailable. The following sections describe ways to evaluate low-volume roads using data and tools available to FLH and FLMAs nationwide.

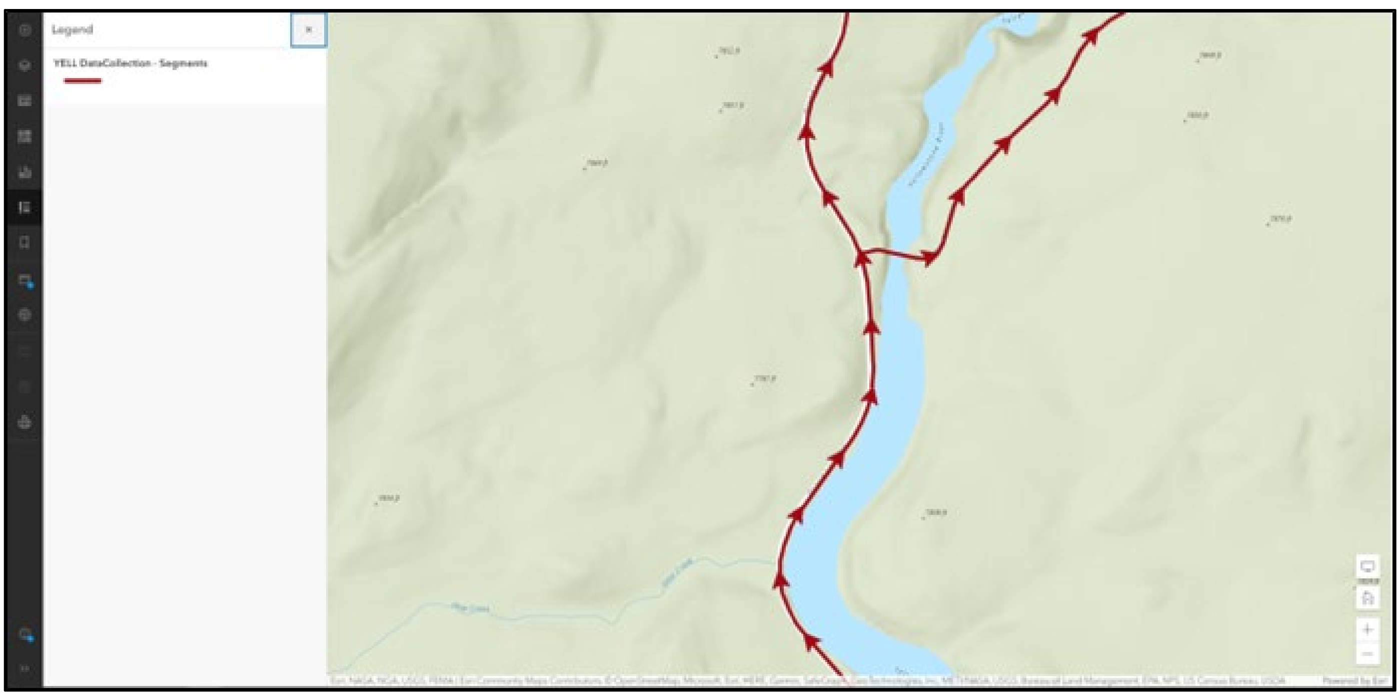
Segmentation

Segmentation refers to the process of organizing data to develop individual units of analysis and site development. It can vary by use case. For simpler analyses, assigning segments as either curves or tangent sections can help refine risks at general locations. More complex analyses, particularly when linear referencing is available, can use mileposts to generate segments of equal length (e.g., 0.1 miles). This is beneficial when screening for conditions that may change frequently along a corridor (e.g., roadside clear zone). Figure 9 and figure 10 illustrate the spatial differences between these two approaches. Future data development could apply linear referenced data (i.e., route and milepost) to dynamically segment FLMA roads for analysis; this is particularly useful when analyzing several characteristics (e.g., posted speed limit, number of lanes, lane width, median type, etc.) from a safety perspective.



Source: FHWA

Figure 9. Graphic. Sample of curve-based screening in Yellowstone National Park.



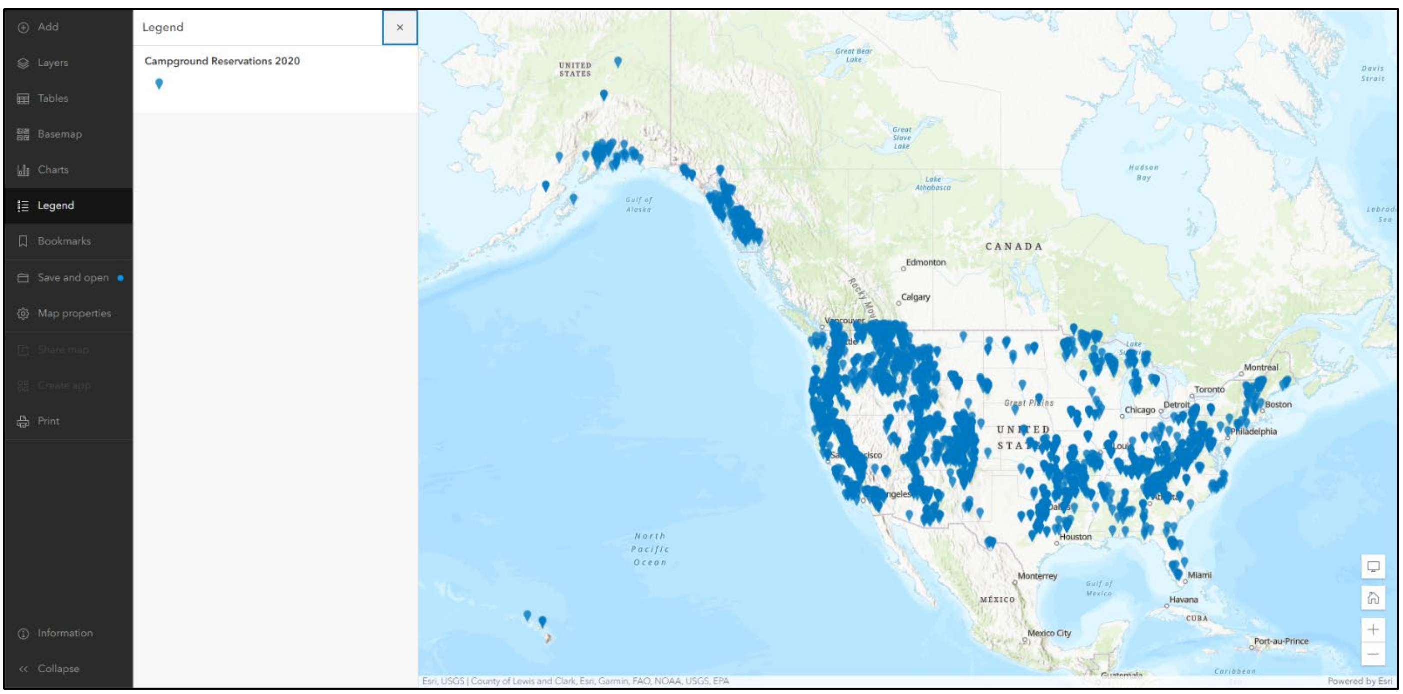
Source: FHWA

Figure 10. Graphic. Sample of equal length segment screening in Yellowstone National Park.

Exposure and Surrogates for Exposure

Exposure is important for assessing safety on FLMA roads. Many of these roads are located in highly rural contexts and carry relatively low traffic volumes; roads with a high number of risk factors and a relatively high exposure should be prioritized for safety improvement. Traffic may also vary considerably throughout the year, as some roads may be closed for several months at a time while others may lead to destinations with discernable peak seasons. Traditional traffic counts are a highly effective method for assessing exposure, but the case studies also documented several other methods for assessing seasonal exposure:

- **Functional Classification:** Specific functional classification definitions may vary by FLMA (see maintenance levels for USFS roads), but the intent is consistent; functional classification is an indication of the purpose and use of a particular road. Safety analyses, particularly at a planning level, could focus on higher functional classification roads (i.e., arterials) where vehicular traffic tends to be highest. Furthermore, moderately high functional classifications (i.e., collectors) may carry less traffic, but these roads may not be built to the same standard as higher functional classes (i.e., unpaved or narrow travel way). The combination of moderate traffic and design standard could be a focus of safety improvements.
- **Reservation Data:** Reservation data collected and aggregated by the National Recreation Reservation System (NRRS) provides a catalog of historic visitation data. Although these data reflect active reservations and would not include pass through traffic, it allows analysts to review trends month over month and year over year. Data from the Recreation Information Database (RIDB) can be geolocated by destination (figure 11).



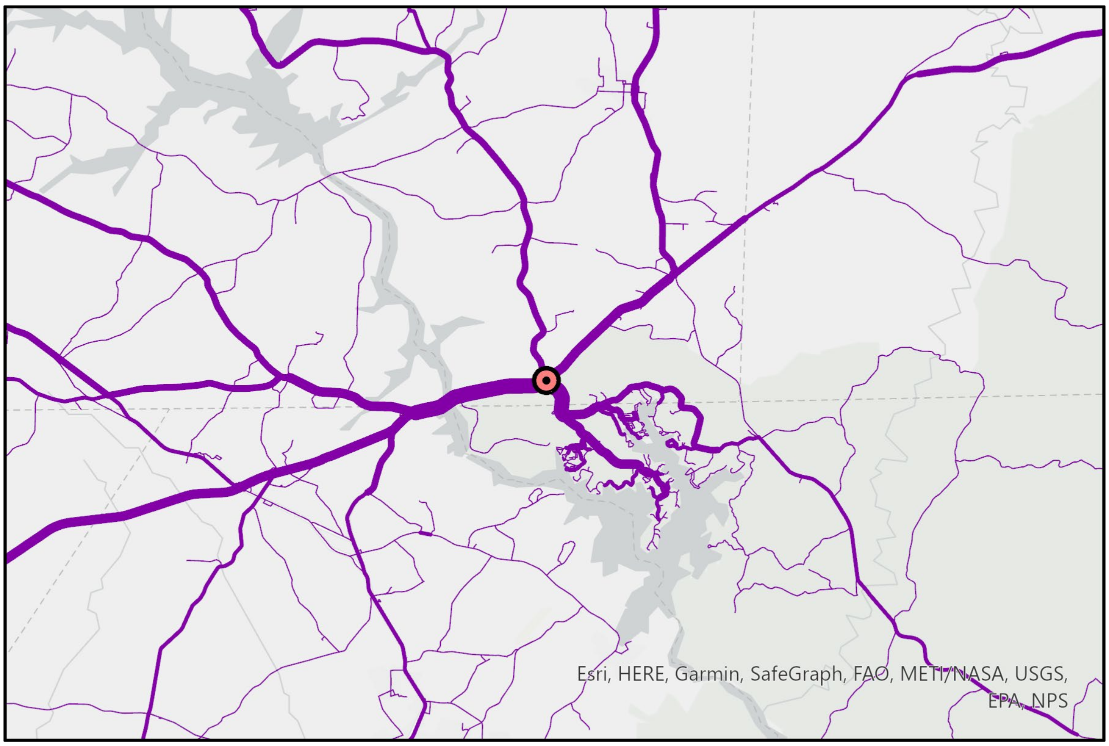
Source: FHWA

Figure 11. Graphic. Geolocated reservation data for 2020.

- **Points of Interest:** Absent reservation or other count data, points of interest can provide key indicators of trip destinations, crossings, and parking. This also includes multimodal analysis, as trails and trailheads are indicators of non-motorized exposure.

› **Big Data:** There are a host of datasets that provide samples of exposure from probe, connected vehicle, Bluetooth, or location-based services (LBS). Traffic counts are a more reliable indicator of exposure at the time of the count because Big Data tend to have a relatively low "capture rate," or proportion of total traffic included in the data estimate. The following are advantages of Big Data:
   - The ability to estimate exposure when no traffic counts are available.
   - The ability to track origins and destinations of vehicles that pass through a key point in the road network (figure 12).
   - Estimates of average travel speed for particular road segments.

One drawback of Big Data is that these data are typically available for purchase through third-party vendors, and this approach may not be the most cost effective for jurisdiction-wide analyses.

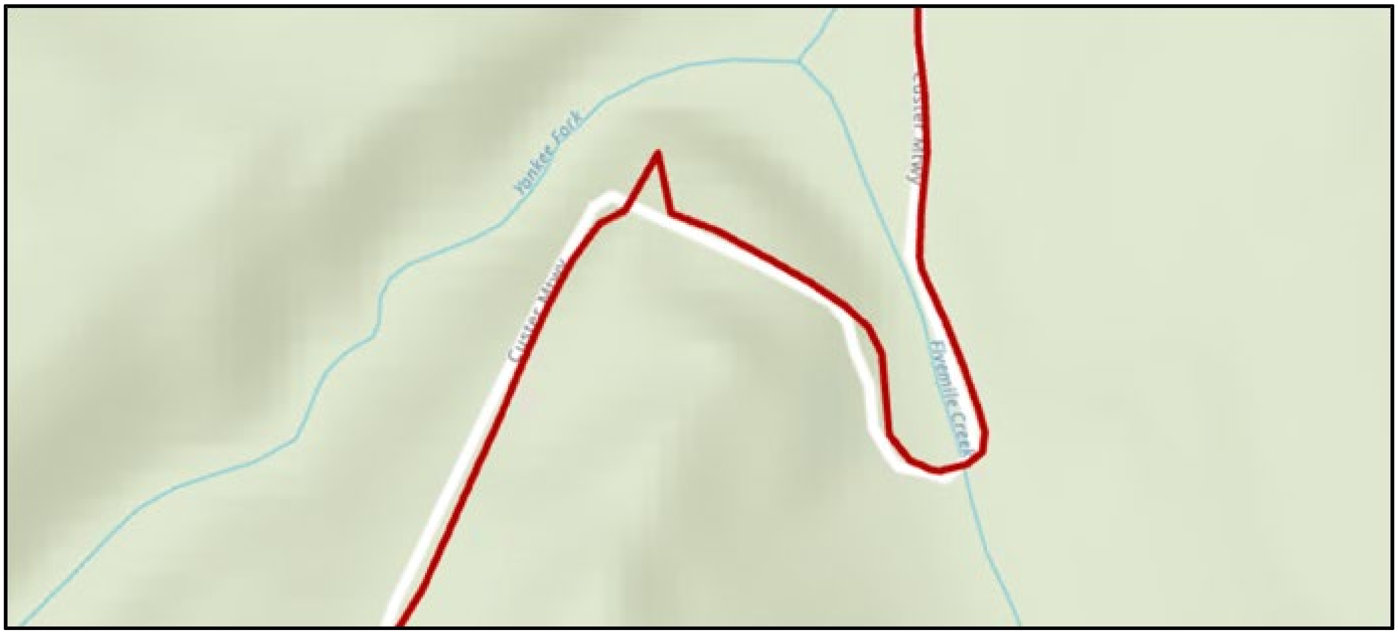


Source: FHWA

Figure 12. Graphic. Sample web map application showcasing trip origins and destinations associated with connected vehicle and probe data.

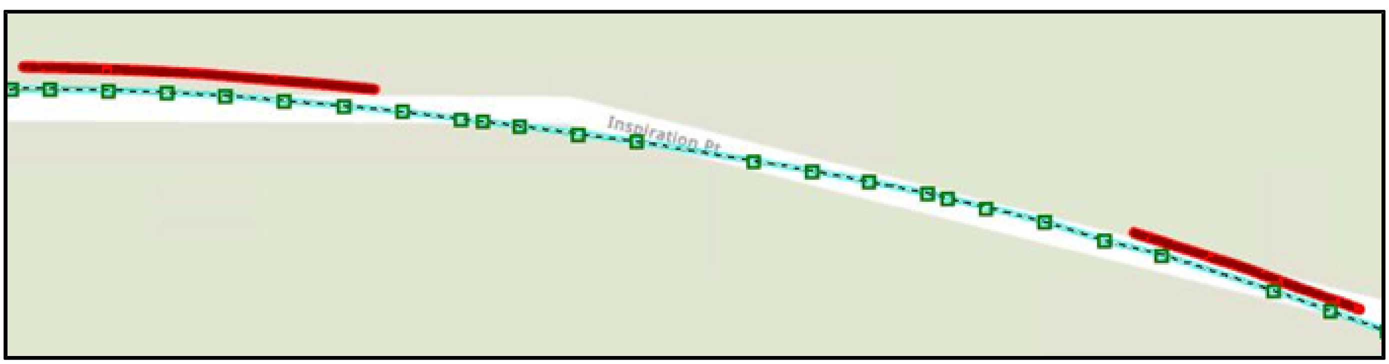
Horizontal Geometry and Risk

Horizontal curvature is a potential risk factor for FLMA roads, particularly on sharp curves that have sight distance limitations or fixed roadside objects that could be struck as a vehicle departs the roadway. Horizontal curvature can be derived from a GIS centerline network; however, the accuracy of the centerline as a representation of the curve will affect tool outputs. Common issues with centerline geometry include sharp angles that do not reflect smoother ground conditions (figure 13), as well as closely spaced vertices that may not exhibit enough deflection between points to indicate a curve is present (figure 14).



Source: FHWA

Figure 13. Graphic. Example of a harsh angle in centerline geometry.



Source: FHWA

Figure 14. Graphic. Example of closely spaced vertices along a curve.

Design Consistency

AASHTO's *A Policy on Geometric Design of Highways and Streets* (i.e., the Green Book) provides two key notes related to horizontal alignment design consistency(47):

1. "Sharp curves should not be introduced at the ends of long tangents."
2. "Where sharp curvature is introduced, it should be approached, where practical, by a series of successively sharper curves."

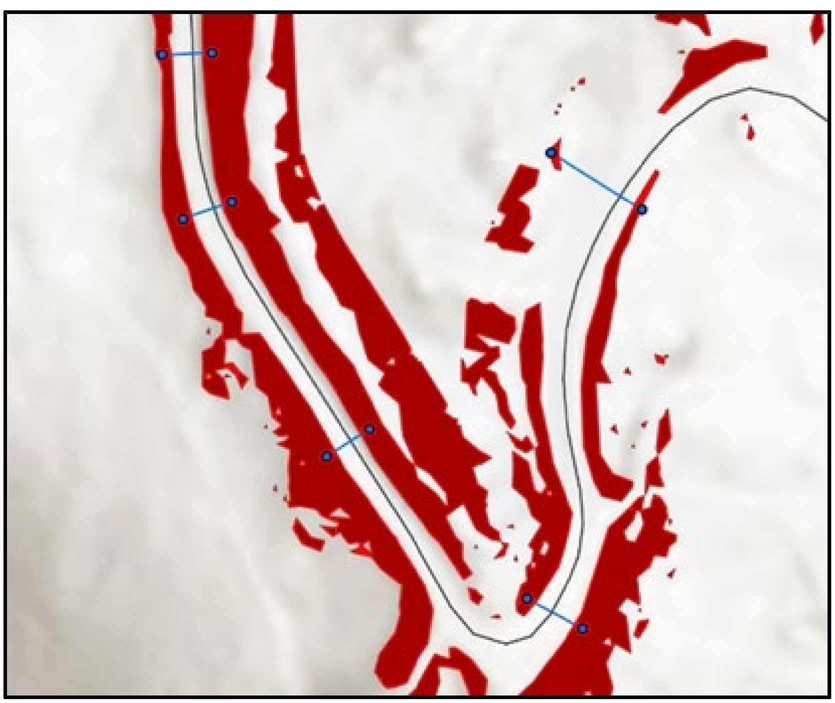
Subsequent research has observed that the safety risk associated with horizontal curvature increases if sharp, low radius curves are preceded by longer tangent segments.[48] This relates to driver expectations and the speed at which vehicles may enter the curve. Horizontal curvature derived from centerlines can be used to derive tangent segments. These can be linked to curves to highlight locations that have longer tangents entering and exiting the curve.

Vertical Geometry and Risk

Like horizontal geometry, vertical grade is another contributing factor with respect to safety. Elevation data, in the form of a digital elevation model (DEM), is available for most of the United States via the USGS National Map. These data have a resolution of 10-meters (i.e., one pixel is 10 meters wide), although some locations have higher resolution information. Using the Add Surface Information Tool in ArcGIS Pro, elevation data stored in raster format can be applied to linear segments and curves; this can produce a minimum, average, and maximum slope, as well as elevation along the segment. Note, target segment data should be projected with similar measurement units as the source DEM or elevation raster (i.e., meters to match data in the National Map) to obtain reasonable slope estimates.

Recoverable Area Assessment

High resolution elevation data (i.e., higher than 1 meter) can also help calculate sideslopes, and by extension, recoverable area. Sideslopes between 1V:3H (19 degrees) and 1V:4H (14 degrees) are considered traversable (but not recoverable), while sideslopes greater than 1V:3H (>19 degrees) are considered non-traversable. These thresholds can be calculated by converting the DEM to a slope calculation in raster format in ArcGIS Pro. Locations that exceed these thresholds can be extracted and analyzed to calculate traversable area and a clear zone along a corridor (figure 15).



Source: FHWA

Figure 15. Graphic. Distance between non-traversable slopes.

Although high resolution data are preferred for detailed assessments, lower resolution elevation data (i.e., between 1 and 10 meters) can still provide a visual assessment of clear zone limitations. Figure 16 and figure 17 provide a comparison of outputs between different DEM resolutions.

Source: FHWA

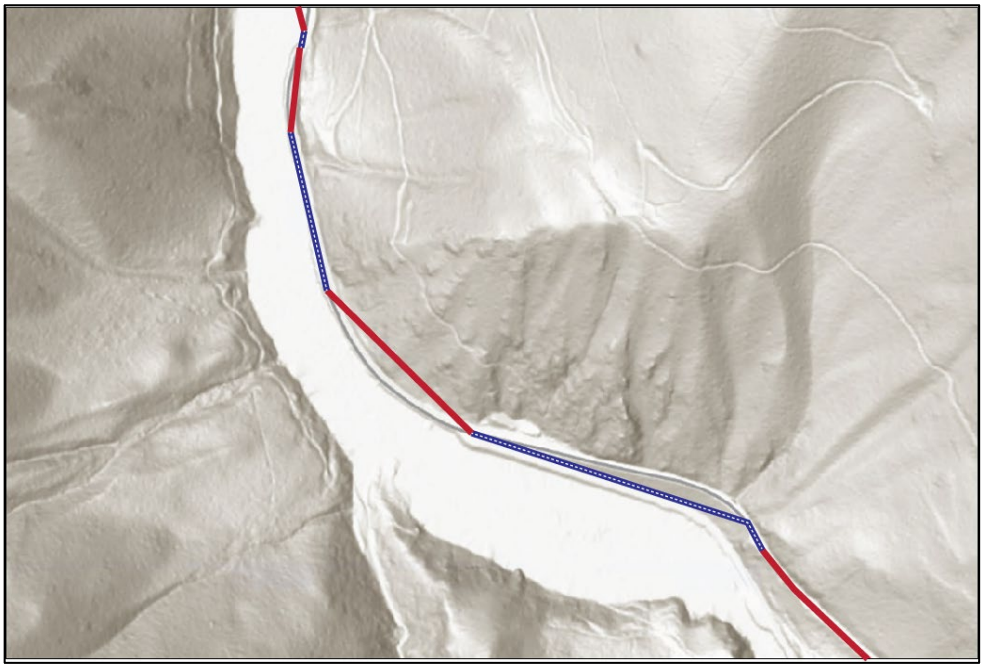
Figure 16. Graphic. Non-traversable slope output with 1-meter data.

Source: FHWA

Figure 17. Graphic. Non-traversable slope output with 10-meter data.

Sight Distance

Vertical elevation data (i.e., bare Earth) can be applied to help inform sight distance as well. Horizontal sight distance is especially relevant at horizontal curvature, and ArcGIS Pro can calculate sight distance using origin and target points. For ease of use, case studies tested the ability for a vehicle (using a subject height of four feet) to observe the far end of a curve (figure 18). Target points can be adjusted to reflect other destinations or criteria such as stopping sight distance, but the far end of horizontal curvature can suffice for planning-level applications.



Source: FHWA

Figure 18. Graphic. Sight distance on horizontal curvature (red indicates not visible).

Input elevation data should typically have a resolution of one meter or higher. Furthermore, canopy height data, such as the data furnished by Oregon's Department of Geology and Mineral Industries (DOGAMI), can supplement bare Earth data to flag locations where vegetation near the road might inhibit visibility.

Side Slope and Roadside Assessment

Clear zone and traversable area represent one component of a roadside assessment. In addition to sideslope, elevation points can complement differences between shallow and substantial drops in elevation, the latter being more of a safety concern. Table 8 and figure 19 illustrate how non-traversable slope and elevation can be combined to analyze roadside hazard.

Table 8. Sample calculations from figure 19.

Characteristic	Value (Feet)
Distance Between Non-Traversable Slopes	43.5
Roadbed Elevation	3,357
Roadside Elevation 1	3,366
Roadside Elevation 2	3,350
Roadside Elevation Difference 1	+8.9
Roadside Elevation Difference 2	-7.0

Source: FHWA

Figure 19. Graphic. Example location with sideslope and elevation data.

If canopy cover LiDAR are unavailable, another method to assess potential roadside objects, particularly trees and vegetation, is image classification from aerial imagery. The National Agriculture Imagery Program (NAIP) provides reasonably high-resolution imagery for much of the United States, although higher resolution sources may exist on a case-by-case basis. Similar analyses can be performed with image classification indicating the presence of vegetation or objects near roadsides (figure 20).

Source: FHWA

Figure 20. Graphic. Classified NAIP imagery used for roadside object analysis in Idaho.

Qualitative Methods

Qualitative methods refer to those that obtain anecdotal or observational data from local stakeholders or subject matter experts (SMEs). Qualitative data can be stratified by the intended source, either 1) SMEs or technical staff or 2) the general public and frequent users of FLMA facilities. Resources identified in this research include:

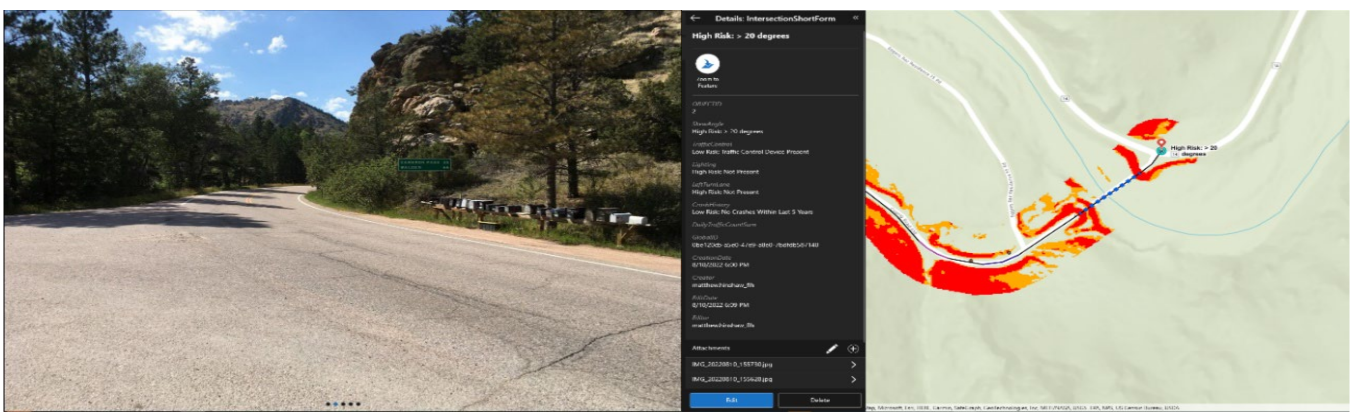
- DOI's ROaDS framework.
- Crowdsource ("wiki") web maps hosted through FLH's ArcGIS Online.
- CVTS program.
- RSAs or other observational studies conducted with FLH's custom data collection applications.

Verification

In addition to efficient methods of obtaining (or deriving) new quantitative or qualitative safety data, field verification is an important component of safety analysis. This could include several circumstances where existing data may be out of date (i.e., pavement condition issues) or where analysis requires additional detail (i.e., pavement drop offs or sight distance limitations; figure 21). The presence (or quality) of countermeasures may also modify plan recommendations or project development. In addition to risk-based and qualitative Short Forms, the project team developed a Short Form for users to record countermeasure observations (figure 22).

Source: FHWA

Figure 21. Graphic. Example of field verifying safety risk.



Source: FHWA

Figure 22. Graphic. Sample intersection short form collected at Route 63E in Larimer County, CO.

Prioritize and Implement

The final component of the data collection framework is prioritization and implementation. This is the result of:

- Developing a safety focus and documenting it in a plan.
- Establishing a use case for safety data.
- Identifying gaps in the data that would support the intended use case.
- Addressing those gaps in available safety data.

Key prioritization activities will vary by use case, but key considerations when applying safety data include:

Star Ratings and Systemic Safety: Star ratings (or point ratings or counts of risk factors) are a common method for prioritizing sites in systemic safety analysis. Locations with a high number of risk factors (i.e., meeting or exceeding high risk thresholds in the Short Form checklists) are locations where improvements could be prioritized. Short Forms are the most readily implementable concept of this research for immediate application on FLMA roads.

Priority Countermeasures: FHWA updated its Proven Safety Countermeasures initiative (PSCi) in 2021. This list provides a collection of countermeasures that are proven effective at reducing fatalities and serious injuries.(49) FLH safety data would focus on network characteristics that would help identify these locations.

Equity: Equity is an increasingly important component in modern transportation safety analysis. The USDOT's NRSS emphasizes equity as a key component of reaching the overall national goal of reducing fatalities and serious injuries.(50) Specific criteria for underserved and disadvantaged populations will vary by context, but there are national resources available to assist practitioners. The USDOT's Areas of Persistent Poverty Project (APP) and Historically Disadvantaged Community (HDC) Status Tool(51) provides jurisdiction-wide screening for disadvantaged communities that may be used under Justice40-covered grant programs, and FHWA's Screening Tool for Equity Analysis of Projects (STEAP) allows users to buffer potential projects and screen against various demographic and socioeconomic characteristics.

Tool Support for Project Development and Design

A critical component for implementation will be tool support. This research identified data needs and associated collection methods for supporting key safety analysis applications, including Safety Analyst™ and IHSDM. As FLH and FLMAs propose additional or custom support tools, FLH should consider the requirements of these tools for future data collection needs (see *Evaluate Data Driven Priorities and Expand Capacity*).

This research and the *Quantitative Methods* can greatly improve the ability for FLH staff to perform analysis and evaluate designs as part of FLH PS&E packages. There is often limited survey, asset, roadway, crash, and traffic data for road projects. This challenge is compounded by limited resources (i.e., staff time) to perform safety analysis during project development. By using the aforementioned data sources and methods to address data gaps, particularly the use of publicly accessible terrain data, staff can efficiently locate the highest risk locations and provide context-sensitive safety improvements where they are needed most. This includes low-cost proven safety countermeasures. For instance, if available data cannot support an HSM analysis using IHSDM, staff can utilize the "star rating" approach with the key risk factors in the Short Form to assess the project corridor and prioritize safety improvements with a data-driven, systemic approach.

Data Integration

As FLH and its partners collect and analyze safety data over time, integration of new data and archiving of older data will become essential in a comprehensive data management strategy. This also includes project results and non-spatial data (e.g., plan documents) after project close out. The Implementation Roadmap provides key steps for supporting this cyclical workflow that supports data collection and enhancements over time (see *Establish Transportation GIS for Federal Lands Highway*).

4

Case Studies

The research team conducted case studies as part of testing the framework and methods discussed in the previous chapter. The case studies build upon this initial conception by testing methods and tools available to FLH, as well as articulating how the framework applies to different stages of plan development, preliminary safety analyses, and project development. Case studies generally fell within two categories: 1) field visits and 2) applied case studies.

- **Field visits and methods testing:** Field visits tested the functionality and workflow of FLH's custom Data Collection application which is still in development as of this report. This section includes the objectives, applicable pre-visit preparation, attendees, and findings of each visit. The section concludes with a synthesis of high-level findings for FLH's consideration.
- **Applied case studies:** The research team applied the data and methods documented during previous stages of the research. Each of these case studies highlight components of the data collection framework by addressing individual data needs for systemic safety analysis.

A case study report details the specific findings from each case study, and the following sections summarize the key findings from the case studies.

Field Visit Findings

This section documents key findings and takeaways from field visits to Larimer County, CO and the Olympic Peninsula, WA. These include:

- Data Collection application functionality and opportunities for improvement.
- Potential use cases of the Data Collection application.
- Importance of linear referencing and data management.
- Suitability of readily available data and analysis methods.
- Additional priority variables.

Data Collection Application Functionality

Site visits documented several potential improvements for the custom Data Collection application. There are two broad needs that represent priority considerations for future safety data collection support on Federally-managed roads:

1. Future data storage should consider using related tables as the primary method for storing data elements. A multi-level related data table schema should allow for more flexible display of data elements in the user interface (i.e., avoid cluttering the user interface), as well as smoother integration of different data element types (i.e., one layer containing spatial information linked to multiple tables through unique identification values).
2. The Data Collection application could use a related table format to allow users to flexibly select and incorporate data elements on the fly in the field. The Short Forms provide a prioritized list of data elements for users with limited available data or expertise. However, field visits recognized that unique (i.e., unanticipated) situations can be relatively common, and users should be able to adapt in the field.

Potential Application Use Cases

Site visits noted that the likeliest use cases of the mobile Data Collection application include:

- RSAs and field assessments.
- Verification of field conditions (e.g., damaged hardware).
- Incident tracking (e.g., wildlife collisions and carcasses).
- Planning-level roadway characteristic and exposure data collection and maintenance.

Furthermore, the field visits reinforced the need to make data available outside of FLH's information technology (IT) firewall and accessible to external users (i.e., local planners, engineers, and stakeholders) to support these use cases.

Importance of Linear Referencing

Data collected by the application could use linear referencing to support long term data collection and maintenance more efficiently. This would also support data integration necessary to conduct systemic and HSM-based safety analysis. This includes:

- Single route and milepost values for point data.
- Beginning and ending route and milepost values for linear and polygon data (where applicable).
- For intersection-related data elements, entries should possess route and milepost values for all intersecting routes.

This approach would also allow the custom mobile Data Collection application to directly edit data on FLMA centerlines and dynamically segment routes based on homogenous characteristics. This format would not only preserve relative location information on FLMA road networks, but it also allows for relatively efficient data integration and compilation to conduct network-level analysis.

Suitability of Framework Data and Methods

Field measurements and observations during the Larimer County site visit noted opportunities for improving desktop-level analysis. These measurements provided reference points to compare improved data analysis with ground conditions. The field visits also noted the priority of the following characteristics to assess safety needs for low volume roads:

- Roadway design consistency and impact on driver expectations.
- Sharpness of horizontal curvature.
- Steepness of vertical grade.
- Width of traversable area and clear zone.
- Roadside hazards, including non-traversable slopes, differences in roadside elevation, and objects in the clear zone.
- Sight distance limitations.

The project team observed the following opportunities for refining desktop-level analysis:

- 10-meter elevation data is adequate for assessing vertical grade associated with individual curves and segments (using an average value); however, users should "project" these data using a projected coordinate system to obtain reasonably accurate results. The project team generally recommends a North American Datum of 1983 (NAD 83) Universal Transverse Mercator (UTM) projection system to match data from the USGS National Map.[1]
- 1-meter elevation data (or higher resolution) should be used to calculate sideslopes. This generally limits the applicability of this analysis method to a corridor-level screening without considerable processing time and computational resources.
- Consequently, 1-meter elevation data should be used to calculate traversable area and clear zone calculations along roadsides.
- In addition to the non-traversable slopes, differences in elevation should be used to screen for potential roadside hazard (figure 23). This method is consistent with roadside design guidance and the roadside hazard rating data element.
- Bare Earth elevation data can provide some reasonable indication of sight distance limitations at horizontal curves; however, canopy height elevation data are required to generate potential sight obstructions from roadside vegetation.

[1] At a minimum, spatial units (e.g., meters) used in the "target" (e.g., curve) and "join" (e.g., DEM) datasets must match.

Source: FHWA

Figure 23. Graphic. Parallel examples of non-traversable slope and roadside hazard in Larimer, CO.

Additional Priority Variables

The site visits reinforced and validated many of the data elements incorporated within the Short Forms. These data elements represent high priority safety issues that users can collect to develop a “star” rating for individual curves, tangents, or smaller segments. As supplementary improvements, VHB noted the following adjustments to the Short Form data approach:

- Create Short Forms for qualitative and anecdotal data elements (e.g., speeding issues or frequent animal crossings) and countermeasures (e.g., barrier presence and condition).
- Modify desktop analysis to reflect Short Form data elements more accurately (as applicable).

Applied Case Study Summary

The case studies covered in this research cover a broad spectrum of use cases, geographic context, and applications of safety data. These included:

- Oregon statewide Needs Assessment for roads eligible for FLAP funding.
- Larimer County site visit and corridor review.
- San Juan National Forest (SJNF) Forest Road Safety Plan (FRSP).
- Frontier MPO/Western Arkansas Planning and Development District (WAPDD) SAP.
- Yellowstone systemic review with Safety Analyst™ data.
- USFWS Wichita Mountains Wildlife Refuge RSA.
- Tohono O'odham Nation Virtual Tours.
- Custer Motorway (Idaho) FLAP Project.

This section summarizes key takeaways, successes, and challenges noted by the project team during the research process. It is organized according to the framework bullet points illustrated in figure 5.

Develop a Focus for Safety Analysis

Prior to analysis, practitioners should have a focus to channel limited analysis resources and target specific safety needs based on context.

- **The Oregon Needs Assessment** was a strategic planning effort that represents an opportunity to establish regional safety needs. Stakeholder input can provide strategic guidance for subsequent planning and analysis activities.
- **The SJNF FRSP** focused on roadway departure in a very rural context. A Risk Factor Focused approach identified roadway departure risk factors along the Forest network to overcome limited available data.
- **The Frontier MPO SAP** referenced the State's SHSP to focus preliminary analysis on specific emphasis areas. A Crash Data Focused approach prioritized regional priorities even further.
- **The Yellowstone National Park Curve Radii Assessment** focused on heavy vehicle roadway departures, particularly along horizontal curves. A Risk Factor Focused approach, supported by NPS's Network Safety Management screening, can be used to identify locations where trucks are potentially at risk of overturning.
- **The Tohono O'odham Nation RSA** occurred in a highly rural context, and anecdotal data collected during the virtual tour reflected rural safety issues.

Establish a Use Case

The analysis use case should guide the type of data required. This will vary by planning and project development phase, as well as by geographic size and scope of the study area.

- **The Oregon Needs Assessment** engaged stakeholders with varying degrees of technical understanding of safety concepts. Rather than focusing on detailed safety criteria, needs assessments should request qualitative inputs to guide strategic planning. Discussions can be supported with general safety-related data:
  - Crash locations (if available).
  - Posted speed limits.
  - Traffic volume.
  - Travel lane width.
- **The SJNF FRSP and Frontier MPO SAP** both cover broad jurisdictions with different safety emphasis areas. As a result, data should reflect the inputs required to support motor vehicle safety in highly rural SJNF (functional classification, horizontal curvature, vertical grade), and multi-modal safety in mixed urban and rural western Arkansas (travel lanes, posted speed, traffic volumes, origins and destinations).
- **The SJNF FRSP** included campground occupancy as a contextual supporting surrogate for individual traffic counts to help focus improvements where exposure is highest (in addition to other risk factors).
- **The Frontier MPO** used overrepresented crash characteristics to identify regionally specific emphasis areas and roadway characteristics that could be prioritized for improvements.
- **The Wichita Mountains Wildlife Refuge** is an example of how RSAs can be supported through a mix of roadway, crash, and contextual characteristics that could help focus the objectives of a field assessment.
- **The Larimer County Site Visit** demonstrated the applicability of highly detailed elevation data to scan for roadside hazards and sight distance issues along a specific corridor.
- **The Custer Motorway FLAP Project** is an example of these methods applied to project development, particularly in a context that lacks detailed survey data.

Identify Gaps

Data should be selected to support the individual use case. Table 7 provides an overview of key data types that could be considered for safety analysis. Each use case will likely have data gaps that could be addressed (or replaced with a surrogate) prior to analysis.

- **The SJNF FRSP** had different datasets available by road network. Colorado DOT roads had a full suite of traditional crash, roadway, and traffic data that could support systemic safety analysis, while local roads had few characteristic variables and limited crash data.
- **The Frontier MPO SAP** had different datasets available for different road networks (on-system and off-system), as well as different geographies (urban vs. rural).
- **The Yellowstone National Park Curve Radii Assessment** had a suite of traditional safety-related data and predictive crash analysis results. However, heavy vehicle overturns were the focus of the analysis based on geometric factors such as horizontal curvature and vertical grade.

Address Gaps

There are several methods for addressing gaps in existing data. This includes quantitative methods (e.g., traffic counts, connected vehicle data, and LiDAR), qualitative methods (e.g., surveys, interviews, and crowdsource applications), and field verification.

- **Several case studies** derived horizontal curvature from existing centerlines and derived vertical grade from DEMs. This allowed these case studies to focus risk factors by curve and tangent sections.
- **Several case studies** used crowdsource applications to obtain targeted anecdotal evidence for safety issues. This supported all stages of the planning process, including strategic planning, action planning, and site reviews.
- **Several case studies** derived roadside safety criteria and sight distance limitations using publicly available DEMs and widely available GIS tools.
- **The Larimer and Olympic Peninsula Site Visits** helped refine key inputs and workflow criteria for improvements to FLH’s custom Data Collection application. This application can help verify existing datasets in the field.

Prioritize

Data collected in support of an analysis will help prioritize key needs for safety improvement. This includes identification of priority sites and countermeasures, as well as supporting tools that can refine alternatives (e.g., IHSDM and Safety Analyst™).

- **The SJNF FRSP** identified higher risk corridors with a limited number of characteristics and delineated high-risk curve and intersection locations based on a suite of risk criteria. This allowed the project team to prioritize countermeasures, develop costs associated with high-risk sites, and prioritize costs by high-risk corridors.
- **The Yellowstone National Park Curve Radii Assessment** used Short Form risk criteria and predictive crash analysis to identify locations where safety concerns might be present. Future iterations of the study can revise risk thresholds associated with curve radii based on future study and refinement.
- **The Larimer Site Visit** helped refine the data inputs and GIS analysis methods that can be employed for systemic risk factor assessments on roads with limited crash data.
- **The Custer Motorway FLAP Project** supported the corridor review to refine low-cost safety improvements for a long corridor with limited scope and project survey data

Finally, all data elements and Short Form variables defined in this research are intended to support safety analysis tool implementation, including Safety Analyst™ (or other HSM implementation), usRAP, and IHSDM in rural and limited data contexts.

5

Deployment Objectives

This section summarizes a roadmap for FLH as it engages with partner agencies both inside the Federal government as well as external agencies at the Tribal, State, and local level. The activities identified as part of this research effort are best practices FLH can consider adopting for inter-agency data sharing and development. This roadmap addresses a core component of the Innovation and Research Council (IRC) program—deployment of a Marketing and Communication Plan. A more detailed version of this roadmap is presented in an accompanying *Development of Safety and Traffic Data Collection System and Analysis Framework for Federal Lands: Implementation Plan*. The subsequent activity recommendations would greatly enhance the safety data capabilities of FLH, FLMA, and Tribal agencies:

- Cultivate relationships with partner agencies.
- Develop a common road basemap.
- Establish Transportation GIS for FLH.
- Develop and refine data collection methods.
- Develop and refine analytical tools.
- Evaluate data driven priorities and expand capacity.

Cultivate Relationships with Partner Agencies

FHWA's *Informational Guide for State, Tribal, and Local Safety Data Integration* provides a framework for approaching multi-agency and multi-disciplinary data collection.[35] It presents a nine-step process for safety data integration that can be flexibly applied to meet agency needs (figure 4). FLH is in the *Preparation* stage of safety data integration, with data relationships between FLH and FLMA, State, and Tribal partners being largely informal. FLH would benefit by establishing a more formal data relationship with its FLMA partners (i.e., laying the foundation).

This relationship can begin by formalizing existing collaboration between FLH and FLMAs, but it should be expanded to include key safety data stakeholders among partner agencies. These roles and positions could include:

- Safety engineers.
- Planners.
- Infrastructure managers.
- Maintenance staff.
- Data managers.
- Data analysts.
- IT staff.

Key Implementation Strategies

Engage Executive Leadership

Executive leadership buy-in is crucial to the success of data governance, integration, and management. This allows participating agencies to foster formal processes and engage resources toward data capability enhancements. Executive buy-in and direction can help reduce planning redundancy (i.e., parallel or overlapping data activities) and help staff better plan future data investments.

Establish Data Working Groups of Key Data Stakeholders

Data working groups are the foundation of data governance and integration activities. Agencies with robust safety data capabilities create strong relationships that span DOT offices and coordinate roles and activities.

Conduct Pilots as a Model for All Partners

Not all agencies will be initially motivated or prepared to participate in data integration and management processes. Some may lack resources (i.e., staff time) or adequate data, while others may hesitate out of other concerns. Pilot projects in collaboration with one or two organizations may help troubleshoot potential challenges and address others' concerns over collaboration. FLH's recent collaboration with the NPS Navigator and RIP Planning teams as part of this research illustrate how targeted initiatives can foster cross-agency collaboration and planning.

Establish Data Sharing Agreements and MOUs with Partner Agencies

Formal agreements may be necessary to secure partnerships and create lasting commitments among agencies. These may be especially important for relationships at different levels of political jurisdiction and responsibility, where periodic elections may change who is responsible for fulfilling agreements. These agreements provide clear responsibilities and expectations with respect to data usage and privacy that may assuage concerns between agencies. States and local agencies (municipal, county, MPOs, RPCs), as well as Tribal governments use data sharing agreements and MOUs to establish and maintain their relationships long term without interruption to keep data available for decision-making.

Conduct Gaps Analyses Where Applicable

FLH data working groups will be well positioned to conduct thorough safety data gaps analyses. Gaps analyses help clarify two components of safety data:

1. User data needs.
2. Data availability.

The results of these analyses identify data that need to be collected. They can help prioritize future investments in data collection and point to opportunities for data sharing. The current research uncovered several national and FLMA data resources that could be leveraged for systemic safety analysis. However, the research also uncovered that data coverage and quality may vary by agency, region, and individual park, forest, or unit.

Conduct Continued Education and Outreach

Data governance is achieved by cultivating relationships and establishing formal processes. Although a formal data governance committee can be a long-term goal of the FLH framework, many of the aforementioned strategies can flexibly achieve many of FLH's safety data goals in the interim. Safety data champions at each FLMA can help promote the objectives of the FLH working group(s) within their agency. Key outreach and communication opportunities include:

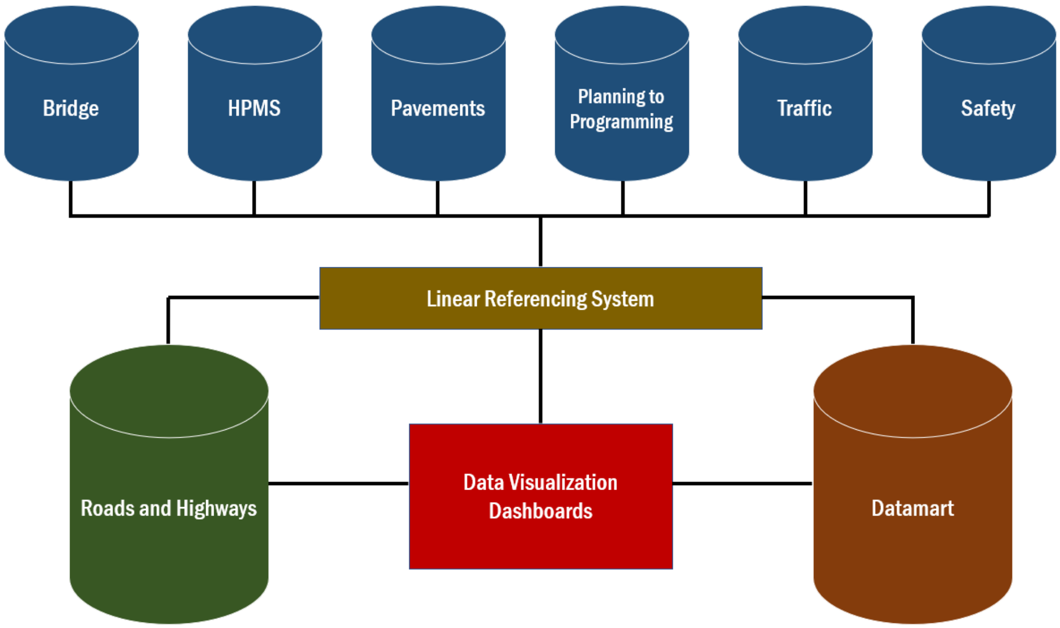
- **Debrief meetings with FHWA, FLMA, and Tribal partners.**
  - Includes potential presentations to the Federal Lands Planning Program (FLPP) Council.
- **Webinars through the National Center for Rural Road Safety or Transportation Research Board (TRB) committees, including:**
  - ACS10 – Transportation Safety Management Systems.
  - ACS20 – Safety Performance and Analysis.
  - AEP20 – Transportation Needs of National Parks and Public Lands.
- **Presentations and papers submitted to:**
  - TRB International Conference on Low-Volume Roads.
  - TRB Annual Meeting.
  - Annual AASHTO GIS for Transportation Symposium (GIS-T).
- **Articles in industry publications, including FHWA's Public Roads.**
  - The summer 2022 edition documented a case study from this research regarding crowdsource tools to support a virtual RSAs.[52]
- **Technical assistance through FHWA Focused Approach and Every Day Counts (EDC) initiatives.**
  - Technical assistance provided to the Frontier MPO (AR/OK) and SJNF via FHWA's Focus on Reducing Rural Roadway Departures (FoRRRwD) program used methods discussed in this research.

Develop a Common Road Basemap

Data governance provides several critical data integration benefits, including:

- Establishing authoritative datasets and reducing redundancy in agency data.
- Improving access to data by communicating the source and provider of authoritative data.

One basic objective of data governance in transportation agencies is establishing a common basemap for data integration and analysis. Arizona DOT is an example of a DOT that manages data across different offices through integration on a common LRS basemap (figure 24).



Source: FHWA

Figure 24. Graphic. ADOT's LRS is the common link for many data systems.

This research documented that all FLMAs have a road network developed in a geospatial format. However, not all agencies have a basemap that functions as an LRS for linking asset locations along the network; primarily, the RIP program for DOI agencies and the USFS have LRS-enabled networks. FLH's efforts to develop a comprehensive data management and analysis system would benefit from a common, routable road basemap where users can access the latest authoritative data, conduct relevant analyses, and manage data updates. All spatial safety data should link through that one LRS network.

Key Implementation Strategies

Ingest FLMA and Partner Road Networks

FLH will work with FLMAs and Tribal agencies to coordinate roadway data management. FLH already receives annual extracts of each FLMA road network, and a cornerstone implementation strategy will be for FLH to become the authoritative source (although not necessarily the dataset owner) for these data. FLH's collaboration with NPS and the EFLHD RIP Team is an early practical example of this approach.

Access Technical Assistance Through the Applications of Enterprise GIS for Transportation (AEGIST) Program

Creating and maintaining a uniform spatial inventory and network of roads in the United States is a core USDOT policy objective. The FHWA Office of Planning's AEGIST program is a State-led Pooled Fund Study (PFS) that assists agencies with spatial data infrastructure development. AEGIST technical assistance can help FLH and FLMAs coordinate data integration to develop a common basemap for all users.

Establish Transportation GIS for Federal Lands Highway

FLH is working with its contractor to develop a cloud-based managed services portal (i.e., the GCX Portal). This portal will be accessible to FLH employees, as well as by invitation to contractors and other external partners. Non-public information will be secured by *login.gov* authentication. Each FLMA and participating partner will have its own platform and custom access settings.

Key requirements of the portal will include access to the current Geocortex Web Studio license subscription, as well as the Inline T2 subscription for working with linear referenced data. Both of these subscriptions are accessible via a software as a service (SaaS) model. This will allow FLH to manage the RIP program for FHWA and NPS, as well as serve as a model for managing data on a common LRS-enabled basemap. An additional feature of the managed services platform will include continued support and integration for the mobile data collection platform.

Key Implementation Strategies

Linear Referencing and Spatial Data

The GCX Portal will be a key implementation step for managing safety-related GIS data. LRS management tools, including ESRI's Roads and Highways application, will further enhance asset data management and flexibility of analysis capabilities on FLMA roads. Most core applications for safety analysis require integration between crash, traffic, and roadway data, and changes to the network should be tracked over time. This will allow FLH to implement systemic and predictive methods, as well as conduct effectiveness evaluations after improvements are implemented. Spatial data management will also support data visualization tools such as dashboards and web maps that could effectively communicate safety needs (i.e., similar to the NPS Navigator application).

Non-Spatial Data

Non-spatial data (i.e., plan and project documents) are important context for safety analysis. Some of these data and documents would benefit from public distribution (e.g., SAPs and needs assessments) while others may have personally identifiable or draft material that may not be appropriate for broader distribution (i.e., RSAs or crash investigations). The flexibility of the GCX Portal will allow FLH to manage appropriate access to non-spatial documents and data.

Develop and Refine Data Collection Methods

This research identified data collection and derivation methods available to FLH. These are articulated in the final research report and summarized in the proposed Data Development Framework. FLH can pursue data collection methods according to the priority established by the data use case and prior relationship development activities. The 2022 BIL legislation provides grant funding to States for improving crash data collection and use.(1) FLH can benefit from these efforts by participating in States' crash data improvement working groups, sharing crash data, and working with other stakeholder agencies on improved safety analyses.

Key Implementation Strategies

Apply Data Gap Analysis to Identify Derivable Data

Many safety data elements are already available in (or can be derived from) existing FLMA data inventories. This research noted several that could apply to safety on FLMA roads. FLH will consolidate these datasets to establish a baseline of safety data that can be supplemented by subsequent data collection.

Prioritize Data Collection According to the Data Development Framework

The Data Development Framework provides a method for assessing necessary safety data (e.g., Risk Factor Focused and Crash Data Focused). FLH will derive or collect data through a variety of methods (e.g., Curve Finder™, digital elevation model analysis, field verification, and desktop collection) that will support the use of Short Form data across all FLMAs; this will support rudimentary systemic analysis on FLMA and Tribal roads. Additional datasets, particularly those that support more robust safety analysis (e.g., HSM predictive and evaluation methods), can be collected as FLH and FLMAs determine the future of Safety Analyst™ and develop requirements for future analysis applications (see *Evaluate Data Driven Priorities and Expand Capacity*). **Crash data collection, standardization, and geolocation should be prioritized as these methods are considered for implementation.**

Evaluate Successes and Challenges Identified during NPS RIP Cycle 7 Data Collection

FLH coordinated directly with the NPS and EFLHD RIP Team as part of the Cycle 7 requirements development process. This Cycle planned to collect data via mobile Data Collection Vehicles (DVCs) that applied a variety of methods:

- Streetview camera imagery.
- 3D street surface camera (for pavement cracking and rutting).
- Global positioning systems (GPS).
- Gyroscope and computer.
- Distance Measuring Instrument (DMI).
- Laser (for determining pavement roughness).

The Cycle 7 RIP collection included a 500-mile pilot mobile LiDAR collection for generating roadway element data (scheduled for 2023). FLH will discuss successes and challenges of the RIP Cycle 7 collection for application in other contexts.

Link Crash Data to Common Road Basemap

Additional RIP data collection and management of the RIP in the Transportation GIS for FLH will provide a pilot test case for linking crash data on a common road basemap. This will allow FLH and its FLMA partners to develop more robust safety analysis methods; this includes support for Safety Analyst™ or a future custom SMS.

Ingest Supporting FLMA and Tribal Datasets via Feature Services and Portal Collaboration

FLH may not become the custodian for all datasets that could be relevant in a safety study or establishing safety priorities. FLMAs may retain both ownership and management responsibilities for these data. For data that are not within the Transportation GIS for FLH environment, these data can be shared as feature services and consumed by FLH applications for analysis. This will promote access to authoritative and current data across agencies. FLH will work with FLMA and partner agencies to "Enable Sync" associated with these feature services; this will allow FLH to use these data in "offline" field applications.

FLH will work with FLMA and partner agencies to "Enable Sync" associated with these feature services; this will allow FLH to use these data in "offline" field applications.

Develop and Refine Analytical Tools

FLH and FLMA partners have access to several safety analysis tools. These include Safety Analyst™ for network screening and implementation of the HSM Part B roadway safety management process and IHSDM project development modules. However, the future of Safety Analyst™ at NPS is uncertain, and the Transportation GIS for FLH presents an opportunity for the development of custom analysis applications.

FLH and its FLMA partners could proceed with analysis applications in a modular, step-by-step approach. Not all agencies will have the data capabilities to implement robust safety analytics tools (e.g., crash data availability and reliability, traffic count coverage, countermeasure installation databases, and others). This plan organizes potential safety applications, beginning with the most readily implementable and broadly applicable and ending with the most robust and limited to only the most advanced FLMA and Tribal partners.

Key Implementation Strategies

Adopt Systemic Tools Developed Through This Research Effort

In addition to the Short Form criteria and framework for collecting additional safety data, FLH can readily adopt the methods and tools developed specifically as a result of this research. These tools will help FLH address key systemic risk factors on low volume roads with limited available data such as:

- Horizontal and vertical geometry risk threshold assessment.
- Recoverable area assessment.
- Sight distance assessment based on horizontal and vertical geometry.
- Sideslope and roadside elevation assessment.

Open Data Hub

Delivering safety data to internal and external users is an important component of the vision for the Transportation GIS at FLH. Open data hubs will allow users, regardless of credentials, access to curated and approved safety-related datasets. Access to secure data and analysis applications can be restricted based on appropriate permissions and security functionality.

Web Maps and Dashboards

Web maps and dashboards are the most readily implementable analysis application for FLMAs and Tribes. These have limited ability to derive specific policy and project recommendations, but they convey transportation safety data in a readily digestible format. They also enable data collection and sharing via FLH's custom Data Collection application. FLH can use cloud resources, such as ArcGIS Online and the Transportation GIS for FLH, to deliver safety data and analysis results to FLMAs, Tribes, and other partner agencies. Example use cases include:

- Data summary and reporting.
- Interactive data for exploratory analysis.
- Targeted data exports (i.e., by study area) for local desktop analysis.

Network Screening – Risk Based Results

Network screening based on systemic risk factors is a useful safety analysis application for most FLMA and Tribal users. Systemic risk analysis does not necessarily require access to robust crash data and can be supported even with only a limited number of roadway attributes. FLH can share analyses conducted by FLH staff and it can host results produced by FLMA, State, Tribal, local, or consultant analysts. An interactive application can allow users to filter systemic screening results by emphasis area (e.g., roadway departure and pedestrians), geography (e.g., agency or jurisdiction), or level of priority (e.g., primary, secondary, or other).

Test of Proportions

The Test of Proportions application would be a faithful implementation of FHWA's Crash Data Summary Template.[(33)] This tool's data requirements may be beyond the current capabilities of many agencies, but a user with reliable crash data (with sufficiently detailed attributes) could use the application for systemic analysis support. This application would compare crash proportions from a study area (e.g., a park or forest) with crash proportions from a reference region (e.g., a State, region, or agency).

Crash Trees

Crash trees are an especially effective method for establishing a Focus Facility Type in systemic analysis. This application would be most appropriate for agencies with crash data that are spatially located and that can be easily integrated with road and traffic characteristics. Ideally, the integration will be automated through location coding to a common basemap and LRS. Many of the same considerations (and limitations) that apply to a Test of Proportions application would also apply to a potential crash tree application.

Custom Safety Management System

While the FLH Data Collection Framework can support existing safety management systems, particularly NPS's current implementation of Safety Analyst™, future developments may require FLH to adopt an alternative to Safety Analyst™. If additional agencies pursue an SMS to implement Part B of the HSM (or if NPS elects to pursue a custom alternative to Safety Analyst™), the Transportation GIS at FLH can serve as a platform for key applications.

Network Screening – Crash Based

As opposed to systemic risk-based screening, which is based on the presence of risk factors, crash-based network screening is based on historical (observed) and future (predicted) crashes. The network screening application capabilities could include traditional methods such as observed crash frequency and crash rate as well as more reliable methods that incorporate SPFs and the empirical Bayes method described in the HSM. FLH and FLMAs could calibrate SPFs to local agency or regional conditions or conduct additional research to produce agency-specific SPFs.

Diagnosis and Countermeasure Selection

After identifying sites with a potential for safety improvement via network screening, diagnosis and countermeasure selection supports analysts as they identify underlying crash contributing factors and relevant countermeasures. This module could be developed with the following considerations:

- Diagnosis Tools:
    - Collision diagram capabilities.
    - Condition diagram capabilities.
    - Test of proportion tool for identifying over-represented crash types.
- Countermeasure Selection Tools:
    - Preferred countermeasures by agency and region.
    - Implementation of an intersection control evaluation (ICE) policy or similar countermeasure selection method.
    - Application of the Safe System approach methodology and associated preferred countermeasure screening.

Economic Appraisal

Economic appraisal would assess the benefit-cost ratio (BCR) of proposed countermeasures at specific locations. To implement this module, FLH and FLMAs would need to consider:

- Default and customizable relevant crash costs associated with specific severity levels and regions of the country.
- Default CMFs for preferred countermeasures to estimate reduction in target crashes; this would be comparable to a no-build scenario that did not include a particular countermeasure.
- Default and customizable typical costs associated with countermeasure implementation by region of the country.
- Default and customizable service life and maintenance costs.

This module would satisfy key data-driven policy priorities for safety analysis, as well as help establish a return on investment (ROI) for FLMA safety programs.

Effectiveness Evaluation

The final component of the roadway safety management process is effectiveness evaluation. This module would track countermeasure implementation and allow FLMAs and other users to conduct effectiveness evaluations of implemented countermeasures. The results of this analysis module will inform default CMF values in previous modules (e.g., *Diagnosis and Countermeasure Selection* and *Economic Appraisal*).

Evaluate Data Driven Priorities and Expand Capacity

Preventing fatalities and serious injuries on FLMA roads is the most important goal of the FLH Data Development Framework. ROI (i.e., cumulative benefits divided by investment costs) is the method for determining its effectiveness and evaluating future data and analysis activities. State and FLMA agencies have developed methods for assessing ROI at the project and programmatic level.

NPS already incorporates Value Analysis (VA) as part of the agency's investment decision framework.[(53)] This approach can be adapted to the FLH data and analysis capability development framework. The VA process considers the following objectives prior to an investment:

- Essential functional requirement is met.
- All viable alternatives are considered.
- Factors used to evaluate alternatives are sound and fully considered.
- All alternatives are tested equally against these factors.
- Solutions are cost effective on an initial and life-cycle cost basis.
- Benefit to cost relationships are considered.
- Independent second opinions and perspectives are considered.
- Rationale for decisions is clearly documented.

Key Implementation Strategy

Relationships and working groups established during prior phases of the roadmap (see *Cultivate Relationships with Partner Agencies*) can provide the technical and institutional expertise to evaluate ROI and program future investments in expanded data capabilities.

Appendix A: Interview Summaries

To: Matthew Hinshaw, WFLHD
Amit Armstrong, WFLHD

Date: August 26, 2021

From: Ian Hamilton, VHB
Michael Amoabeng, VHB

Re: Federal Land Management Agency (FLMA) Data Discussion Summary – Bureau of Land Management

Purpose and Background

The purpose of this memorandum is to document the key points noted in geographic information systems (GIS) data discussions between Western Federal Lands Highway Division (WFLHD) and members of the Bureau of Land Management (BLM). These discussions focused on the availability of roadway, asset, and visitor information for BLM-managed areas.

General Themes

Much of the data most relevant to systemic safety analysis currently exists in tabular form. However, BLM is currently undergoing substantial upgrades to many of its data systems, including spatially locating roadway and asset information. BLM is digitizing its road inventory in conjunction with the agency's land use plans and special designations planning. At the time of the interview, BLM has inventoried roughly 30 percent of the network. The ground transportation linear feature (GTFL) is the primary public-facing roadway centerline network. This network does not include all possible road features, and it excludes closed roads or roads in Wilderness Study Areas (WSAs).

The Facility Asset Management System (FAMS) is the primary database for linear roadway geometrics and other transportation asset information. BLM joins tabular asset data to actively maintained roads via a FAMS ID; primitive roads are not stored in FAMS. Like other data at BLM, FAMS data are being converted to geospatial format. This project is ongoing, and it involves a Maximo database similar to other Federal Land Management Agencies (FLMA). FAMS and other asset data are not publicly accessible, and these would need to be provided through a formal transfer.

Other Specific Data Sources and Notes

Traffic counts are not collected or stored centrally, but spot counts may be conducted as part of engineering and corridor assessments around specific recreational areas. BLM extensively tracks visitor recreational area information. The Recreational Sites Database contains physical recreational site information in point and polygon features. These data are linked to other asset and visitor information via unique identifiers. The Recreation Management Information System (RMIS) stores recreational and social use on BLM managed land. This includes visitor counts, permits, and other reported information. Like FAMS, it is only directly accessible to BLM staff; however, the BLM also has recreational data available through the Recreation Information Database via Recreation.gov. These data are readily publicly available. For third-party data, the BLM has access to Google and Waze data via the United States Department of Transportation (USDOT), but this is more on a trial and exploratory basis for the most heavily visited sites. BLM is also interested in crowdsourcing data from visitors and "citizen scientists." The "Leave No Trace" Program has an application that allows users to report observations (e.g., informal, unmarked area parking or congested areas).

To: Matthew Hinshaw, WFLHD
Amit Armstrong, WFLHD

Date: September 14, 2021

From: Ian Hamilton, VHB
Michael Amoabeng, VHB

Re: Federal Land Management Agency (FLMA) Data Discussion Summary – Bureau of Reclamation

Purpose and Background

The purpose of this memorandum is to document the key points noted in geographic information systems (GIS) data discussions between Western Federal Lands Highway Division (WFLHD) and Dan Staton of the Bureau of Reclamation (BOR). These discussions focused on the availability of roadway and bridge information for BOR-managed areas.

General Themes

As a Federal agency primarily concerned with the management of water resources in the western United States, BOR has a similar focus and mission as the United States Army Corps of Engineers (USACE). Although the agency is responsible for managing transportation assets and roads, these assets support the primary goal of water resource management.

Like other agencies in the Department of the Interior (DOI), the BOR participates in the Road Inventory Program (RIP). The agency is currently on its first collection cycle and expects to have its first complete inventory in 2022. This first cycle will cover paved and unpaved maintained roads; native material roads may be included, but they are not a priority. The RIP should provide a mile-posted road network that could be leveraged by future data collection efforts.

Much of the BOR-owned road network is maintained by local and non-Federal agencies. This means that most transportation asset data that could be relevant for systemic or local safety analysis would be owned and maintained by the applicable agency (and not BOR). Furthermore, certain assets, such as signage and roadside barriers, could potentially be installed without being comprehensively tracked by BOR at a national level. As a result, bridge and road centerline inventories are the only significant transportation safety data resources readily available to BOR.

BOR also does not currently dedicate planning funds for the purposes of road safety audits (RSAs) and other studies, and many transportation planning functions are not conducted through a central office (although internal conversations indicate they may be interested in future studies). Local BOR staff would coordinate with local stakeholders to identify safety concerns, conduct studies, or install countermeasures. This also applies to data collection, as these data would not be delivered to a central repository.

Other Specific Data Sources and Notes

BOR maintains and publishes an open data portal, Reclamation Information Sharing Environment (RISE). However, these data are largely comprised of administrative boundaries, hydrological and environmental features, and structures. The RISE catalog also has reports and non-spatial documents available to the public, and these documents are spatially linked to geographic points on an interactive web map viewer. Still, there is very limited to no readily available information pertinent to roadway safety.

To:	Matthew Hinshaw, WFLHD Amit Armstrong, WFLHD	Date:	August 4, 2021
From:	Ian Hamilton, VHB Michael Amoabeng, VHB	Re:	Federal Land Management Agency (FLMA) Data Discussion Summary – Collaborative Visitor Transportation Survey (CVTS)

Purpose and Background

The purpose of this memorandum is to document the key points noted data discussions between Western Federal Lands Highway Division (WFLHD) and Margaret Petrella at the Volpe Center. These discussions focused on the subject, use, and method of the Collaborative Visitor Transportation Survey (CVTS), and the possibility of sharing these surveys and the output data with WFLHD. There was also conversation about the data clearances needed for the surveys created, collaboration of Federal Land Management Agencies (FLMAs), and agency interest moving forward.

General Themes

The original purpose of the CVTS was to encourage collaboration. FLMAs may have adjacent lands managed by other FLMAs, and the CVTS is a method for streamlining and administering surveys. Margaret noted an example of this collaboration in Alaska. All FLMAs have access to the Generic Clearance for conducting user and visitor surveys. This Generic Clearance is housed at the United States Forest Service (USFS), although, the National Park Service (NPS) has its own particular Generic Clearance. In other words, any FLMA can proceed with a user/visitor survey as long as it generally conforms to the Generic Clearance. The CVTS has a compendium of questions available online. Agencies are encouraged to use pre-approved questions but are not required to and can go through the channels listed above to get questions and surveys approved. To have a successful question or survey there must be tailoring to the specific road, trail, or area, and these will change based on the data collection needs of the agency asking the questions.

In order to create and submit a survey, an agency must fill out a justification form which answers what the purpose and methodology of the survey are, then Margaret reviews the justification form before it is submitted to the USFS (where the Generic Clearance is housed), USFS reviews and submits to the Office of Management and Budget (OMB). If another FLMA requests a survey through the Generic Clearance, then that FLMA will typically work with their information collection officer to pull together a package. Surveys usually focus on visitor experiences, attitudes, and perceptions, not count data. However, the specific information will vary by survey and agency goal.

The agencies expected to be interested in surveys moving forward are USFS (who submits the most), Bureau of Land Management (BLM), United States Army Corps of Engineers (USACE), and the United Stated Fish and Wildlife Service (USFWS). There are other agencies interested in conducting surveys, but it was not discussed which ones. National Parks Service (NPS) typically does not submit through the Volpe-associated Generic Clearance because they have their own process and pool of known questions; however, this approach may vary if they are collaborating with other FLMAs. Margaret stated that one of the goals of CVTS was to have agencies collaborate, but they are not seeing as much as they would like. Similarly, USFWS has been working on its own Generic Clearance because they do surveys on refuges across the country either annually or bi-annually. Margaret said she could reach out to the desk officer at USFWS to ask if they have their own Generic Clearance.

Specific Data Sources and Notes

All of the approved surveys (and justification form) can be viewed on reginfo.gov. This resource shows the information collection title (survey title), status, number of responses, and you can download the survey itself. This information is useful to see what information other agencies are trying to glean and how they are doing it. The goal is to have all surveys made publicly available (possibly on sciencebase.gov), but agencies are not required to submit the response data to the database. To find that data you would need to request it from the originating/performing agency or talk to Margaret about getting the data from that specific survey.

To:	Matthew Hinshaw, WFLHD Amit Armstrong, WFLHD	Date:	August 4, 2021
From:	Ian Hamilton, VHB Michael Amoabeng, VHB	Re:	Federal Land Management Agency (FLMA) Data Discussion Summary – Roadkill Observation and Data System (ROaDS)

Purpose and Background

The purpose of this memorandum is to document the key points noted data discussions between Western Federal Lands Highway Division (WFLHD) and Amanda Hardy of the National Park Service (NPS) and Vince Ziols of the United States Fish and Wildlife Service (USFWS). These partners helped develop the Roadkill Observation and Data System (ROaDS). These discussions focused on the availability of existing ROaDS data, and the possibility of sharing these data and the data collection model with WFLHD.

General Themes

ROaDS is a Survey 123, ESRI-based application used to document roadkill observations and wildlife-vehicle collisions through a spatially-located form. These data can be collected and visualize safety-related hotspots of roadkill in a given area. The input form is shareable to any agency (or organization) that wants to use it, and it aims to create a consistent, collaborative, and comprehensive way of recording roadkill safety issues. Each form may be a little different regarding domains and field attributes based on specific context (e.g., Pacific Island areas or the Rocky Mountains), but the questions will be the same.

ROaDS is a partnership between Federal Land Management Agencies (FLMAs) at the Department of the Interior (DOI), primarily NPS and USFWS. Although any agency can access the form, data collected by FLMAs housed under the DOI are restricted to DOI storage and server space behind an enterprise firewall. As a result, these data cannot be readily accessible in a third-party repository. Furthermore, any data that is produced by a non-DOI entity using the form is owned by that agency, organization, park, or station, and it does not go into a national database. WFLHD would need to contact each individual data owner to potentially link to these live data or request standalone extracts.

Specific Data Sources and Notes

The ROaDS form can be modified to fit an agency's specific needs, and Amanda indicated she would share the Survey123 Excel document with WFLHD. This form can be incorporated into FLH's data collection application and repository for users accessing WFLHD tools.

During the conversation, Amanda indicated that the agency possesses a GIS-based screening tool for environmental needs in project (the "TRSPT"). This tool buffers project extents and screens against GIS environmental layers. While this tool has similar functionality to the proposed WFLHD repository, albeit for a different purpose, it does not appear to be widely adopted by NPS project staff. Amanda mentioned Logan Simpson and Joe Regula as potential contacts for more information.

To: Matthew Hinshaw, WFLHD
Amit Armstrong, WFLHD

Date: August 4, 2021

From: Ian Hamilton, VHB
Michael Amoabeng, VHB

Re: Federal Land Management Agency (FLMA) Data Discussion Summary – United States Fish and Wildlife Service (USFWS)

Purpose and Background

The purpose of this memorandum is to document the key points noted data discussions between Western Federal Lands Highway Division (WFLHD) and the United States Fish and Wildlife Service (USFWS). These discussions focused on the availability of existing USFWS transportation data sources, and the possibility of sharing these data with WFLHD. There was also conversation about the future of Geography Information Systems (GIS) data and data collection at USFWS, supporting safety initiatives with data, connections with the Road Inventory Program (RIP), and real-time communication with the public.

General Themes

As part of the Department of the Interior (DOI), USFWS participates in the RIP at all of their stations that have roads managed by USFWS. The USFWS is currently on RIP Cycle 5 (2017-2022). The trails that USFWS manages are not part of RIP, and they are managed separately even if they parallel to roads managed in RIP. A trail database will be able available to the public once it is finished, but as of June 2021, the conditions assessments were still being performed in some regions. USFWS interviewees estimated that final assessments may not be complete for another year (i.e., summer 2022). Through this process, USFWS has begun to discuss more efficient ways of collecting data using GIS compared to the current process. Currently, data collection at USFWS is very decentralized, and some stations may not have long-term GIS staff or experience (which slows data collection and management).

There is no national central data structure to manage the agency-wide collections, and there is no clear overarching GIS policy which affects data. This affects the sign inventory required by Congress, crash and citation databases run by law enforcement, and non-spatial data that needs to be stored spatially. USFWS uses an internal website, SurfCat, to share and maintain any non-spatial data that accompanies spatial data. This method is best for obtaining disparate data from the regions, although data aggregated at the national level is more intuitive and user friendly. USFWS transportation asset data link to roadway data provided by RIP. Asset records are stored in a Maximo database and these are linked to the roadway inventory according to the real property inventory asset number. However, the link requires a manual data "push." This may cause issues or require data clean up.

To communicate with the public using advanced warning systems, the USFWS puts an announcement on the agency website, or a sign on the road affected. There is no record of the historical public communications unless there was an emergency report conducted; however, there is no central repository that hosts these reports.

Specific Data Sources and Notes

Vince Ziols of USFWS can share sample documentation of the crash database for a case study in Crab Orchard, as well as the documentation for a refuge visitor satisfaction survey (the project team has since received this documentation). However, the data for that survey will not be available until 2027. Vince also noted that USFWS is currently developing the National Wildlife Refuge System (NWRS) Sign Inventory. Stations will use this to collect the point location of NWRS signage, attributes, condition, and an associated picture. Users can also note recommendations for follow up actions such as repair, replace, clean, etc. and record those actions completion dates. However, these data may not be readily available outside of the Department of the Interior (DOI). The

Information in Planning and Consultation (IPAC) is a planning tool for assessing environmental impacts associated with planned construction and maintenance. It us a public facing tool that hold a lot of environmental data on the website. All public-facing GIS data can be found at USFWS's public facing ArcGIS Online open data portal.

To: Matthew Hinshaw, WFLHD
Amit Armstrong, WFLHD

Date: August 4, 2021

From: Ian Hamilton, VHB
Michael Amoabeng, VHB

Re: Federal Land Management Agency (FLMA) Data Discussion Summary – National Park System (NPS)

Purpose and Background

The purpose of this memorandum is to document the key points noted in geographic information systems (GIS) data discussions between Western Federal Lands Highway Division (WFLHD) and members of the National Park Service (NPS) and Roadway Inventory Program (RIP). These discussions focused on the availability of existing NPS transportation data sources, and the possibility of sharing these data with WFLHD. These discussions also included a vision for the future of the NPS Navigator site. Although the site is currently maintained by the NPS and available to the public, NPS plans on upgrading the current site or creating a new platform and interface. WFLHD noted that a new data repository being on WFLHD's ArcGIS Online (AGOL) site could either host this for NPS, or the data repository could link to the NPS's new platform. This should allow for flexibility in future discussions and allow both agencies to meet their core business needs.

General Themes

As part of the Department of the Interior (DOI), the NPS participates in the RIP; this program inventories road and asset information with video and vehicle telemetry according to semi-routine cycles. The program is currently on Cycle 6, and it was preparing for Cycle 7 as of the interaction with NPS.

Like many other Federal Land Management Agencies (FLMAs) engaged by the project team, NPS manages many datasets centrally, but regions or individual units may manage their own individual datasets that are not submitted to central databases. Traffic counts and other special inventories are examples of this. Still, the NPS data systems tended to be more centralized than other FLMAs interviewed by the project team.

NPS has two primary repositories of information, the Integrated Resource Management Application (IRMA) and Facility Management Software System (FMSS). The former is more of a general repository of authoritative datasets (including visitor information and traffic counts), and the latter is specifically focused on asset data. As previously noted, there are issues with park-level data not being incorporated in national datasets, but these aforementioned resources represent the most authoritative sources for various GIS and non-spatial data. The Highway Pavement Management Application (HPMA) ingests pavement condition data produced from the RIP data collection effort and capital planning staff develop projections for future maintenance needs.

NPS's Guardrail Inventory Program (GIP) and Wall Inventory Program (WIP) exist in the NPS Navigator application, but the data are becoming dated (efforts conducted between 2008 and 2012). RIP and NPS interviewees noted this concern, but felt the data were still useful as a general guide and were reasonably accurate and reliable. Interviewees also noted that recent efforts to update these data have not progressed.

Although not explicitly covered in the meeting, NPS has developed detailed safety data for 24 parks. These data are intended to be used in AASHTOWare's Safety Analyst software or applied for other systemic safety analyses. These data are not available publicly, but these datasets would not be updated rapidly. Stand-alone extracts of these data could be incorporated in the WFLHD repository. Wayne Emington with NPS also noted interest in applying other data collection tools (i.e., Curve Finder) to RIP and Safety Analyst data for deeper safety insights and reviews.

Finally, although the Incident Management Analysis and Reporting System (IMARS) is the current system for managing crash or incident data in national parks, this system will likely be superseded in the near to medium term (referred to as the Crash Data System – CDS – in previous discussions).

Other Specific Data Sources and Notes

NPS publishes a diverse array of information through its NPS Navigator application, as well as individual datasets through the NPS Open Data Portal. These will be the primary sources of data ingested by the WFLHD repository. NPS also publishes some traffic count information, although there is not a necessarily permanent location to store and publish these data in a spatial format (traffic count reports and graphs by month and year are available through IRMA). Transit data in NPS jurisdictions is relatively uneven in quality and spatial location. Some transit services may use the General Transit Feed Specification (GTFS), a format that provides spatial information, but many do not. Most transit fleet and service information, including traffic incidents and injuries involving transit vehicles, is stored in tabular format.

For non-spatial technical documents, plans, and analyses, NPS uses the Electronic Technical Information Center (ETIC) repository. This resource stores archives of technical reports and documents that might be helpful for safety planning and analysis. However, it does not provide any spatial component (e.g., a point on the map) associated with these technical documents.

The NPS has several exploratory data analytics efforts ongoing. Several parks are exploring blue tooth-based applications for internal park circulation and exposure. This is driven by long-range planning initiatives, and it is still very much in a research and development phase. Erica Cole is a key contact for that work. There is also an effort by the Inter-Agency Visitor Use Council to understand visitor movement patterns. This applies to both internal park research, as well as inter-agency patterns (e.g., with Bureau of Land Management and the United States Forest Service). Wayne Emington noted that this agency is using multiple sources, traffic, campground occupancy, and visitor counts, to develop these numbers. Additional exploratory research included Strava and cell phone-based (e.g., Streetlight) data evaluations in the Inter-Mountain region. The applicability of these efforts varies widely across the country. Like other agencies, NPS representatives noted that Recreation.gov was the best resource for campground occupancy and use (however, this would only apply to *reservable* campground space).

To: Matthew Hinshaw, WFLHD
Amit Armstrong, WFLHD

Date: August 4, 2021

From: Ian Hamilton, VHB
Michael Amoabeng, VHB

Re: Federal Land Management Agency (FLMA) Data Discussion Summary – Road Inventory Program (RIP)

Purpose and Background

The purpose of this memorandum is to document the key points noted in geographic information systems (GIS) data discussions between Western Federal Lands Highway Division (WFLHD) and Brandon Strohl of the Road Inventory Program (RIP). RIP collects transportation asset information on roads and parking areas for planning, asset management, and operations purposes networkwide. These discussions focused on the availability of existing RIP transportation data sources, and the possibility of sharing these data with WFLHD. There was also conversation about the data collection operation and method, and the possible overlap and synergy of work between agencies needs and this project.

General Themes

The RIP performs mobile data collection of paved roadway inventories and assets. These data cover road mileage, global positioning systems (GPS), and video logs, as well as pavement cracking, rutting, and roughness records (using downward facing lasers and 3-D imagery). Gyroscopic information also helps track location information when GPS signal is lost. It is important to note that the RIP process only includes video logs for remote sensing, and it does not currently use Light Detection and Ranging (LiDAR) technologies.

RIP conducts these efforts in cycles, roughly five-year periods. RIP primarily collects data and produces products for three Federal Land Management Agencies (FLMAs), 1) National Parks Service (NPS; figure 25), 2) Bureau of Reclamation (BOR), and 3) United States Fish and Wildlife Service (USFWS). Each agency is on the following cycles:

- NPS: Completing Cycle 6 and planning Cycle 7.
- USFWS: Currently on Cycle 5.
- BOR: Currently on Cycle 1.

Route ID Information
- Route Names and Numbers
- Functional Class / FLTP
- Surface Types

Condition Data
- Automated and Manual
- Paved/Unpaved Surface Types
- Surface Distress & Rutting
- Roughness

GIS Location Data
- GPS is field collected/verified
- Route descriptions (From/To)
- Shapefiles and Web Mapping
- Linear Referencing
- Capturing changes

Data Collection Vehicle (DCV)
- Mileage
- GPS
- Video/Photos
- Cracking
- Rutting
- Roughness

Partner Management Systems
- Data Alignment
- Data Transfer
- Data Request

Roadside Features Data
- Road Logs & Milepost definition
- Signage, culverts, bridges, tunnels, walls, ditches, guardrail, curbing, etc.
- Mile Marker Signs (BLRI and NATR)

Other Data
- RIP PDF Reports and Website
- Wall Inventory Program (WIP)
- Guard Wall Inventory Program (GIP)
- PathView and Visidata
- NPS Navigator and Pathweb

Source: FHWA

Figure 25. Graphic. RIP data collection for NPS cycle 6.

Once a collection cycle is locked in, the data stays consistent until a new cycle is finalized so that data don't fluctuate throughout the creation of a new cycle. RIP has also supported the United States Air Force, United States Forest Service (USFS), Bureau of Land Management (BLM), and United States Army Corps of Engineers (USACE) in their data needs.

To streamline the collection process, RIP holds a meeting with an agency before collecting data to review and confirm attributes such as route IDs and names, functional class, and surface type; however, data schemas and attribute values vary by agency. These meetings are critical as they keep the RIP aligned with other asset management systems (e.g., NPS's Facility Management Software System). With all the attributes, RIP has guidelines to attempt to create a consistent national inventory, but parks and refuges have final say in their data collection and how they manage assets. Each agency also keeps their own copy of the database that refers to their assets to keep the data between RIP and the agency aligned.

Separate cycle collections also help prevent overlap between the years on asset collection. Once a data set gets collected in a new cycle it replaces the old cycle's data—a sign cannot be duplicated in the wrong place in more recent years. Brandon indicated he wanted to improve the milepost system using ESRI Roads and Highways so that the mileposts would be automatically updated. The features also contain a latitude and longitude which means starting a linear referencing system (LRS) with RIP data for WFLHD wouldn't be as big as a lift as it might seem. RIP currently maintains an LRS, and their data is attached to the LRS.

RIP collects roadway information using a data collection vehicle (i.e., the Data Collection Vehicle – DCV) that drives all the NPS paved roads and some USFWS roads if they are paved. The vehicle utilizes GPS in the driving lane, which means the road data is not perfectly aligned with the centerline. The road cannot be driven the same every time, so the data is snapped to existing road features when it is driven for a new cycle. The vehicle also collects video, cracking and rutting, roughness, and mileage of the road. Parking data and unpaved roads are done using manual assessments, not using the vehicle. Pavement condition is one of the most heavily utilized datasets. The pavement management team is the biggest user of collected data (e.g., Highway Pavement Management Application). They utilize the information to predict the future condition of pavement which dictates projects and upkeep for the next few years.

RIP databases contain asset information in tabular GIS form, and the NPS Navigator team wants it to be on the Navigator website. This poses challenges with firewalls and data sharing between agencies. This may preclude NPS Navigator continuing as a public facing resource (although subsequent conversations with Volpe indicate that there is a preference for Navigator to remain public). Brandon also detailed how Navigator is just for NPS, but USFWS and BOR could benefit from a tool like Navigator; this is potentially a goal of the WFLHD repository living on ArcGIS Online.

Considering the overlap between the data collection tool being developed for this project and what RIP does, it is important to coordinate with RIP so there isn't duplication of effort. To avoid the duplication, Brandon Strohl of RIP could present to the RIP project team on what they do and how they do it. This would facilitate discussion on the best way to work in tandem and with the same goals in mind. Brandon offered to have the WFLHD project team come up with data to collect and he and RIP would investigate opportunities to collect it.

Specific Data Sources and Notes

The data collected per Cycle has evolved over time, and not all assets are collected each cycle. Figure 26 is a matrix of the availability and coverage of each asset for NPS that was collected during a given cycle. The guardrail/walls datasets have not been updated since Cycle 4, but there was discussion for creating a Survey 123 application through ESRI to continue data collection in an ad-hoc or opportunistic manner. However, this was not possible due to a lack of funding. Signs have been spatially located, but it is still an old dataset. RIP hopes to update the roadside features dataset in Cycle 7, which should begin in 2022. The RIP team also hopes to use 360-degree cameras in Cycle 7 for greater asset capture. There is potential for Cycle 7 to conduct a limited pilot with LiDAR data, but it is uncertain (if not very unlikely) whether this will be pursued.

NPS/FHWA – Road Inventory Program – Cycle Overview

	CYCLE 3 2001-2005	**CYCLE 4 2006-2010**	**CYCLE 5 2010-2014**	**CYCLE 6 2014-2021**
PARKS COLLECTED	**All Large* and Small* Park Units** 312 parks	**Large Parks Only** 89 parks	**All Large and Small Park Units** 315 parks	**All Large and Small Park Units** >315 parks
PAVED ROADS COLLECTED	**Yes** - All paved roads - Loaded into HPMA	**Yes** - All paved roads - Loaded into HPMA	**Large Parks (Partial)** - *Only FC 1, 2, 7, and 8* roads + new or changed roads for other FC's - Loaded into HPMA **Small Parks (Full)** - All paved roads - Loaded into HPMA	**Yes** - All paved roads - Large Parks: 1 Full plus 1 or 2 Partial collections - 1 full collection of Small Parks - Loaded into HPMA
PAVED PARKING COLLECTED	**Yes** - All paved parking - Loaded into HPMA	**Yes** - All paved parking - Loaded into HPMA	**Large Parks - No** Unless parking was new or changed **Small Parks - Yes** All paved parking	**Yes** - All paved parking - Loaded into HPMA
ROADSIDE FEATURES COLLECTED	**Yes** Examples: Signs, guardrails/walls, bridges, and culverts (inconsistent quality)	**Yes** Examples: Signs, guardrails/walls, bridges, and culverts when locations marked	**Large Parks:** Features collected ONLY on **new** or **changed** roads/parking **Small Parks** – Yes. Features collected on ALL roads/parking	**No**
ROAD MILEAGE	New length applied	New length applied	- Route length matched** to Cycle 4 length for Large Parks - New length applied to Small Parks	Route length matched** to a previous collection
PARKING SQ FT	New square footage applied	New square footage applied	New square footage applied	New square footage applied
ROADWAY VIDEO	Roadware format	Roadware format	Pathway format	Pathway format
UNPAVED COLLECTION	**No**	**No** 2005 Pilot at 2 parks	Very limited	- Piloting at NER/SER Parks in 2019/2020 - Alaska Region: All unpaved roads/pkg - GIS/conditions verified/collected in field

Source: FHWA

Figure 26. Graphic. Assets by cycle in NPS collection through RIP.

The final NPS RIP data are stored at Eastern Federal Lands Highway Division (EFLHD), and they are distributed to individual parks. The RIP reports are available for all parks for Cycles 3 through 6 on the RIP reports website (USFWS and BOR SharePoint sites are in production). NPS Navigator displays some of the data, and PathWeb displays any park and cycle video that was taken by the collection vehicle. Figure 27 provides an overview of NPS spatial data collected through RIP.

Roadside Features were collected in Cycles 4 and 5 from DCV video
Cycle 4 – features collected only in **Large Parks** (Visidata)
Cycle 5 – features collected only in **Small Parks** (PathView)
Cycle 6 – no features collection

POINT FEATURES

Cattle Guard
Culvert
Drop Inlet*
Gate
Intersection
Mile Marker
Overpass – Vehicular
Overpass – Pedestrian
Overpass – Railroad Crossing
Park Boundary
Railroad Crossing
Signs
State Boundary
Traffic Light

LINEAR FEATURES

Bridge*
Construction Zone
Curb
Curb-And-Gutter
Debris on Road
Guard/Guide wall
Guard/Guide rail
Lane Deviation
Low water crossing
One-way
Paved Ditch
Pullout
Retaining wall
Surface type
Tunnel*

Where to find Features Data?

1. Park Geodatabases – PMS_FEATURES table
   - Tabular Form, contains all of the details (latitude / longitude)
2. RIP Report PDF's
   - Road Logs in Section 9 of Cycle 4 and 5 Reports, show only RIP milepost and side
3. Visidata and PathView Programs
   - See Features in Video and on Map

Source: FHWA

Figure 27. Graphic. NPS features collected spatially in RIP.

To: Matthew Hinshaw, WFLHD
Amit Armstrong, WFLHD

Date: August 4, 2021

From: Ian Hamilton, VHB
Michael Amoabeng, VHB

Re: Federal Land Management Agency (FLMA) Data Discussion Summary – United States Army Corps of Engineers (USACE)

Purpose and Background

The purpose of this memorandum is to document the key points noted in geographic information systems (GIS) data discussions between Western Federal Lands Highway Division (WFLHD) and Meredith Bridgers of the United States Army Corps of Engineers (USACE). These discussions focused on the availability of existing USACE transportation data sources, and the possibility of sharing these data with WFLHD. There was also conversation about the data ownership structure of USACE, the reporting of fatal crashes through multiple sources, traffic metering, asset management, and data overhauls and ownership. The data that USACE manages is more specific to their niche than other agencies (i.e., water usage and navigation) which limits the amount of data available and needed for roadway transportation safety. In other words, most land-based transportation is primarily intended to get people to the water, and these supporting data are secondary to management of water resources.

General Themes

USACE data are constructed in a decentralized manner where data models and owners may vary based on where in the country the data are managed and who is managing them. This also means that some data are on the local level while other data are on the national level. One national level tool is called EngLink where incidents (fatalities and any crashes that involve USACE property or when a government employee is involved) are reported and housed. Fatalities are also reported by State and local law enforcement which are then reported into the Fatality Analysis Reporting System (FARS). However, the correlation between EngLink reports and FARS reports is not 1:1 due to USACE not having knowledge of events that occurred in all rural areas (in other words, EngLink is not a complete source of information). While EngLink is used for crashes, it is not used for citations, which are defined in Title 36. This document details what vehicles can be cited for, and who has the authority in any given situation to cite them. There will be a new citation system or server to host the database, but there is not yet a timeline for this new system to be completed.

USACE meters their roads to help them to estimate visitation, control the traffic volume in units, and monitor turnover in the units which they manage. Metering occurs on up to 70 percent of roads managed by USACE. There are two categories of roads—recreation areas, which are metered, and project areas, where assets are assigned to primary missions and roads do not get metered (e.g., a road over a dam). Along with the metering, USACE collects visitor surveys that collects information on visitors, such as who is visiting, how long they stay, and their activities. These data are collected for different subclasses—daytime activities, multi-purpose day/overnight, campground overnight, and land/water access—to develop load factors for sites. Currently the data show the visitation load is stable, and there is no need to update factors until there is a large shift. To supplement this approach, GIS analytics are used to show any dispersed use computation (i.e., if users are coming to USACE land for recreation, but not through developed recreation areas). Meredith mentioned Dr. Brownley at Clemson University in South Carolina and an inter-agency group called Together as a contact for these methods.

During COVID and stay-at-home conditions, USACE created a park status website for the public. This website mostly deals with general operations related to flooding. Additionally, USACE does local press releases through the public affairs offices that announce road closures or construction. There is no central database for these announcements, and they are not retained in any way at the national level. It is possible that each district may retain their releases, but that would be on a case-by-case basis.

Specific Data Sources and Notes

It is possible to get estimates on federal camping in the USACE areas from recreation.gov and the previously discussed load factors will only be extrapolated if the sites do not use recreation.gov.

USACE has just started an asset management program called the Operational Conditions Assessment where each business line must create key assets and rate them. The Maximo database is for USACE's internal use. It is built in a decentralized manner like the data previously discussed; it applies to the Project Site Area (PSA) level. The road inventory has a different Department of Defense (DOD) spatial database standard. The inventory was cross walked to Federal Lands Highway's (FLH) requirements with data elements not captured. In January of 2021, about 10% of the inventory had been submitted with up to 40% being completed upon the next submission. While there isn't much centerline data, a tabular database with road mileage counts can be made available. Meredith also subsequently provided the tabular dataset of public road mileage, as well as a link to a Department of Interior (DOI) report on *Estimating Recreational Visitation to Federally Managed Lands*.

USACE runs a geospatial Open Data portal through ESRI, but it was indicated that it might not contain relevant information due to the USACE focus on bridges, dams, water areas, and other water-centric assets. There are some potential datasets that may be helpful, such as district division boundaries. Everything on the portal is public-facing and would be available for use in the data repository.

To: Matthew Hinshaw, WFLHD
Amit Armstrong, WFLHD

Date: August 4, 2021

From: Ian Hamilton, VHB
Michael Amoabeng, VHB

Re: Federal Land Management Agency (FLMA) Data Discussion Summary – United States Forest Service (USFS)

Purpose and Background

The purpose of this memorandum is to document the key points noted in Geographic Information Systems (GIS) data discussions between Western Federal Lands Highway Division (WFLHD) and Mark Roper of the United States Forest Service (USFS). These discussions focused on the availability of existing USFS transportation data sources, and the possibility of sharing these data with WFLHD. There was also conversation about how live transportation updates and communications with the public occur, traffic and campsite count data, and collaboration with law enforcement to receive and maintain the highest quality crash data.

General Themes

The USFS uses the National Resource Manager (NRM) for internal data processes and application management. Originally, the data were called iWeb, but that represented mostly tabular data. iWeb was enhanced to create the NRM once GIS became more popular and established as a common data format. Events such as signs, culverts, or anything associated with the road or trails are milepost-based and stored on USFS's custom Linear Referencing System (LRS). Note, the USFS does not participate in the Roadway Inventory Program (RIP) and develops these data systems internally. USFS is in the process of trying to bring all legacy applications and databases that tie into the NRM into modern data systems with the goal of having all data locatable in GIS (if applicable). Progress is ongoing, but this process could take several years to be completed.

The USFS's Enterprise Data Warehouse (EDW) provides most of the agency's current externally-facing tabular and spatial data. Most datasets that could be readily ingested by the WFHLD repository are stored here. However, there may be relevant datasets behind the USFS enterprise firewall that could be relevant. If more data are needed, Mark indicated he could pull data himself or put VHB and WFLHD in contact with a national or regional USFS employee who may be able to pull larger data sets for use in the repository (as standalone extracts). These data would not be "live," but it would act as a starting point for ingesting USFS data.

Traffic data are not consistent throughout USFS. Individual forests vary on how they count, which roads they count, and the consistency with which they record traffic counts. There is a possibility that traffic data could be created in GIS or NRM, but it would need to bring together many different individual datasets, and it would require a significant effort. As an example, San Juan National Forest (SJNF) collects traffic data via TRAFx DataNet, and this may apply to other forests as well.

The discussion then moved to using campground information to show contextual information in USFS jurisdictions, as well as any public-facing communications or warning systems recording flooding, traffic, road closures, or other event-based data. The National Visitor Use Monitoring (NVUM) program provides general sampling of visitors and counts in the USFS forests across the country. As with other interviews, Mark cited Recreation.gov as the best resource for campground visitation (although it should be noted that this would only track *reservable* campground space). While there is no consistent public data indicating current conditions in forests, USFS produces news releases when a road is closed, logging has commenced, or for any large announcement on rules and regulations; they typically do not provide news releases on the live status of traffic and congestion. News releases are not retained in a database or storage space, but Mark indicated he could reach out to the public affairs office to see if they have retained them in any capacity.

Throughout the conversation there was a significant theme of data being collected in piecemeal, and WFLHD would have to reach out to individual owners for potential access. Law enforcement data had been previously used in some GIS applications, but the data are not immediately available to the public (continuing the theme). Mark mentioned that States may have higher quality data and easier access to it.

Other Specific Data Sources and Notes

Toward the end of the meeting, Mark detailed a few specific data sources that could be helpful and are more public facing than what was discussed earlier. He mentioned the National Agriculture Imagery Program (NAIP) and individual counties would be best sources for aerial imagery. Furthermore, the USFS Public Affairs' Twitter and Facebook pages could be tracked; these feeds both provide information to the public, as well as field questions and sentiment feedback from visitors. Lastly, SJNF was able to download a large Light Detection and Ranging (LiDAR) file from USGS that covers 80% of the forest. This LiDAR dataset is high quality and covers many roads in the forests. It has already proved to be a useful resource for finding issues with roads in the forest.

There is a proprietary application created by the State of Colorado called COTREX that focuses on road and trail warnings and closures. The SJNF office has attempted to work with COTREX to see if it can be incorporated into the special orders and closures in the forest. Strava is another commonly used resource for non-motorized activity and exposure.

Appendix B: Short Form User Manual

The purpose of this data schema is to support the Federal Lands Highway (FLH) division of the Federal Highway Administration (FHWA). These data elements represent priority safety data needs, comprising both potential sources of risk, as well as countermeasures intended to reduce risk. Short Forms are a priority list of variables for FLH and its partners to use as key evaluation criteria for safety on Federally maintained roads. This includes particular applicability to low volume, rural contexts; however, most proven safety countermeasures are included for municipal or urban contexts as well.

This schema separates Short Form data elements into six categories:

1. **Tangent Risk Factors:** These risk factors apply to tangent sections (i.e., between horizontal curves) in particular, but they can also apply to combined corridors with tangents and curves merged into a single Short Form.
2. **Curve Risk Factors:** These risk factors apply to horizontal curves. Most risk factors are shared with the Tangent Short Form; however, there are curve specific risk factors that do not apply to tangent sections.
3. **Intersection Risk Factors:** These risk factors apply to the intersection of two or more public roads or driveway access locations.
4. **Nonmotorized Risk Factors:** These risk factors apply to non-motorized users. This includes bicyclists and pedestrians, as well as other users that may cross or travel with motor vehicles (e.g., equestrians or small motorized personal conveyances).
5. **Qualitative/Site Observations:** These characteristics represent safety-related observations that non-technical users can use to help convey safety needs. As a result, this Short Form does not include quantitative information or specific thresholds; observations are meant to convey impressions or anecdotal characteristics.
6. **Countermeasure:** This Short Form is intended to capture proven safety countermeasures on FLH roads. The absence of countermeasures relative to factors noted in the aforementioned Short Forms could indicate an increased risk at applicable locations (e.g., sharp curvature without delineation or rumble strips).

Data elements listed in this framework schema can be stored as individual point features (or linear features as noted in the Countermeasure Short Form), but these can also be stored as events or attributes along a road centerline network. All data elements should have an associated unique Route ID, as well as relevant milepost information if a linear referencing system (LRS) is available.

Tangent

This section documents variables related to the research-based tangent risk factors to consider during data collection. These could also apply to combined sections of tangents and horizontal curvature.

Average Lane Width

Definition: The average width of all travel lanes. If travel lanes are not delineated by pavement markings or if the road is unpaved, then analysts should capture the total travel-way width and divide by the assumed number of lanes (i.e., two lanes on an unpaved road unless road is exceptionally narrow).

Source: Al-Kaisy and Huda, 2020(54); Harwood et al., 2000(55); Saleem et al., 2020(56)

Risk Level: Coded:

- ≤ 10 ft (High)
- 10 – 12 ft (Moderate)
- ≥ 12 ft (Low)

Shoulder Type

Definition: The predominant shoulder type material on the roadside in the direction of inventory.

Source: Porter et al., 2020(57)

Risk Level: Coded:

- Unpaved (High; figure 28)
- Paved (Low; figure 29)

Source: FHWA

Figure 28. Photograph. Narrow and unpaved shoulder.

Source: FHWA

Figure 29. Photograph. Example of a paved shoulder.

Shoulder Width

Definition: The average width of outside shoulder, including both paved and unpaved parts (figure 30), measured from the center of the edge line outward.

Source: Harwood et al., 2000[55]; Porter et al., 2020[57]

Risk Level: Coded:

- ≤ 2 ft (High)
- 2 – 6 ft (Moderate)
- ≥ 6 ft (Low)

Source: FHWA

Figure 30. Photograph. Example of combined paved and unpaved shoulder area.

Delineation

Definition: Indicator of visual delineation (e.g., signage, reflective posts, etc.) on road.
Source: iRAP[29]/usRAP[28]
Risk Level: Coded:

- Poor (High)
- Adequate (Low; figure 31)

Source: FHWA

Figure 31. Photograph. Example of curve chevrons providing adequate delineation on a horizontal curve.

Grade

Definition: Observed vertical longitudinal grade for a particular point on the roadway. This is intended to be representative for a particular segment.

Source: AASHTO, 2010[(23)]; Porter et al., 2020[(57)]

Risk Level: Coded:

- ≥ 6% (High)
- 3 – 6% (Moderate)
- ≤ 3% (Low)

Driveway/Access Point Density

Definition: Number of driveways or access points along segment per mile.

Source: Al-Kaisy and Huda, 2020[(54)]

Risk Level: Coded:

- ≥ 6 per mile (High)
- < 6 per mile (Low)

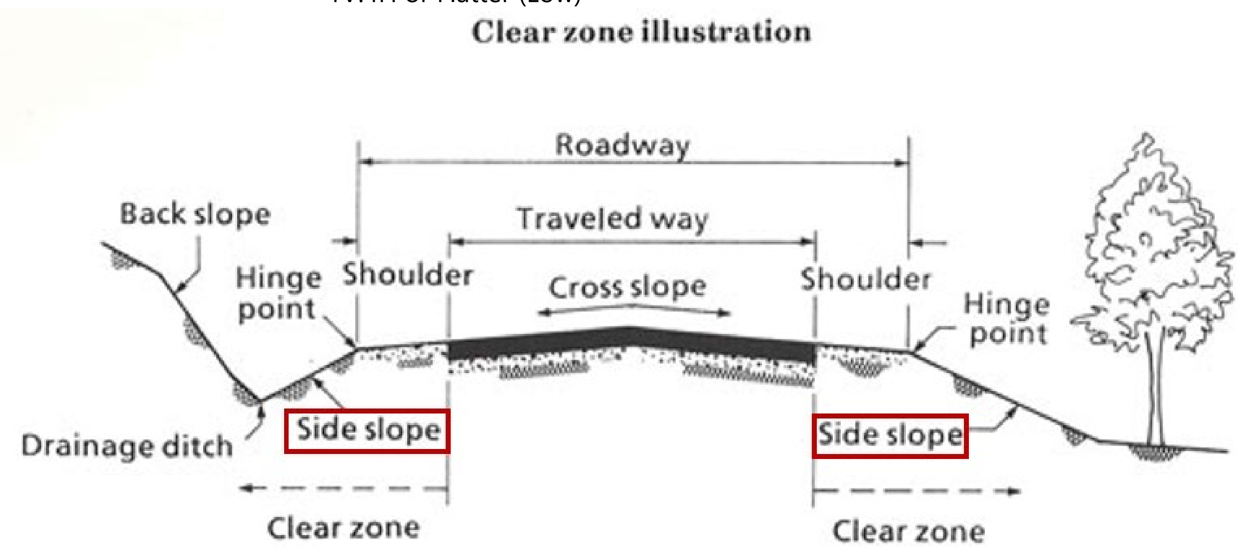
Sideslope

Definition: The sideslope (foreslope or backslope) on right side of roadway immediately adjacent to the travel lane, shoulder edge, or drainage ditch in direction of inventory. Apply typical conditions if sideslope varies along a section of roadway (figure 32).

Source: Al-Kaisy and Huda, 2020[54]

Risk Level: Coded:

- 1V:3H or Steeper (High)
- 1V:4H-1V:3H (Medium)
- 1V:4H or Flatter (Low)



Source: FHWA

Figure 32. Graphic. Clear zone illustration with sideslope component highlighted.[58]

Sight Distance - Vertical

Definition: Presence of a sight distance issue related to vertical grade or vertical curvature (figure 33 and figure 34).

Source: iRAP[29]/usRAP[28]

Risk Level: Coded:

- Restriction Present (High)
- No Restriction (Low)

Source: FHWA

Figure 33. Photograph. Vehicle entering a vertical curve with substantial vertical grade.

Source: FHWA

Figure 34. Photograph. Vehicle obscured by vertical curvature at the same location in figure 33.

Fixed Roadside Objects - Distance

Definition: Distance of fixed objects from roadside edge line or assumed edge of the travel way in unmarked or unpaved. This is the effective clear zone.

Source: Al-Kaisy and Huda, 2020[54]; iRAP[29]/usRAP[28]

Risk Level: Coded:

- ≤ 3 feet of roadway (High; figure 35)
- 3-15 feet of roadway (Moderate; figure 36)
- ≥ 15 feet of roadway (Low; figure 37)

Source: FHWA

Figure 35. Photograph. Example of fixed objects less than 3 ft from the edge of the road.

Source: FHWA

Figure 36. Photograph. Example of fixed objects 3 to 15 ft from the edge of the road.

Source: FHWA

Figure 37. Photograph. Example of fixed objects more than 15 ft from the edge of the road.

Fixed Roadside Objects - Type

Definition: The type of object located on the roadside of the tangent.
Source: Stephens, 2005[59]
Risk Level: Coded:

- Higher risk objects (High)
  - Water
  - Bridge Pier, Abutment, or Railing End
  - Groups of Trees (4+ In. Diameter)
  - Boulder (1+ Ft. Diameter)
  - Retaining wall
- Moderate risk objects (Moderate)
  - Boulder (<1 Ft. Diameter)
  - Non-Breakaway Sign
  - Non-Breakaway Light Support
  - Individual Trees (4+ In. Diameter)
  - Culvert
  - Utility Pole
- Lower risk objects (Low)
  - Individual Trees (<4 In. Diameter)

Unpaved Road

Definition: Indicator of the surface condition of the roads.
Source: Al-Kaisy and Huda, 2020[54]
Risk Level: Coded:

- Unpaved (High)
- Paved (Low)

Poor Pavement Condition

Definition: Type of pavement distress present on the segment (figure 38 and figure 39).
Source: Al-Kaisy and Huda, 2020(54)
Risk Level: Coded:

- Rutting, potholes, or other surface issues (High)
- No to minimal issues (Low)

Source: FHWA

Figure 38. Photograph. Example of pavement rutting.(60)

Source: FHWA

Figure 39. Photograph. Example of potholes and pavement edge deterioration.

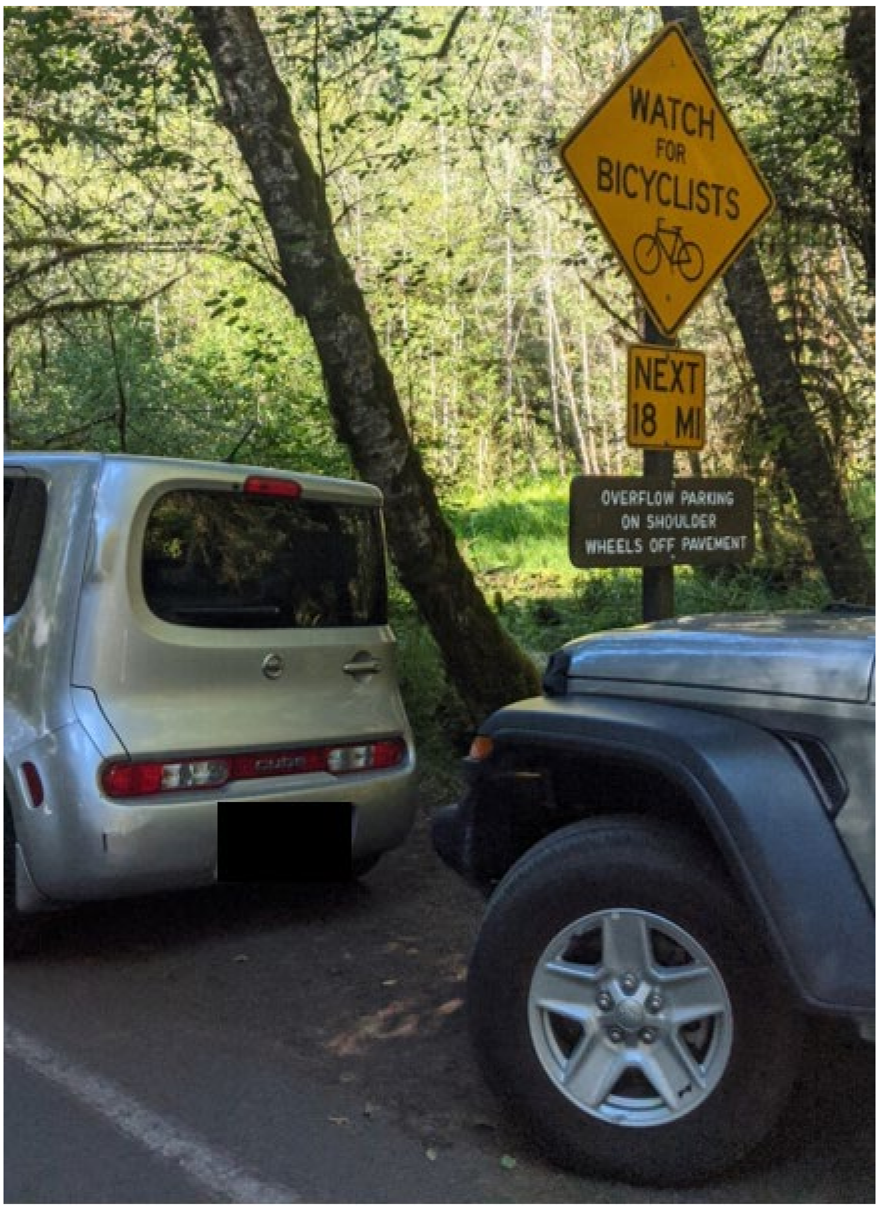
On-street Parking

Definition: Type of on-street parking present on the tangent (i.e., not present, on one side of the approach, or on both sides of the tangent; figure 40).

Source: iRAP[29]/usRAP[28]

Risk Level: Coded:

- Two Sides (High)
- One Side (Moderate)
- None (Low)



Source: FHWA

Figure 40. Photograph. Example of overflow on street parking.

Crash History

Definition: Indicator of frequent vehicular and non-motorist crashes on a particular tangent (anecdotal or from another source).

Source: Al-Kaisy and Huda, 2020[54]

Risk Level: Coded:

- Crash occurred in the last 5 years (High)
- No crashes within the last 5 years (Low)

Daily Traffic Count

Definition: Traffic count representing bidirectional (or single direction in the case of one-way facilities) traffic for a typical weekday. This could be an official annual average daily traffic (AADT) value, or a single traffic count based on data available (figure 41).

Source: Al-Kaisy and Huda, 2020[54]

Risk Level: Coded:

- >1,000 vpd (High)
- 601 – 1,000 vpd (Moderate-High)
- 300 – 600 vpd (Moderate- Low)
- ≤ 300 vpd (Low)

Source: FHWA

Figure 41. Photograph. Example of an active traffic count in progress.

Posted Speed Limit

Definition: The daytime regulatory speed limit for automobiles posted or statutorily mandated on the greater part of the section.

Source: Al-Kaisy and Huda, 2020[54]

Risk Level: Coded

- ≥ 50 mph (High)
- < 50 mph (Low)

Curve

This section documents research-based risk factors related to curves (horizontal and vertical).

Average Lane Width

Definition: The average width of all travel lanes. If travel lanes are not delineated by pavement markings or the if the road is unpaved, then analysts should capture the total travel-way width and divide by the assumed number of lanes (i.e., two lanes on an unpaved road unless road is exceptionally narrow).

Source: Al-Kaisy and Huda, 2020(54); Harwood et al., 2000(55); Porter et al., 2020(57)

Risk Level: Coded:

- ≤ 10 ft (High)
- 10 – 12 ft (Moderate)
- ≥ 12 ft (Low)

Shoulder Type

Definition: The predominant shoulder type material on the roadside in the direction of inventory.

Source: Porter et al., 2020(57)

Risk Level: Coded:

- Unpaved (High)
- Paved (Low)

Shoulder Width

Definition: The average width of outside shoulder, including both paved and unpaved parts (figure 30), measured from the center of the edge line outward.

Source: Harwood et al., 2000(55); Porter et al., 2020(57)

Risk Level: Coded:

- ≤ 2 ft (High)
- 2 – 6 ft (Moderate)
- ≥ 6 ft (Low)

Radius

Definition: The radius of horizontal curve.
Source: Al-Kaisy and Huda, 2020[54]; iRAP[29]/usRAP[28]; Porter et al., 2020[57]
Risk Level: Coded:

- <300 ft (High)
- 300 – 600 ft (Moderate-High)
- 651 – 1,000 ft (Moderate)
- >1,000 (Low)

Delineation

Definition: Indicator of visual delineation (e.g., signage, reflective posts, etc.) on road.
Source: iRAP[29]/usRAP[28]
Risk Level: Coded:

- Poor (High)
- Adequate (Low; figure 31)

Grade

Definition: Observed vertical longitudinal grade for a particular point on the roadway. This is intended to be representative for a particular segment.
Source: AASHTO, 2010[23]; Porter et al., 2020[57]
Risk Level: Coded:

- ≥ 6% (High)
- 3 – 6% (Moderate)
- ≤ 3% (Low)

Sideslope

Definition: The sideslope (foreslope or backslope) on right side of roadway immediately adjacent to the travel lane, shoulder edge, or drainage ditch in direction of inventory. Apply typical conditions if sideslope varies along a section of roadway (figure 32).
Source: Al-Kaisy and Huda, 2020[54]
Risk Level: Coded:

- 1V:3H or Steeper (High)
- 1V:4H-1V:3H (Medium)
- 1V:4H or Flatter (Low)

Fixed Roadside Objects - Distance

Definition: Distance of objects from roadside edge line; this is the effective clear zone.
Source: Al-Kaisy and Huda, 2020[54]; iRAP[29]/usRAP[28]
Risk Level: Coded:

- ≤ 3 feet of roadway (High; figure 35)
- 3-15 feet of roadway (Moderate; figure 36)
- ≥ 15 feet of roadway (Low; figure 37)

Fixed Roadside Objects - Type

Definition: The type of object located on the roadside of the tangent.
Source: Stephens, 2005[59]
Risk Level: Coded:

- Higher risk objects (High)
  - Water
  - Bridge Pier, Abutment, or Railing End
  - Groups of Trees (4+ In. Diameter)
  - Boulder (1+ Ft. Diameter)
  - Retaining wall
- Moderate risk objects (Moderate)
  - Boulder (<1 Ft. Diameter)
  - Non-Breakaway Sign
  - Non-Breakaway Light Support
  - Individual Trees (4+ In. Diameter)
  - Culvert
  - Utility Pole
- Lower risk objects (Low)
  - Individual Trees (<4 In. Diameter)

Intersection, Driveway, or Other Access Point Present

Definition: Presence of an intersection, driveway (i.e., not an intersecting public road), or access point (figure 42).

Source: Albin et al., 2016[(61)]

Risk Level: Coded:

- Present (High)
- Not Present (Low)

Source: FHWA

Figure 42. Photograph. Access point on a horizontal curve combined with sight distance limitations.

Presence of a Visual Trap

Definition: Presence of a potential sight distance issue related to horizontal curvature (figure 43 and figure 44).

Source: Albin et al., 2016[61]

Risk Level: Coded:

- Present (High)
- Not Present (Low)

Source: FHWA

Figure 43. Photograph. Break in the tree line providing a visual cue that can be a potential visual trap.

Source: FHWA

Figure 44. Photograph. Vehicle turning and demonstrating the horizontal curve and visual trap in figure 43.

Sight Distance - Vertical

Definition: Presence of a potential sight distance issue related to vertical grade or vertical curvature (figure 33 and figure 34).

Source: iRAP[29]/usRAP[28]

Risk Level: Coded:

- Restriction Present (High)
- No restriction (Low)

Sight Distance - Horizontal

Definition: Presence of a potential sight distance issue related to horizontal curvature. This could be related to vegetation (figure 45) or other obstructions (figure 46).

Source: iRAP[29]/usRAP[28]

Risk Level: Coded:

- Restriction Present (High)
- No restriction (Low)

Source: FHWA

Figure 45. Photograph. Sight distance issue related to vegetation on the inside of a horizontal curve.

Source: FHWA

Figure 46. Photograph. Sight distance issue related to terrain and vegetation.

Crash History

Definition: Indicator of frequent vehicular and non-motorist crashes on a particular curve (anecdotal or from another source).

Source: Al-Kaisy and Huda, 2020[54]

Risk Level: Coded:

- Crash occurred in the last 5 years (High)
- No crashes within the last 5 years (Low)

Daily Traffic Count

Definition: Traffic count representing bidirectional (or single direction in the case of one-way facilities) traffic for a typical weekday. This could be an official annual average daily traffic (AADT) value, or a single traffic count based on data available (figure 41).

Source: Al-Kaisy and Huda, 2020[54]

Risk Level: Coded:

- >1,000 vpd (High)
- 601 – 1,000 vpd (Moderate-High)
- 300 – 600 vpd (Moderate- Low)
- ≤ 300 vpd (Low)

Intersection

This section documents research-based risk factors related to individual intersections or driveway access points.

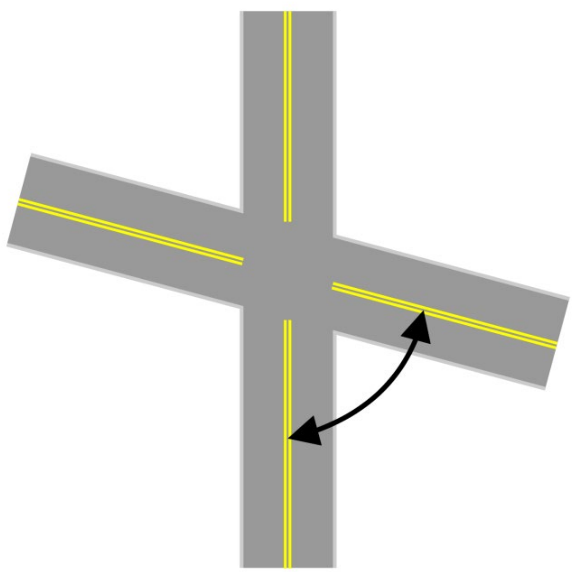
Intersection Angle

Definition: The measurement in degrees of the smallest angle between any two legs of the intersection. This value will always be within a range of 0 to 90 degrees (i.e., for non-zero angles, always measure the acute rather than the obtuse angle). This should be measured from the location where a typical vehicle would be stopped at an approach (figure 47).

Source: Al-Kaisy and Huda, 2020[54]

Risk Level: Coded:

- <70 degrees (High)
- ≥70 degrees (Low)



Source: FHWA

Figure 47. Graphic. Diagram of intersection angle.[13]

Traffic Control

Definition: Traffic control present at intersection/junction. Traffic control could be signage, traffic signal, or other regulatory pavement marking.

Source: Al-Kaisy and Huda, 2020[54]

Risk Level: Coded:

- Uncontrolled (High)
- Traffic control device present (Low)

Lighting

Definition: Indicator that street lighting is present.
Source: Al-Kaisy and Huda, 2020(54)
Risk Level: Coded:

- Not Present (High)
- Present (Low)

Left Turn Lane (on uncontrolled approach)

Definition: Presence of left-turn lanes that accommodate left turns from the uncontrolled approach.
Source: Al-Kaisy and Huda, 2020(54)
Risk Level: Coded:

- Not Present (High)
- Present (Low)

Crash History

Definition: Indicator of frequent vehicular and non-motorist crashes at a particular intersection (anecdotal or from another source).
Source: Al-Kaisy and Huda, 2020(54)
Risk Level: Coded:

- Crash occurred in the last 5 years (High)
- No crashes within the last 5 years (Low)

Daily Traffic Count

Definition: Traffic count representing the sum of traffic volumes on all named routes at the intersection; if a single named route comprises more than one approach and the traffic volume is substantially different (i.e., due to turning movements), take the larger of the two count values. This could be an official annual average daily traffic (AADT) value, or a single traffic count based on data available.
Source: Al-Kaisy and Huda, 2020(54)
Risk Level: Coded:

- >1,000 vpd (High)
- 601 – 1,000 vpd (Moderate-High)
- 300 – 600 vpd (Moderate- Low)
- ≤ 300 vpd (Low)

Non-Motorized and Motorized Mixed Use

This section documents research-based risk factors related to non-motorized and motorized mixed use.

Sidewalk/Sidepath

Definition: Indicator that an adequate path or accommodation is present for non-motorists. This includes marked or separated facilities for bicyclists and pedestrians (figure 48 and figure 49).

Source: iRAP[29]/usRAP[28]

Risk Level: Coded:

- None (High)
- Paved Shoulder (Moderate-High)
- Separated ≤ 3 ft from traffic (Moderate-Low)
- Separated >3 ft from traffic (Low)

Source: FHWA

Figure 48. Photograph. Example of a paved shoulder for non-motorists.[62]

Source: FHWA

Figure 49. Photograph. Example of a sidewalk with vegetated buffer from the street.[62]

Informal or "Desire" Path

Definition: Presence of an informal "desire" or "goat" path created by frequent use by non-motorist users (figure 50).

Source: --

Risk Level: Coded:

- Present (High)
- Not Present (Low)

Source: FHWA

Figure 50. Photograph. Example of an informal desire path created by pedestrians.[63]

Lighting

Definition: Indicator that street lighting is present.
Source: Blackburn et al., 2018[44]
Risk Level: Coded:

- Not Present (High)
- Present (Low)

Crossing Markings

Definition: Indicator of a marked pedestrian or other non-motorist crossing (i.e., crosswalk or other pavement marking).
Source: Blackburn et al., 2018[44]
Risk Level: Coded

- Not Present (High)
- Present (Low)
- Unknown

Crossing Signage

Definition: Signage to warn drivers of non-motorists crossing at a marked location. Signage includes the W-11, W16, and R1 series (figure 51).
Source: Blackburn et al., 2018[44]
Geometry Type: Coded:

- Not Present (High)
- Present (Low)

Source: FHWA

Figure 51. Graphic. Examples of advanced crossing signage.[64]

Crossing Refuge

Definition: Indicator that a raised median island that is intended as a pedestrian refuge is present on the approach (figure 52).

Source: iRAP[29]/usRAP[28]

Data Type: Coded:

- Not Present (High)
- Present (Low)

Source: FHWA

Figure 52. Photograph. Examples of non-motorist refuge.

Crossing Signal

Definition: Indicator that a type of pedestrian signal is present. This could be a rectangular rapid flashing beacon (RRFB), pedestrian hybrid beacon (PHB), or other dynamic signal.

Source: Blackburn et al., 2018[44]

Risk Level: Coded

- Not Present (High)
- Present (Low)

Daily Traffic Count

Definition: Traffic count representing bidirectional (or single direction in the case of one-way facilities) traffic for a typical weekday. This could be an official AADT value, or a single traffic count based on data available.

Source: --

Risk Level: Coded:

- >500 (High)
- 50-500 (Medium)
- <50 (Low)

Posted Speed Limit

Definition: The daytime regulatory speed limit for automobiles posted or statutorily mandated on the greater part of the section.

Source: Blackburn et al., 2018[44]

Risk Level: Coded

- ≥ 35 mph (High)
- < 35 mph (Low)

Crash History

Definition: Indicator of frequent vehicular and non-motorist crashes.

Source: --

Risk Level: Coded:

- Crash occurred in the last 5 years (High)
- No crashes within the last 5 years (Low)

Qualitative/Site Observation

This section documents variables related to qualitative data and site observations. This Short Form is intended to be used by non-technical users in particular to convey safety-related needs. Specific quantitative thresholds can be found elsewhere in the research report, but these are characteristics that users can note if conditions appear potentially unsafe.

Sight Distance Limitation

Definition: Indicator for a potential sight distance issue related to horizontal or vertical curvature. This could be the result of:

- Vertical curves obscuring approaching or entering vehicles (figure 34)
- Horizontal curves obscuring approaching or entering vehicles
- Vegetation or terrain obscuring signage (figure 53)
- Vegetation or terrain obscuring an intersection or entering vehicles

Source: FHWA

Figure 53. Photograph. Example of a sign obscured by vegetation.

Narrow Roads or Limited Passing Width

Definition: Road has very narrow lanes or has limited available travel way to accommodate passing vehicles (figure 54).

Source: FHWA

Figure 54. Photograph. Example of a narrow road with limited passing area.

Narrow Shoulders

Definition: Road shoulders are narrow or have limited opportunity for a vehicle departing the roadway to recover. This could be limited pavement on the shoulder (figure 28) or narrow clear zones (figure 55).

Source: FHWA

Figure 55. Photograph. Example of a narrow recoverable area.

Steep Sideslopes

Definition: The presence of steep sideslopes (foreslope or backslope) immediately adjacent to the travel lane, shoulder edge, or drainage ditch in direction of inventory based on field observations or anecdotal information (figure 56).

Source: FHWA

Figure 56. Photograph. Example of steep slopes by a roadway.

Pavement Edge Dropoff

Definition: Presence of elevation drop along edge of pavement based on field observations or anecdotal information (figure 57).

Source: FHWA

Figure 57. Photograph. Example of a pavement edge drop off.

Absence of Crossing Markings Signage

Definition: Lack of markings or signage at (or in advance of) a non-motorized crossing that warns motorists of non-motorized crossing activity (figure 51).

Roadside Objects - Distance

Definition: Hazardous fixed objects are near the roadway (figure 35).

Roadside Objects - Type

Definition: Presence of large, fixed objects along the roadside. These include concrete structures, exposed railing, wide diameter trees, large boulders, or utility poles.

High Use Turnout/Scenic View

Definition: The presence of a turnout or scenic view location that generate increased traffic, roadside parking, or pedestrians.

Public Events

Definition: There are regular public events during the year that lead to irregular congestion or generate increased traffic, roadside parking, or pedestrians.

Speeding Issue (Anecdotal)

Definition: Anecdotal knowledge or experience that speeding (either exceeding the posted speed limit or driving too fast for conditions) is prevalent on a particular segment.

High Crash Location (Anecdotal)

Definition: Anecdotal knowledge or experience that traffic crashes are relatively frequent on a particular segment.

Intermittent Obstruction

Definition: Road is intermittently obstructed, either by falling objects (figure 58) or frequent flooding (figure 59).

Source: FHWA

Figure 58. Photograph. Signage warning of frequent rock falls.

Source: FHWA

Figure 59. Photograph. Signage warning of frequent flash floods.

Pavement Condition

Definition: Pavement along a particular segment is old or particularly distressed (figure 38 and figure 39). A loss of friction may lead to potential safety issues.

Motorized Mixed Use

Definition: Presence of off-highway vehicles (OHV)— personal recreation vehicles that may be motorized that can include all-terrain vehicles (ATVs), 4-wheel-drives (4WDs), and trail bikes— along the segment.

Informal or "Desire" Path

Definition: Presence of an informal "desire" path created by frequent use by non-motorist users (figure 50).

Frequent Non-Motorized Crossings

Definition: A segment has frequent non-motorist crossings, including trail crossings or land uses (i.e., retail establishments or transit stops) that may generate crossing non-motorists (figure 60).

Source: FHWA

Figure 60. Photograph. Pedestrian crossing between destinations in Olympic National Forest.

Parking on Shoulder

Definition: Informal or overflow parking occurs frequently in a particular location (figure 61).

Source: FHWA

Figure 61. Photograph. Informal roadside parking at a trailhead.

Seasonal Closure

Definition: A road is off limits to the general public or to particular users for all or a portion of the year.

Large Vehicles

Definition: Large trucks or other heavy vehicles frequently travel along a particular road segment (figure 62).

Source: FHWA

Figure 62. Photograph. Example of a warning for trucks entering or leaving the roadway.

Countermeasure

This section documents variables related to proven safety countermeasures that could apply to Federally managed roads. Documented countermeasure locations can help analysts determine where additional countermeasures could be installed or where maintenance could be required.

Traffic Control Type

Definition: Traffic control present at intersection/junction.
Geometry Type: Point
Data Type: Coded

- All-Way Stop
- None
- Signal
- Stop
- Yield – Roundabout
- Yield - Traffic Control

Post-Mounted Delineators

Definition: The presence of post-mounted reflective delineators.
Geometry Type: Line
Data Type: Coded:

- Yes
- No
- Unknown

Lighting

Definition: Indicator that lighting is present.
Geometry Type: Point
Data Type: Coded:

- Continuous
- Lighted at Night
- Unlighted
- Unknown

Sign(s)

Definition: The type of sign(s) on the segment.
Geometry Type: Point
Data Type: Coded:

- Curve Warning
- Curve Chevrons-Static
- Dynamic Curve Warning System
- Other Warning
- Posted Speed-Regulatory
- Posted Speed-Advisory
- Wayfinding
- Advance Guide Signs and Street Names
- Variable Message

Additional Fields

Additional supporting data include:

MUTCD

Definition: Applicable Manual on Uniform Traffic Control Devices (MUTCD) code.
Data Type: Text

Dynamic

Definition: "Dynamic" signs will have flashing lights or dynamic electronic text.
Data Type: Coded

- Yes
- No
- Unknown

Centerline Markings

Definition: Presence of centerline markings (i.e., delineating two directions of travel).
Geometry Type: Line
Data Type: Coded

- Yes
- No
- Unknown

Additional Fields

Additional supporting data include:

Marking Width

Definition: Width of the marking.
Data Type: Short integer
Unit Type: Inches

Edge Line Markings

Definition: Presence of edge line markings (i.e., delineating the travel way from the roadside shoulder).
Geometry Type: Line
Data Type: Coded

- Yes
- No
- Unknown

Additional Fields

Additional supporting data include:

Marking Width

Definition: Width of the marking.
Data Type: Short integer
Unit Type: Inches

Number of Approaches Exclusive Left-turn Lanes

Definition: Number of exclusive (i.e., marked) left-turn lanes that accommodate left turns from the approach.
Geometry Type: Point
Data Type: Short Integer
Units Type: Number of lanes

Number of Approaches Exclusive Right-turn Lanes

Definition: Number of exclusive (i.e., marked) right turn lanes that accommodate right turns from the approach.
Geometry Type: Point
Data Type: Short Integer
Units Type: Number of lanes

Centerline Rumble Strips

Definition: The type of centerline rumble strips on the segment.
Geometry Type: Line
Data Type: Coded:

- Milled-In
- Raised
- Rolled-In
- Formed

Shoulder Rumble Strips/Stripes

Definition: The type of shoulder rumble strips or stripes on the segment.
Geometry Type: Line
Data Type: Coded:

- Milled-In
- Raised
- Rolled-In
- Formed

Additional Fields

Inside Shoulder

Definition: The presence of rumble strips on the inside (i.e., left) shoulder.
Data Type: Coded

- Yes
- No
- Unknown

Outside Shoulder

Definition: The presence of rumble strips on the outside (i.e., right) shoulder.
Data Type: Coded

- Yes
- No
- Unknown

Advisory Pavement Marking

Definition: Pavement markings intended to provide additional advance warning and reduce vehicular speeds approaching intersections, curves, or other higher risk situations.
Geometry Type: Line
Data Type: Coded:

- Speed Limit Advisory Marking Lane
- Curve Advance Marking
- Optical Speed Bars (figure 63)

Source: FHWA

Figure 63. Photograph. Example of optical speed bars.[65]

Additional Fields

Durable Pavement Markings

Definition: Indicator that durable pavement markings of any type are present (e.g., Waterborne, epoxy, thermoplastic, etc.; figure 64).

Data Type: Coded

- Yes
- No
- Unknown

Raised Pavement Markers

Definition: Indicator that raised pavement markers are present (figure 65).

Data Type: Coded

- Yes
- No
- Unknown

Source: FHWA

Figure 64. Photograph. Example of profile thermoplastic pavement markings.[66]

Source: FHWA

Figure 65. Photograph. Example of raised pavement markers.[67]

Dynamic Speed Signage

Definition: Type of digitally adjustable speed display sign present.
Geometry Type: Point
Data Type: Coded

- Variable speed limit
- Dynamic speed feedback signs
- Road geometry speed warning systems

Additional Fields

Additional supporting data include:

Speed Limit

Definition: The daytime regulatory speed limit for automobiles posted or legally mandated on the greater part of the section.
Data Type: Coded

- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- 60
- 65
- 70
- 75
- 80+

Unit Type: Miles per hour

Outside Barrier Type

Definition: The type of outside barrier (i.e., roadside, not in a road median) on the segment.
Geometry Type: Line
Data Type: Coded

- Modified Thrie-Beam
- Concrete Safety Shape (figure 66)
- Precast Concrete Guardwall, Type 1 (figure 67)
- Stone Masonry Guardwall (figure 68)
- Steel-Backed Timber Rail (figure 69)
- Box Beam (figure 70)
- Strong Post W-Beam (figure 71)
- Thrie-Beam (figure 72)
- High-Tension Cable (figure 73)
- Three-Strand Cable (figure 74)
- Weak Post W-Beam (figure 75)
- Steel-Backed Log Rail (figure 76)
- Random Rubble Cavity Wall (figure 77)

Source: FHWA

Figure 66. Photograph. Example concrete safety shape.[59]

Source: FHWA

Figure 67. Photograph. Example precast concrete guardwall.[59]

Source: FHWA

Figure 68. Photograph. Example stone masonry guardwall.[59]

Source: FHWA

Figure 69. Photograph. Example steel-backed timber rail.[59]

Source: FHWA

Figure 70. Photograph. Example box beam.[59]

Source: FHWA

Figure 71. Photograph. Example strong post w-beam.[59]

Source: FHWA

Figure 72. Photograph. Example thrie-beam.[59]

Source: FHWA

Figure 73. Photograph. Example high-tension cable.[59]

Source: FHWA

Figure 74. Photograph. Example three-strand cable.[59]

Source: FHWA

Figure 75. Photograph. Example weak post w-beam.(59)

Source: FHWA

Figure 76. Photograph. Example steel-backed log rail.(59)

Source: FHWA

Figure 77. Photograph. Example random rubble cavity wall. [59]

Additional Fields

Additional supporting data include:

Reflective Barrier Delineation

Definition: Presence of reflective barrier delineation.

Data Type: Coded:

- Yes
- No
- Unknown

Barrier Height

Definition: The height to the top of the barrier.

Data Type: Short Integer

Unit Type: Inches

Barrier Damage

Definition: Presence of visual damage on barrier.

Data Type: Coded:

- Yes
- No
- Unknown

Barrier Condition

Definition: The condition of barrier.

Data Type: Coded

- Good
- Fair
- Poor

Impact Attenuators

Definition: Impact attenuators are end treatments intended to reduce kinetic energy of collisions between vehicles and the barrier; impact attenuators present on barrier.

Data Type: Coded

- Yes
- No
- Unknown

Delineation

Definition: Adequate visual delineation (e.g., signage, reflective posts, etc.) present on median and/or median barrier.

Data Type: Coded:

- Yes
- No
- Unknown

Median Type

Definition: The type of median present at the junction approach.

Geometry Type: Line

Data Type: Coded:

- Raised median with curb
- Depressed median
- Flush paved median (at least 4 feet in width)
- Two-Way Center Left Turn Lane
- Other divided
- Undivided
- Other
- Unknown

Additional Fields

Median Width

Definition: Width of the median.

Data Type: Long integer

Unit Type: Feet

Barrier

Definition: Barrier type present on median.

Data Type: Coded

- Modified Thrie-Beam
- Concrete Safety Shape (figure 66)
- Precast Concrete Guardwall, Type 1 (figure 67)
- Stone Masonry Guardwall (figure 68)
- Steel-Backed Timber Rail (figure 69)
- Box Beam (figure 70)
- Strong Post W-Beam (figure 71)
- Thrie-Beam (figure 72)
- High-Tension Cable (figure 73)
- Three-Strand Cable (figure 74)
- Weak Post W-Beam (figure 75)
- Steel-Backed Log Rail (figure 76)
- Random Rubble Cavity Wall (figure 77)

Barrier Height

Definition: The height to the top of the barrier.

Data Type: Short Integer

Unit Type: Inches

Barrier Damage

Definition: Barrier (i.e., concrete, guardrail, etc.) present on median.

Data Type: Coded:

- Yes
- No
- Unknown

Barrier Condition

Definition: Condition of barrier (if present).

Data Type: Coded:

- Good
- Fair
- Poor

Impact Attenuators

Definition: Impact attenuators are end treatments intended to reduce kinetic energy of collisions between vehicles and the median barrier; impact attenuators present on barrier.

Data Type: Coded:

- Yes
- No
- Unknown

Delineation

Definition: Adequate visual delineation (e.g., signage, reflective posts, etc.) present on median and/or median barrier.

Data Type: Coded:

- Yes
- No
- Unknown

Safety Edge

Definition: The presence of SafetyEdge[SM] pavement treatment (figure 78).

Geometry Type: Line

Data Type: Coded:

- Yes
- No
- Unknown

Source: FHWA

Figure 78. Photograph. SafetyEdge[SM] example.[(68)]

Sidepath

Definition: A bidirectional shared use path located immediately adjacent and parallel to a roadway.
Geometry Type: Line
Data Type: Coded:

- Yes
- No
- Unknown

Additional Fields

Additional supporting data include:

Width

Definition: Width of sidepath.
Data Type: Short Integer
Unit Type: Feet

Physical Separation

Definition: Presence of physical separation (i.e., physical distance or barrier between sidepath and motor vehicle travel way).
Data Type: Coded:

- Yes
- No
- Unknown

Sidewalk

Definition: A paved path, typically concrete or inlayed brick, that serves walking pedestrians and is aligned along the side of a street.
Geometry Type: Line
Data Type: Coded:

- Yes
- No
- Unknown

Additional Fields

Additional supporting data include:

Width

Definition: Width of sidewalk.
Data Type: Short Integer
Unit Type: Feet

Physical Separation

Definition: Presence of physical separation (i.e., physical distance or barrier between sidewalk and motor vehicle travel way).

Data Type: Coded:

- Yes
- No
- Unknown

Marked Crossing

Definition: Indicator of a marked pedestrian or other non-motorist crossing.

Geometry Type: Point

Data Type: Coded:

- Yes
- No
- Unknown

Additional Fields (Applicable to Marked Crossings)

Additional supporting data include:

Raised Pavement Markers

Definition: Indicator that raised pavement markers are present.

Data Type: Coded:

- Yes
- No
- Unknown

High Visibility Crosswalk Marking

Definition: Crosswalk is a high visibility type.(64)

Data Type: Coded:

- Yes
- No
- Unknown

Lighting

Definition: Indicator that lighting is present.

Data Type: Coded:

- Yes
- No
- Unknown

Parking Restriction

Definition: Indicator that parking is restricted prior to crossing area.

Data Type: Coded:

- Yes
- No
- Unknown

Curb Extension

Definition: Indicator that a curb extension is present.

Data Type: Coded:

- Yes
- No
- Unknown

Advance Stop/Yield Sign

Definition: Presence of advanced stop/yield sign (figure 51).

Data Type: Coded:

- Yes
- No
- Unknown

Advance Stop/Yield Line

Definition: Presence of advanced stop/yield line.

Data Type: Coded:

- Yes
- No
- Unknown

In-street Stop/Yield Sign

Definition: Indicator of in-street stop/yield sign present (R1-6).

Data Type: Coded:

- Yes
- No
- Unknown

Pedestrian Refuge Island

Definition: Indicator that a raised median island that is intended as a pedestrian refuge is present on the approach.

Data Type: Coded:

- Yes
- No
- Unknown

Raised Crosswalk

Definition: Indicator that a raised crosswalk is present.

Data Type: Coded:

- Yes
- No
- Unknown

Type of Bicycle Lane

Definition: Type of on-street bicycle lane; this should include unmarked, wide paved shoulders.

Geometry Type: Line

Data Type: Coded:

- None
- Wide curb lane with no bicycle markings
- Wide curb lane with bicycle markings (e.g., sharrows)
- Marked bicycle lane
- Separate parallel bicycle path
- Signed bicycle route only (no designated bicycle facility)
- Other

Additional Fields

Additional supporting data include:

Physical Separation

Definition: Presence of physical separation (i.e., physical buffer or barrier between bicycle and motor vehicle travel way).

Data Type: Coded:

- Yes
- No
- Unknown

High Friction Surface Treatment

Definition: Date of installation of a high friction surface treatment (HFST) for the section of roadway.

Geometry Type: Line

Data Type: Date

Appendix C: Data Element User Manual

The purpose of this data schema is to support the Federal Lands Highway (FLH) division of the Federal Highway Administration (FHWA). These data elements represent priority safety data needs, comprising both potential sources of risk, as well as countermeasures intended to reduce risk. Furthermore, the schema is specifically intended to be used as part of FLH's custom Data Collection application (developed in parallel to this research effort). This schema separates data elements into six categories:

1. **Wildlife:** These data could support safety needs with respect to wildlife crossings and reducing instances of wildlife-vehicle collisions (WVCs). This category could also support the Roadkill Observation and Data System (ROaDS) schema developed by the Western Transportation Institute (WTI).
2. **Intersection and Driveway:** These data could support safety needs with respect to intersections and driveways. These data would be singularly located at the center of the junction and comprise intersection-level data elements.
3. **Intersection Approach:** These data could support safety needs with respect to approaches to junctions. Each approach could incorporate data elements in this section. **NOTE:** Intersection approaches should be linkable to the appropriate intersection location according to a unique identifier.
4. **Segment:** These data support safety needs along segments (i.e., midblock locations between junctions). Data in this category could be represented as a linear feature or a point. **NOTE:** Future data developments could allow users to edit these data elements as events along a linear referencing system (LRS), as opposed to individual points and lines spatially separate from Federal Land Management Agency (FLMA) centerline networks.
5. **Alternate Mode:** These data support safety needs specific to alternate modes of travel (i.e., other than a motor vehicle). This could include pedestrians, (e-)bicycles, off-highway vehicles (OHVs), and equestrian users among others.
6. **Project:** These data support project tracking and document storage in a spatial format. Documents could be stored using a SharePoint™ or other storage application and linked to other spatial data through features stored in geographic information systems (GIS).

Data elements listed in this framework schema can be stored as points, lines, or polygons. All data elements should have an associated unique Route ID, as well as relevant milepost information if an LRS is available. Each geometry type should include the following common fields:

Point

- Unique Route ID.
- Milepost.

Line or Polygon

- Unique Route ID.
- Beginning (i.e., lower) milepost.
- Ending (i.e., higher) milepost.

Intersection and driveway data have a slightly more complex structure, as each location should have an applicable major and minor route, as well as the associated mileposts.

Wildlife

This section documents variables related to wildlife crossing patterns, wildlife-vehicle collisions (WVCs), and carcass observations. These data can assist with wildlife crossing- or wildlife observation-related countermeasures.

Wildlife Migration Route

Definition: Anecdotal or documented locations where animals have been observed to frequently cross the roadway as a part of annual migration patterns.

Geometry Type: Line

Data Type: Coded:

- Whitetail deer
- Mule deer
- Unknown deer
- Moose
- Elk
- Pronghorn antelope
- Bighorn sheep
- Bison
- Raccoon
- Striped skunk
- Opossum
- Armadillo
- Black Bear
- Grizzly Bear
- Wolf
- Mountain lion
- Coyote
- Red fox
- Feral pig
- Domestic cat
- Domestic dog
- Other Livestock
- Other mammal
- Other reptile or amphibian
- Other bird

Additional Fields

Additional supporting data include:

Season

Definition: Applicable season in which wildlife migration is observed or documented.

Data Type: Coded

- Spring
- Summer
- Fall
- Winter

Vegetation (Roadside)

Definition: Type of vegetation present along the roadside that may attract or conceal wildlife.

Geometry Type: Polygon

Data Type: Coded:

- Tall Grass
- Brush
- Shrubbery
- Tree-Ornamental
- Tree-Wild

Additional Fields

Additional supporting data include:

Season

Definition: Applicable season for which roadside vegetation is present or overgrown.

Data Type: Coded

- Spring
- Summer
- Fall
- Winter

Wildlife Crossing Signage

Definition: Type of sign for a specific animal species to alert drivers to the potential presence of wildlife on or near a road.

Geometry Type: Line

Data Type: Coded:

- Whitetail deer
- Mule deer
- Unknown deer
- Moose
- Elk
- Pronghorn antelope

- Bighorn sheep
- Bison
- Raccoon
- Striped skunk
- Opossum
- Armadillo
- Black Bear
- Grizzly Bear
- Wolf
- Mountain lion
- Coyote
- Red fox
- Feral pig
- Domestic cat
- Domestic dog
- Other Livestock
- Other mammal
- Other reptile or amphibian
- Other bird

Wildlife Vantage Point (Sightseeing)

Definition: Location with a peak season when visitors typically stop to observe wildlife.
Geometry Type: Point
Data Type: Coded

- Spring
- Summer
- Fall
- Winter

Wildlife Crossing or Carcass Observation

Definition: Location where wildlife has been observed crossing a roadway or a location where the carcass of an animal has been recorded. This methodology matches the Roadkill Observation and Data System (ROaDS) schema developed by the Western Transportation Institute (WTI).
Geometry Type: Point
Data Type: Coded:

- Whitetail deer
- Mule deer
- Unknown deer
- Moose
- Elk
- Pronghorn antelope
- Bighorn sheep
- Bison
- Raccoon

- Striped skunk
- Opossum
- Armadillo
- Black Bear
- Grizzly Bear
- Wolf
- Mountain lion
- Coyote
- Red fox
- Feral pig
- Domestic cat
- Domestic dog
- Other Livestock
- Other mammal
- Other reptile or amphibian
- Other bird

Additional Fields

Additional supporting data include:

Observation Date and Time

Definition: The date and time of the observation.
Data Type: Date and time

Species Confidence

Definition: Self-assessment by the user with respect to their confidence that they can correctly identify the species. If response is less than "High," a photo should be further reviewed to support identification.
Data Type: Coded:

- High (>90%)
- Medium (50-90%)
- Low (<50%)

Number of Animals

Definition: Number of animals observed at the time.
Data Type: Short Integer
Units Type: Number of animals

Animal Status

Definition: Status of the observed animal(s) at the time of recording.
Data Type: Coded:

- Dead
- Alive crossing road
- Alive near road (<100 yards)

Conservation Status

Definition: Conservation status of the observed animal(s).

Data Type: Coded:

- NOT threatened or endangered
- Threatened or endangered
- Unknown

User Affiliation

Definition: Organization of the user/observer.

Data Type: Coded:

- BLM
- BOR
- NPS
- USACE
- USFS
- USFWS
- FLH
- Other federal agency
- State agency
- Tribal agency
- Non-profit organization
- Other agency or organization
- Individual, unaffiliated

Purpose of Observation

Definition: General reason for user being in the field and observing wildlife.

Data Type: Coded:

- Random opportunity
- Crash information
- Carcass removal
- Monitoring program
- Research project
- Other

Comments

Definition: Additional information the user wants to report related to the wildlife data collected.

Data Type: Text

Intersection and Driveway

This section documents variables related to individual intersections or driveway access points. **NOTE:** All data elements are represented by a single point geometry.

Major Route

Definition: Unique identifier of the major route associated with the junction. The major route is typically the route with the higher traffic volume.

Data Type: Text

Major Milepost

Definition: The milepost location associated with the major route. This should be derived from the applicable linear referencing system (LRS).

Data Type: Double

Minor Route

Definition: Unique identifier of the minor route associated with the junction. The minor route is typically the route with the lower traffic volume (or the dead end leg of a three-leg intersection).

Data Type: Text

Minor Milepost

Definition: The milepost location associated with the minor route. This should be derived from the applicable linear referencing system (LRS).

Data Type: Double

Driveway Entrance

Definition: If junction is a driveway (i.e., not an intersecting public road). Type of driveway entrance is based on its associative land use and frequency of level of activity.

Data Type: Coded:

- Major Commercial
- Minor Commercial
- Major Industrial/Institutional
- Minor Industrial/Institutional
- Major Residential
- Minor Residential
- Other
- Not a Driveway

Intersection Lighting

Definition: Type of lighting present at junction.

Data Type: Coded:

- Continuous
- Lighted at Night
- Unlighted
- Unknown

Major Route ADT

Definition: Average daily traffic (ADT) of the major route. If there is more than one major route ADT, the maximum should be used.

Data Type: Long Integer

Units Type: Average daily vehicles

Minor Route ADT

Definition: Average daily traffic (ADT) of the minor route. If there is more than one minor route ADT, the maximum should be used.

Data Type: Long Integer

Units Type: Average daily vehicles

Major Route ADT Category

Definition: If a specific traffic count is not available for the major route, select a general category of daily traffic on the major route based on field observations or anecdotal information.

Data Type: Coded:

- Low: <50
- Medium: 50-500
- High: >500

Minor Route ADT Category

Definition: If a specific traffic count is not available for the minor route, select a general category of daily traffic on the minor route based on field observations or anecdotal information.

Data Type: Coded:

- Low: <50
- Medium: 50-500
- High: >500

Geometry

Definition: The type of geometric configuration that best describes the junction.

Data Type: Coded:

- Tee intersection
- Y intersection
- Four-leg intersection
- Traffic circle/roundabout
- Multileg intersection
- Other
- Unknown

Number of Leg Approaches

Definition: The number of legs entering an at-grade junction.

Data Type: Short Integer

Units Type: Number of approaches

Intersection Angle

Definition: The measurement in degrees of the smallest angle between any two legs of the intersection. This value will always be within a range of 0 to 90 degrees (i.e., for non-zero angles, always measure the acute rather than the obtuse angle).

Data Type: Long Integer

Units Type: Degrees

Traffic Control Type

Definition: Traffic control present at intersection/junction.

Data Type: Coded

- None
- Signal
- All-Way Stop
- Minor Road Stop
- Yield – Roundabout
- Yield – Traffic Control

Overhead Flashers

Definition: The type of overhead flashers (if present) at an unsignalized intersection (figure 79).

Data Type: Coded:

- Two-Way: Red on Cross-Street
- Two-Way: Red on Mainline
- All-Way Red

Source: FHWA

Figure 79. Photograph. Example of overhead flashers at an unsignalized intersection.

Offset T Versus Four-leg

Definition: Indicator that the junction represents two offset tee intersections as opposed to a single four-leg intersection. Indicators of offset tee intersections include different traffic controls for each junction, as well as the need to maneuver on to a mainline to complete the through movement.

Data Type: Coded:

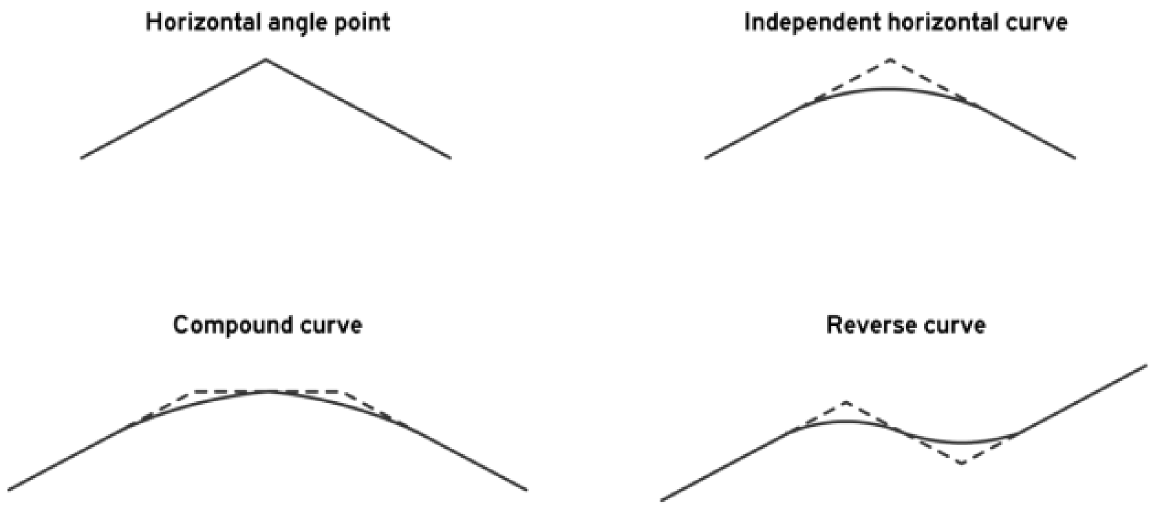
- Yes
- No
- Unknown

Horizontal Curve Present

Definition: The type of horizontal curve present at the intersection (figure 80).

Data Type: Coded:

- Horizontal angle point
- Independent
- Reverse
- Compound



Source: FHWA

Figure 80. Graphic. Illustration of types of horizontal curve features.[13]

Vertical Curve Present

Definition: The type of vertical alignment present at the intersection.

Data Type: Coded:

- Sag (i.e., vertical curve that connects a segment of roadway with a segment of roadway that has a more positive grade)
- Crest (i.e., vertical curve that connects a segment of roadway with a segment of roadway that has a more negative grade)

Intersection Approach

This section documents variables related to each approach to an individual intersection or driveway access point.
NOTE: All data elements are represented by a single point geometry.

Route

Definition: Unique identifier of the route associated with the junction approach.
Data Type: Text

Milepost

Definition: The milepost location associated with the approach route. This should be derived from the applicable linear referencing system (LRS).
Data Type: Double

Number of Approach Through Lanes

Definition: Total number of through lanes on approach (both directions of travel if traffic operation is two-way).
Data Type: Short Integer
Units Type: Number of lanes

Number of Approach Exclusive Left-turn Lanes

Definition: Number of exclusive (i.e., marked) left-turn lanes that accommodate left turns from the approach.
Data Type: Short Integer
Units Type: Number of lanes

Left Turn Acceleration Lane

Definition: The presence of left turn acceleration lane on the approach that facilitates/receives left turning traffic from the perpendicular approach (i.e., turning traffic accelerates in an auxiliary lane leaving the approach).
Data Type: Coded:

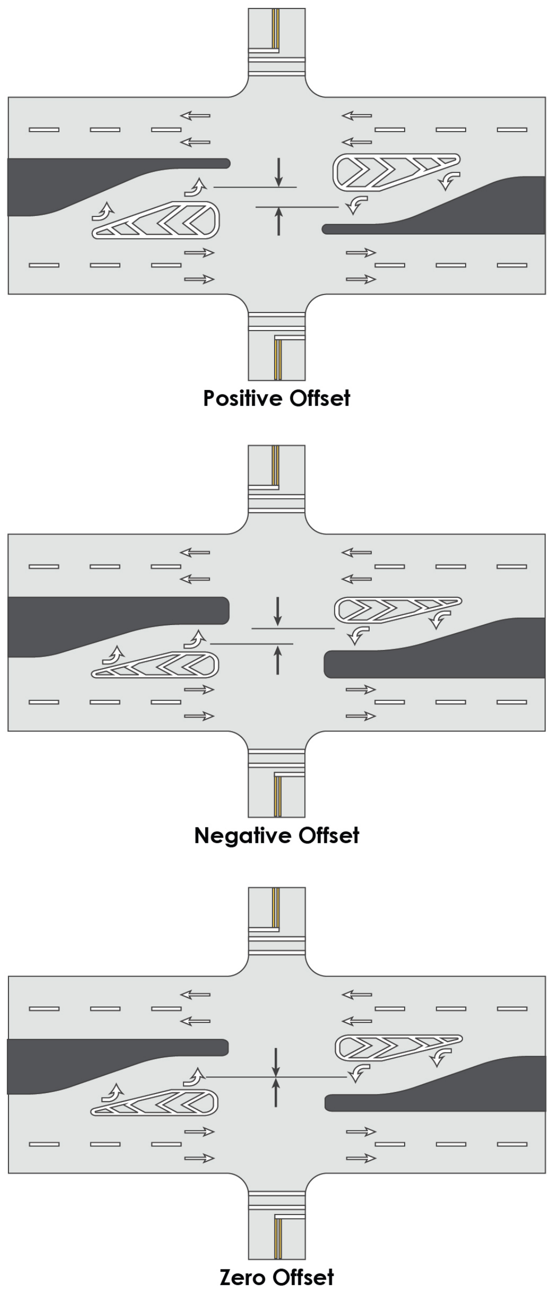
- Yes
- No
- Unknown

Offset Left-turn Lane Indicator

Definition: Indicator that left turn lanes on opposing approaches are offset (figure 81).

Data Type: Coded:

- Yes
- No
- Unknown



Source: FHWA

Figure 81. Graphic. Illustration of positive, negative, and zero offset.[13]

Left-turn Channelization

Definition: The type of left-turn channelization for exclusive left turn(s) on approach.

Data Type: Coded:

- Raised Island
- Painted Marking
- None

Number of Approach Exclusive Right-turn Lanes

Definition: Number of exclusive (i.e., marked) right turn lanes that accommodate left turns from the approach.

Data Type: Short Integer

Units Type: Number of lanes

Right Turn Acceleration Lane

Definition: The presence of right turn acceleration lane on the approach that facilitates/receives right turning traffic from the perpendicular approach (i.e., turning traffic accelerates in an auxiliary lane leaving the approach).

Data Type: Coded:

- Yes
- No
- Unknown

Right-turn Channelization

Definition: The type of right-turn channelization for exclusive right turn(s) on approach.

Data Type: Coded:

- Raised Island
- Painted Marking
- None

Median Type

Definition: The type of median present at the junction approach.

Data Type: Coded:

- Raised median with curb
- Depressed median
- Flush paved median (at least 4 feet in width)
- Two-Way Center Left Turn Lane
- Other divided
- Undivided
- Other
- Unknown

Median Width

Definition: The width of the median, including inside shoulders (i.e., measured from center of left edge line to the center of the edge line on the inside edge of opposing through lanes).

Data Type: Short Integer

Units Type: Feet

Pedestrian Refuge Island Presence

Definition: Indicator that a raised median island that is intended as a pedestrian refuge is present on the approach.

Data Type: Coded:

- Yes
- No
- Unknown

Restricted Turning Maneuvers

Definition: Signed turn prohibitions on the approach.

Data Type: Coded:

- No left turns any time
- No left turns during specific times
- No right turns any time
- No right turns during specific times
- No U turns
- Other
- No turn prohibitions
- Unknown

Intersection Control Beacon

Definition: The presence of intersection control beacon at an unsignalized intersection ().

Data Type: Coded:

- Yes
- No
- Unknown

Post-Mounted Reflective Delineators

Definition: The presence of post-mounted reflective delineators.

Data Type: Coded:

- Yes
- No
- Unknown

Advance Intersection Warning Sign

Definition: Signage to warn drivers of an upcoming intersection (W2 series). It is located a sufficient distance upstream to provide a driver enough time to react and adjust their approach speed as needed. "Static" signs will not have any flashing lights or dynamic electronic text; conversely, "dynamic" signs will have flashing lights or dynamic electronic text.

Data Type: Coded:

- Yes-Static
- Yes-Dynamic
- No
- Unknown

Marked Crossing

Definition: Indicator of a marked pedestrian or other non-motorist crossing.

Data Type: Coded

- Yes
- No
- Unknown

Additional Fields (Applicable to Marked Crossings)

Additional supporting data include:

Durable Pavement Markings

Definition: Indicator that durable pavement markings of any type are present (e.g., Waterborne, epoxy, thermoplastic, etc.; figure 82).

Data Type: Coded:

- Yes
- No
- Unknown

High Visibility Crosswalk Marking

Definition: Crosswalk is a high visibility type.

Data Type: Coded:

- Yes
- No
- Unknown

Lighting

Definition: Indicator that lighting is present.

Data Type: Coded:

- Yes
- No
- Unknown

Parking Restriction

Definition: Indicator that parking is restricted prior to crossing area.

Data Type: Coded:

- Yes
- No
- Unknown

Curb Extension

Definition: Indicator that a curb extension is present.

Data Type: Coded:

- Yes
- No
- Unknown

Advance Stop/Yield Sign

Definition: Presence of advanced stop/yield sign (W11-2 and W16-7P).

Data Type: Coded:

- Yes
- No
- Unknown

Advance Stop/Yield Line

Definition: Presence of advanced stop/yield line.

Data Type: Coded:

- Yes
- No
- Unknown

In-street Stop/Yield Sign

Definition: Indicator of in-street stop/yield sign present (R1-6).

Data Type: Coded:

- Yes
- No
- Unknown

Raised Crosswalk

Definition: Indicator that a raised crosswalk is present.

Data Type: Coded:

- Yes
- No
- Unknown

Source: FHWA

Figure 82. Photograph. Example of profile thermoplastic pavement markings.[66]

Unmarked Crossing

Definition: Indicator of an unmarked pedestrian or other non-motorist crossing.

Data Type: Coded

- Yes
- No
- Unknown

Additional Fields (Applicable to Unmarked Crossings)

Additional supporting data include:

Desire ("Goat") Paths

Definition: Presence of an informal "desire" or "goat" path created by frequent use by non-motorist users (figure 83).

Data Type: Coded:

- Yes
- No
- Unknown

Source: FHWA

Figure 83. Photograph. Example of an informal desire path created by pedestrians.[63]

Horseback/Equestrian Users

Definition: Indicator that crossing is used by horseback or equestrian users (figure 84).

Data Type: Coded:

- Yes
- No
- Unknown

Source: FHWA

Figure 84. Photograph. Horse trailers parked on the roadside indicating equestrian activity.

Stop Bar

Definition: Indicator that a stop bar is present. Stop bar is wide white line pavement marking that extends across all lanes in approaching direction to indicate where to stop.

Data Type: Coded

- Yes
- No
- Unknown

Stop Ahead Warning

Definition: Indicator that in-street STOP-Ahead pavement markings or STOP-Ahead signage are present. STOP-ahead pavement markings are intended to reduce the frequency of crashes related to lack of driver awareness of stop control at unsignalized intersections.

Data Type: Coded

- Yes – sign
- Yes – pavement marking
- No
- Unknown

Transverse Rumble Strips

Definition: Indicator of transverse rumble strip presence on approach. Transverse rumble strips are in-lane rumble strips that alert drivers as they approach a stop-controlled intersection (figure 85).

Data Type: Coded

- Yes
- No
- Unknown

Source: FHWA

Figure 85. Photograph. Example of transverse rumble strips on a rural road.[69]

Intersection Conflict Warning System (ICWS)

Definition: Presence of intersection conflict warning system (ICWS). These systems alert drivers to conflicting vehicles on adjacent approaches at unsignalized intersections, particularly those with one-way or two-way stop control.

Data Type: Coded

- Yes
- No
- Unknown

Signal Head Mount Location

Definition: Location for the signal head associated with a traffic signal on an approach. Only applicable at signalized intersections.

Data Type: Coded

- Pedestal
- Overhead-Pole
- Overhead-Existing Structure

Left Turn Signal Phasing

Definition: Presence and type of left-turn protection on the approach. Only applicable at signalized intersections.

Data Type: Coded

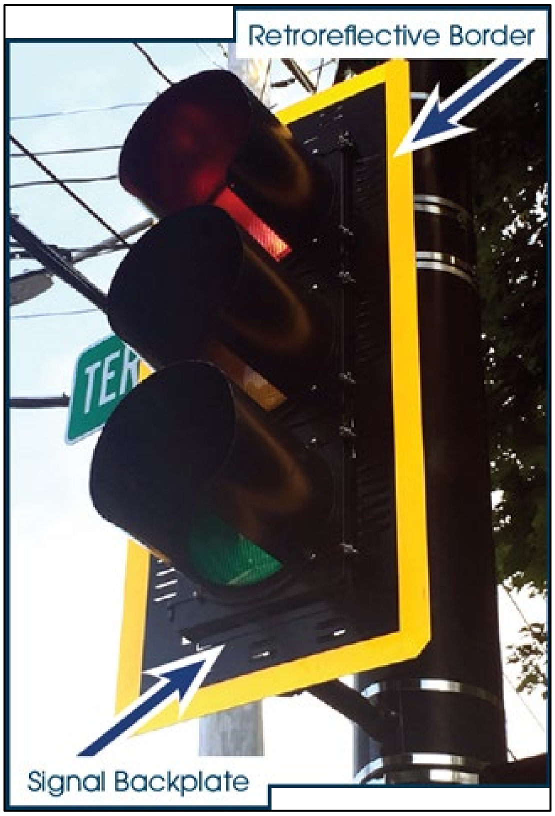
- Protected only left turn
- Protected/permitted left-turn (with flashing yellow arrow)
- Protected/permitted left-turn (no flashing yellow arrow)
- Permitted left-turn
- No left-turn phase
- Not applicable
- Unknown

Retroreflective Back Plates

Definition: Indicator that retroreflective back plates are present on traffic signal heads. Only applicable at signalized intersections (figure 86).

Data Type: Coded

- Yes
- No
- Unknown



Source: FHWA

Figure 86. Photograph. Example of retroreflective back plate.[(70)]

Roadway Drainage

Definition: The quality of roadway drainage; indicator that frequent flooding may be present at junction approach.

Data Type: Coded

- Good
- Fair
- Poor

Driveway Entrance

Definition: Indicator that a driveway entrance is present on the intersection approach prior to the primary junction.

Data Type: Coded

- Yes
- No
- Unknown

On-Street Parking

Definition: Type of on-street parking present on the intersection approach (i.e., not present, on one side of the approach, or on both sides of the approach).

Geometry Type: Line

Data Type: Coded:

- None
- One Side
- Two Sides

Intersection Sight Distance Issue

Definition: Indicator of the type of sight distance issue present on approach (if applicable).

Data Type:

- Cross-Street Visibility
- Traffic Control Device Visibility
- Visual Trap
- No Issue

Segment

This section documents variables related to roadway segments (i.e., between intersections of two or more public roads). **NOTE:** All data elements can be represented by independent geometry OR data elements can be stored as event layers to be referenced as part of an overall LRS. Each feature should have a beginning and ending milepost, as well as a unique route name associated with each record.

Access Control

Definition: The degree of access control for a given section of road. Full access control refers to interstates and freeways where all access is channeled through interchanges. Partial access control is a mix of interchange and at-grade intersection access. No access control is a typical arterial, collector, or local road where all roads intersect at-grade.

Geometry Type: Line

Data Type: Coded:

- Full Access Control
- Partial Access Control
- No Access Control
- Unknown

Additional Fields

Interchange Influence Area

Definition: In general terms, the limits of mainline freeway segments within interchange areas are defined to extend approximately 0.3 mi upstream from the gore (i.e., painted nose of the gore area) of the first ramp of a particular interchange to approximately 0.3 mi downstream from the gore (i.e., painted nose of the gore area) of the last ramp of the given interchange. Conversely, all mainline freeway segments that extend beyond these defined limits for interchange areas are, by definition, mainline freeway segments outside an interchange area.

Data Type: Coded

- Yes
- No
- Unknown

Average Daily Traffic

Definition: Traffic count representing bidirectional (or single direction in the case of one-way facilities) traffic for a typical weekday. This could be an official annual average daily traffic (AADT) value, or a single traffic count based on data available.

Geometry Type: Point

Data Type: Long integer

Unit Type: Average daily vehicles

Additional Fields

Additional supporting data include:

ADT Category

Definition: If a specific traffic count is not available for the major route, select a general category of daily traffic on the major route based on field observations or anecdotal information.

Data Type: Coded:

- Low: <50
- Medium: 50-500
- High: >500

ADT Year

Definition: Year of applicable traffic count.

Data Type: Long integer

Unit Type: Year

Percent Trucks

Definition: Percent of daily traffic that is comprised of Single Unit (FHWA Class 4 – 7) and Multi Unit (FHWA Class 8 – 13) trucks.

Data Type: Double

Unit Type: Percent

Advisory Pavement Marking

Definition: Pavement markings intended to provide additional advance warning and reduce vehicular speeds approaching intersections, curves, or other higher risk situations.

Geometry Type: Line

Data Type: Coded

- Speed Limit Advisory Marking Lane
- Curve Advance Marking
- Optical Speed Bars (figure 87)

Source: FHWA

Figure 87. Photograph. Example of optical speed bars.[(65)]

Additional Fields

Additional supporting data include:

Durable Pavement Markings

Definition: Indicator that durable pavement markings of any type are present (e.g., Waterborne, epoxy, thermoplastic, etc.; figure 82).

Data Type: Coded:

- Yes
- No
- Unknown

Raised Pavement Markers

Definition: Indicator that raised pavement markers are present (figure 88).

Data Type: Coded:

- Yes
- No
- Unknown

Source: FHWA

Figure 88. Photograph. Example of raised pavement markers.[67]

Auxiliary Lane

Definition: The presence and type of auxiliary lane within a roadway segment. High Occupancy Vehicle (HOV) and High Occupancy Toll (HOT) lanes are not included here. **Note:** multiple auxiliary lane fields may be required for both directions of travel.

Geometry Type: Line

Data Type: Coded

- Passing/Climbing Lane
- Acceleration Lane
- Deceleration Lane
- None

Average Inside Shoulder Width

Definition: The average width of outside (left) shoulder, including both paved and unpaved components measured from the center of the edge line outward.
Geometry Type: Line
Data Type: Double
Unit Type: Feet

Additional Fields

Paved Shoulder

Definition: The presence of a fully or partially paved shoulder.
Data Type: Coded

- Yes
- No
- Unknown

Average Lane Width

Definition: The average width of all travel lanes.
Geometry Type: Line
Data Type: Double
Unit Type: Feet

Average Outside Shoulder Width

Definition: The average width of outside (left) shoulder, including both paved and unpaved parts measured from the center of the edge line outward.
Geometry Type: Line
Data Type: Double
Unit Type: Feet

Additional Fields

Paved Shoulder

Definition: The presence of paved shoulder.
Data Type: Coded

- Yes
- No
- Unknown

Centerline Markings

Definition: Presence of centerline markings.
Geometry Type: Line
Data Type: Coded

- Yes
- No
- Unknown

Additional Fields

Additional supporting data include:

Durable Pavement Markings

Definition: Indicator that durable pavement markings of any type are present (e.g., Waterborne, epoxy, thermoplastic, etc.; figure 82).
Data Type: Coded:

- Yes
- No
- Unknown

Raised Pavement Markers

Definition: Indicator that raised pavement markers are present.
Data Type: Coded:

- Yes
- No
- Unknown

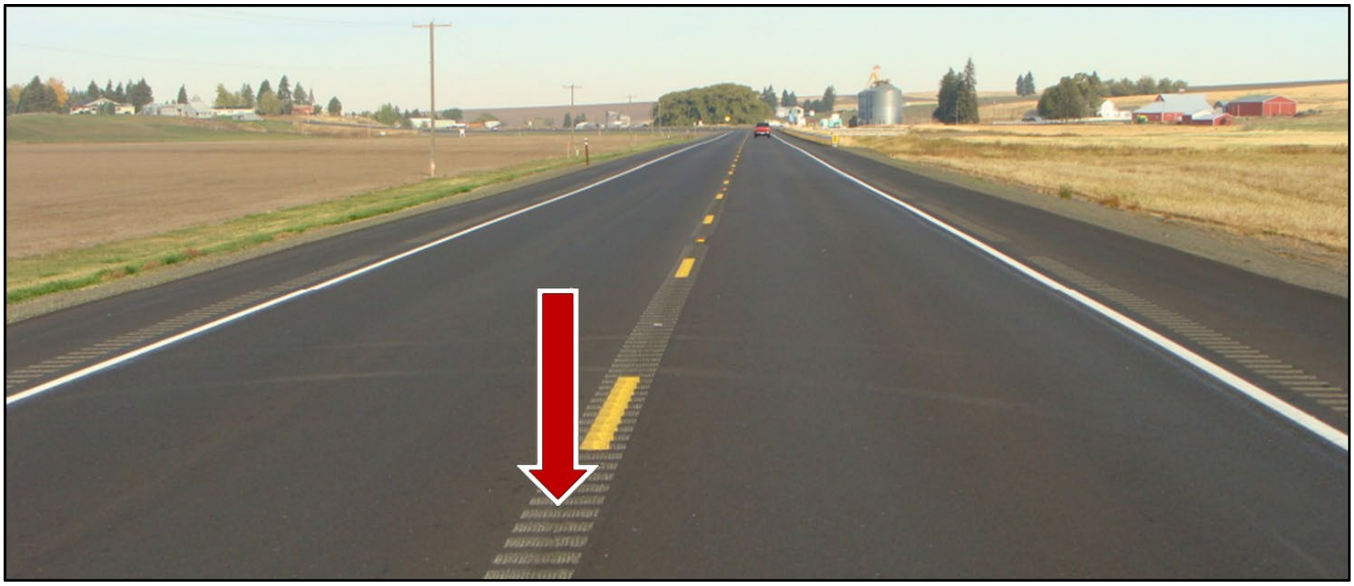
Marking Width

Definition: Width of the marking.
Data Type: Short Integer
Unit Type: Inches

Centerline Rumble Strips

Definition: The type of centerline rumble strips on the segment (figure 89).
Geometry Type: Line
Data Type: Coded:

- Milled-In
- Raised
- Rolled-In
- Formed



Source: FHWA

Figure 89. Photograph. Example of centerline rumble strips.[66]

Deferred Maintenance

Definition: Indicator that routine maintenance may have been deferred for the particular road segment.

Geometry Type: Point

Data Type: Coded:

- Yes
- No
- Unknown

Dynamic Speed Signage

Definition: Type of digitally adjustable speed display sign present.

Geometry Type: Point

Data Type: Coded

- Variable speed limit
- Dynamic speed feedback signs
- Road geometry speed warning systems

Additional Fields

Additional supporting data include:

Speed Limit

Definition: The daytime regulatory speed limit for automobiles posted or legally mandated on the greater part of the section.

Data Type: Coded

- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- 60
- 65
- 70
- 75
- 80+

Unit Type: Miles per hour

Edge Line Markings

Definition: Presence of edge line markings (i.e., delineating the travel way from the roadside shoulder).

Geometry Type: Line

Data Type: Coded

- Yes
- No
- Unknown

Additional Fields

Additional supporting data include:

Durable Pavement Markings

Definition: Indicator that durable pavement markings of any type are present (e.g., Waterborne, epoxy, thermoplastic, etc.; figure 82).

Data Type: Coded:

- Yes
- No
- Unknown

Raised Pavement Markers

Definition: Presence of raised pavement markers.

Data Type: Coded:

- Yes
- No
- Unknown

Marking Width

Definition: Width of the marking.

Data Type: Short Integer

Unit Type: Inches

Flooding

Definition: Indicator that roadway section is susceptible to periodic flooding.

Geometry Type: Point

Data Type: Coded:

- Yes
- No
- Unknown

Additional Fields

Additional supporting data include:

Season

Definition: Applicable season in which flooding typically occurs according to observed or anecdotal information.

Data Type: Coded

- Spring
- Summer
- Fall
- Winter

Month

Definition: Applicable month(s) in which flooding typically occurs according to observed or anecdotal information.

Data Type: Coded

- January
- February
- March
- April
- May
- June
- July
- August
- September

- October
- November
- December

Functional Classification

Definition: The class or group of roads a segment belongs to as defined by the Federal Highway Administration (FHWA). This classification is based on the existing function of the roadway.

Geometry Type: Line

Data Type: Coded

- Interstate
- Principal Arterial-Other Freeway or Expressway
- Principal Arterial-Other
- Minor Arterial
- Major Collector
- Minor Collector
- Local
- Other
- Unknown

Grade

Definition: Observed vertical grade for a particular point on the roadway. This is intended to be representative for a particular segment.

Geometry Type: Point

Data Type: Double

Unit Type: Percent

Additional Fields

Additional supporting data include:

Typical Slope

Definition: Generalized category for vertical grade representative of a particular section; applicable if more detailed measurements are unavailable.

Data Type: Coded

- Less than 3%
- 3-6%
- Greater than 6%

Sight Distance Issue

Definition: Indicator for a potential sight distance issue related to vertical grade or vertical curvature (figure 90 and figure 91).

Data Type: Coded:

- Yes
- No
- Unknown

Source: FHWA

Figure 90. Photograph. Vehicle entering a vertical curve with substantial vertical grade.

Source: FHWA

Figure 91. Photograph. Vehicle obscured by vertical curvature at the same location in figure 90.

High Crash Location (Anecdotal)

Definition: Indicator of frequent vehicular and non-motorist crashes based on anecdotal information; official crash reports may not exist.

Geometry Type: Point

Data Type: Coded:

- Yes
- No
- Unknown

Additional Fields

Additional supporting data include:

Date Start

Definition: Beginning time of a typical year which crashes may be more common (anecdotally).

Data Type: Date

Date End

Definition: Ending time of year which crashes may be more common (anecdotally).

Data Type: Date

Time Start

Definition: Beginning time of a typical day which crashes may be more common (anecdotally).
Data Type: Time

Time End

Definition: Ending time of a typical day which crashes may be more common (anecdotally).
Data Type: Time

High Friction Surface Treatment

Definition: Date of installation of a high friction surface treatment (HFST) for the section of roadway.
Geometry Type: Line
Data Type: Date

High Use Turnout/Scenic View

Definition: Roadside turnout location or parking for a scenic view that allows vehicles to park along roadside. Particularly important if parked vehicles are located in travel lanes, non-motorists may enter road from behind parked vehicles, or merging traffic has limited sight distance (figure 92).
Geometry Type: Point
Data Type: Text

Additional Fields

Additional supporting data include:

Date Start

Definition: Beginning time of a typical year which visitors typically congregate at the pullout and traffic volumes are high at the particular location (anecdotally).
Data Type: Date

Date End

Definition: Ending time of a typical year which visitors typically congregate at the pullout and traffic volumes are high at the particular location (anecdotally).

Data Type: Date

Source: FHWA

Figure 92. Photograph. Example of parking turnout with sight distance limitations due to curvature.

Horizontal Curve

Definition: The type of horizontal curve. A horizontal curve is a roadway segment that provides a transition between two tangents sections of roadway.

Geometry Type: Point

Data Type: Coded:

- Horizontal angle point
- Independent
- Reverse
- Compound

Additional Fields

Additional supporting data include:

Radius

Definition: The radius of horizontal curve.

Data Type: Double
Unit Type: Feet

Curve Length

Definition: The length of horizontal curve.
Data Type: Double
Unit Type: Feet

Approach Length

Definition: Average approach length leading into horizontal curve (i.e., average of both approaches).
Data Type: Double
Unit Type: Feet

Sight Distance

Definition: Indicator for a potential sight distance issue related to horizontal curvature.
Data Type: Coded:

- Vegetation
- Visual Trap (figure 93 and figure 94)
- Obstruction Inside Curve
- Horizontal Sightline Offset
- Other Restriction

Source: FHWA

Figure 93. Photograph. Break in the tree line providing a visual cue that can be a potential visual trap.

Source: FHWA

Figure 94. Photograph. Vehicle turning and demonstrating the horizontal curve and visual trap in figure 93.

Delineation

Definition: Adequate visual delineation (e.g., signage, reflective posts, etc.) present on road.

Data Type: Coded:

- Yes
- No
- Unknown

Superelevation

Definition: Measured superelevation rate or percent on the curve.

Data Type: Double

Unit Type: Percent

Hunting/Fishing Activity

Definition: The type of hunting or fishing activity.

Geometry Type: Point

Data Type: Coded:

- Hunting
- Fishing

Additional Fields

Additional supporting data include:

Date Start

Definition: The date during a typical year which the hunting or fishing activity begins.
Data Type: Date

Date End

Definition: The date during a typical year which the hunting or fishing activity ends.
Data Type: Date

Time Start

Definition: The time during a typical day which the hunting or fishing activity begins.
Data Type: Time

Time End

Definition: The time during a typical day which the hunting or fishing activity ends.
Data Type: Time

Intermittent Obstruction

Definition: The presence of intermittent obstruction (e.g., rock fall; figure 95).
Geometry Type: Point
Data Type: Coded:

- Yes
- No
- Unknown

Source: FHWA

Figure 95. Photograph. Example of a rock fall area with accompanying warning.

Lighting

Definition: The type of roadway lighting present on the segment.
Geometry Type: Point
Data Type: Coded:

- Continuous
- Lighted at Night
- Unlighted
- Unknown

Median Type

Definition: The type of median present on the segment.
Geometry Type: Line
Data Type: Coded:

- Raised median with curb
- Depressed median
- Flush paved median (at least 4 feet in width)
- Two-Way Center Left Turn Lane
- Other divided
- Undivided
- Other
- Unknown

Additional Fields

Median Width

Definition: Width of the median.
Data Type: Long integer
Unit Type: Feet

Barrier

Definition: Barrier type present on median.
Data Type: Coded

- Modified Thrie-Beam
- Concrete Safety Shape (figure 96)
- Precast Concrete Guardwall, Type 1 (figure 97)
- Stone Masonry Guardwall (figure 98)
- Steel-Backed Timber Rail (figure 99)
- Box Beam (figure 100)
- Strong Post W-Beam (figure 101)
- Thrie-Beam (figure 102)
- High-Tension Cable (figure 103)
- Three-Strand Cable (figure 104)
- Weak Post W-Beam (figure 105)
- Steel-Backed Log Rail (figure 106)
- Random Rubble Cavity Wall (figure 107)

Barrier Height

Definition: The height to the top of the barrier.
Data Type: Short Integer
Unit Type: Inches

Barrier Damage

Definition: Barrier (i.e., concrete, guardrail, etc.) present on median.

Data Type: Coded:

- Yes
- No
- Unknown

Barrier Condition

Definition: Condition of barrier (if present).

Data Type: Coded:

- Good
- Fair
- Poor

Impact Attenuators

Definition: Impact attenuators are end treatments intended to reduce kinetic energy of collisions between vehicles and the median barrier; impact attenuators present on barrier.

Data Type: Coded:

- Yes
- No
- Unknown

Delineation

Definition: Adequate visual delineation (e.g., signage, reflective posts, etc.) present on median and/or median barrier.

Data Type: Coded:

- Yes
- No
- Unknown

Number of Approach Through Lanes

Definition: The total number of through lanes on the segment. It is the number of through lanes in the direction of inventory. If the road is inventoried in both directions together, this would be the number of through lanes in both directions. If the road is inventoried separately for each direction, this would be the number of through lanes in one single direction.

Geometry Type: Line

Data Type: Long integer

Unit Type: Number of lanes

On-Street Parking

Definition: Type of on-street parking present on the section of road (i.e., not present, on one side of the approach, or on both sides of the approach).

Geometry Type: Line
Data Type: Coded:

- None
- One Side
- Two Sides

Outside Barrier Type

Definition: The type of outside barrier (i.e., roadside, not in a road median) on the segment.
Geometry Type: Line
Data Type: Coded

- Modified Thrie-Beam
- Concrete Safety Shape (figure 96)
- Precast Concrete Guardwall, Type 1 (figure 97)
- Stone Masonry Guardwall (figure 98)
- Steel-Backed Timber Rail (figure 99)
- Box Beam (figure 100)
- Strong Post W-Beam (figure 101)
- Thrie-Beam (figure 102)
- High-Tension Cable (figure 103)
- Three-Strand Cable (figure 104)
- Weak Post W-Beam (figure 105)
- Steel-Backed Log Rail (figure 106)
- Random Rubble Cavity Wall (figure 107)

Source: FHWA

Figure 96. Photograph. Example concrete safety shape.[(59)]

Source: FHWA

Figure 97. Photograph. Example precast concrete guardwall.[(59)]

Source: FHWA

Figure 98. Photograph. Example stone masonry guardwall.[59]

Source: FHWA

Figure 99. Photograph. Example steel-backed timber rail.[59]

Source: FHWA

Figure 100. Photograph. Example box beam.[59]

Source: FHWA

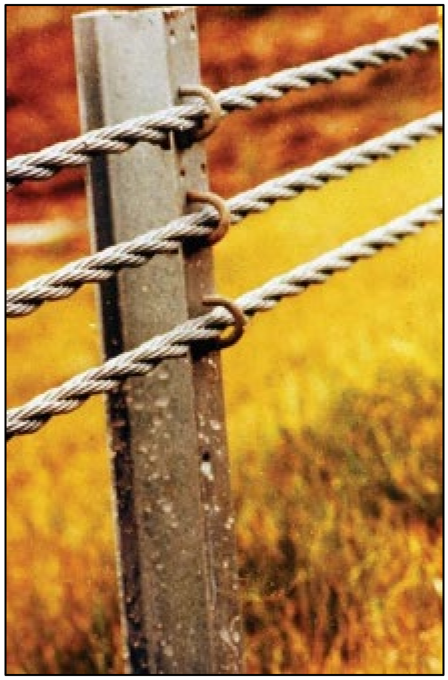
Figure 101. Photograph. Example strong post w-beam.[59]

Source: FHWA

Figure 102. Photograph. Example thrie-beam.[59]

Source: FHWA

Figure 103. Photograph. Example high-tension cable.[59]



Source: FHWA

Figure 104. Photograph. Example three-strand cable.[59]

Source: FHWA

Figure 105. Photograph. Example weak post w-beam.[59]

Source: FHWA

Figure 106. Photograph. Example steel-backed log rail.[59]

Source: FHWA

Figure 107. Photograph. Example random rubble cavity wall.[59]

Additional Fields

Additional supporting data include:

Reflective Barrier Delineation

Definition: Presence of reflective barrier delineation.

Data Type: Coded:

- Yes
- No
- Unknown

Barrier Height

Definition: The height to the top of the barrier.

Data Type: Short Integer

Unit Type: Inches

Barrier Damage

Definition: Presence of visual damage on barrier

Data Type: Coded:

- Yes
- No
- Unknown

Barrier Condition

Definition: The condition of barrier.

Data Type: Coded

- Good
- Fair
- Poor

Impact Attenuators

Definition: Impact attenuators are end treatments intended to reduce kinetic energy of collisions between vehicles and the barrier; impact attenuators present on barrier.

Data Type: Coded

- Yes
- No
- Unknown

Delineation

Definition: Adequate visual delineation (e.g., signage, reflective posts, etc.) present on median and/or median barrier.

Data Type: Coded:

- Yes
- No
- Unknown

Pavement Condition

Definition: Type of pavement distress present on the segment.
Geometry Type: Line
Data Type: Coded

- Alligator cracking
- Longitudinal/ Transverse
- Patching
- Rutting
- Raveling
- Potholes

Pavement Edge Dropoff

Definition: Extent of elevation drop along edge of pavement.
Geometry Type: Point
Data Type: Coded

- Less than 1 inch
- 1 to 2 inches
- Greater than 2 inches

Posted Speed Limit (Regulatory)

Definition: The daytime regulatory speed limit for automobiles posted or legally mandated on the greater part of the section.
Geometry Type: Line
Data Type: Coded

- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- 60
- 65
- 70
- 75
- 80+

Unit Type: Miles per hour

Additional Fields

Additional supporting data include:

Truck Speed Limit

Definition: The regulatory speed limit for trucks posted or legally mandated on the greater part of the section (i.e., differential speed limit).

Data Type: Coded

- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- 60
- 65
- 70
- 75
- 80+

Post-mounted Delineators

Definition: The presence of post-mounted delineators.

Geometry Type: Line

Data Type: Coded:

- Yes
- No
- Unknown

Presence of Bridge

Definition: The presence of bridge on the segment.

Geometry Type: Point

Data Type: Coded:

- Yes
- No
- Unknown

Additional Fields

Additional supporting data include:

Bridge Width

Definition: The width of the bridge travel way on the segment.
Data Type: Long Integer
Unit Type: Feet

Rail Height

Definition: The height of rail on the bridge.
Data Type: Short Integer
Unit Type: Feet

Public Events

Definition: Indicator that a public event (especially one that generates high traffic volumes and non-recurring congestion) occurs. This could be a regular scheduled event, or a note about ad-hoc events at a particular location.
Geometry Type: Point
Data Type: Text

Additional Fields

Additional supporting data include:

Date Start

Definition: Beginning time of a typical year which the noted public event(s) may be more common (anecdotally).
Data Type: Date

Date End

Definition: Ending time of a typical year which the noted public event(s) may be more common (anecdotally).
Data Type: Date

Ramp Type

Definition: The type of ramp associated with a freeway.
Geometry Type: Line
Data Type: Coded:

- Off ramp—exit freeway
- On ramp—enter freeway
- Freeway-to-freeway ramp—connect two freeways
- Other—other type of ramp
- Unknown—unknown type of ramp

Additional Fields

Additional supporting data include:

Ramp Configuration

Definition: Type of ramp configuration.
Data Type: Coded

- Diamond
- Parclo loop
- Free-flow loop
- Free-flow outer connection
- Direct or semi-direct connection
- C-D road or other connector
- Other
- Unknown

Road Closure (seasonal maintenance)

Definition: The period in the year when the road is closed to the public
Geometry Type: Line
Data Type: Coded

- Road Closed
- Seasonally Closed
- Always Open
- Unknown

Additional Fields

Additional supporting data include:

Date Start

Definition: The date for which the road closure begins.
Data Type: Date

Date End

Definition: The date for which the road closure ends.
Data Type: Date

Roadside Hazard Rating

Definition: A roadside hazard rating system that characterizes the accident potential for a roadside design found on two-lane highway. Roadside hazard is ranked on a seven-point categorical scale from 1 (best) to 7 (worst). Refer to *Prediction of the Expected Safety Performance of Rural Two-Lane Highways, Appendix D*[55] for more detailed definitions and examples (figure 108).

Geometry Type: Line

Data Type: Coded

- 1
- 2
- 3
- 4
- 5
- 6
- 7

Typical Roadway with Roadside Hazard Rating Equal to 1.

Typical Roadway with Roadside Hazard Rating Equal to 2.

Typical Roadway with Roadside Hazard Rating Equal to 3.

Typical Roadway with Roadside Hazard Rating Equal to 4.

Typical Roadway with Roadside Hazard Rating Equal to 5.

Typical Roadway with Roadside Hazard Rating Equal to 6.

Typical Roadway with Roadside Hazard Rating Equal to 7.

Source: FHWA

Figure 108. Graphic. Examples of roadside hazard rating.[71]

Roadside Object

Definition: The type of object located on the roadside of the segment.
Geometry Type: Point
Data Type: Coded

- Water
- Bridge Pier, Abutment, or Railing End
- Groups of Trees (4+ In. Diameter)
- Boulder (1+ Ft. Diameter)
- Retaining wall
- Boulder (<1 Ft. Diameter)
- Non-Breakaway Sign
- Non-Breakaway Light Support
- Individual Trees (4+ In. Diameter)
- Culvert
- Utility Pole
- Individual Trees (<4 In. Diameter)

Additional Fields

Additional supporting data include:

Distance

Definition: Distance of objects from roadside edge line; this is the effective clear zone.
Data Type: Short integer
Unit Type: Feet

SafetyEdgeSM

Definition: The presence of SafetyEdgeSM pavement treatment (figure 109).
Geometry Type: Line
Data Type: Coded:

- Yes
- No
- Unknown

Source: FHWA

Figure 109. Photograph. SafetyEdge^{SM} example.[68]

Shoulder Rumble Strips/Stripes

Definition: The type of shoulder rumble strips or stripes on the segment (figure 110).

Geometry Type: Line

Data Type: Coded:

- Milled-In
- Raised
- Rolled-In
- Formed

Source: FHWA

Figure 110. Photograph. Example of shoulder rumble strips.[66]

Shoulder Type

Definition: The predominant shoulder type material on the roadside in the direction of inventory.

Geometry Type: Line

Data Type: Coded

- Paved
- Composite
- Gravel
- Turf
- Curb
- No shoulder
- Not applicable
- Unknown

Sideslope

Definition: The sideslope (foreslope or backslope) on right side of roadway immediately adjacent to the travel lane, shoulder edge, or drainage ditch in direction of inventory. Apply typical conditions if sideslope varies along a section of roadway.

Geometry Type: Line

Data Type: Coded

- 1V:4H or Flatter (Low)
- 1V:4H-1V:3H (Medium)
- 1V:3H or Steeper (High)

Sign(s)

Definition: The type of sign(s) on the segment.
Geometry Type: Point
Data Type: Coded

- Curve Chevrons-Static
- Dynamic Curve Warning System
- Posted Speed-Regulatory
- Posted Speed-Advisory
- Wayfinding
- Advance Guide Signs and Street Names
- Variable Message

Additional Fields

Additional supporting data include:

MUTCD

Definition: Applicable Manual on Uniform Traffic Control Devices (MUTCD) code.
Data Type: Text

Dynamic

Definition: "Dynamic" signs will have flashing lights or dynamic electronic text.
Data Type: Coded

- Yes
- No
- Unknown

Speeding Issue (Anecdotal)

Definition: Indicator of frequent vehicular speeding (either exceeding the posted speed limit or driving too fast for conditions) based on anecdotal information; official citations or speed studies may not exist.
Geometry Type: Point
Data Type: Text

Additional Fields

Additional supporting data include:

Date Start

Definition: The typical time of year which the speeding issues begin or increase in frequency (anecdotally).
Data Type: Date

Date End

Definition: The typical time of year which the speeding issues end or begin to subside (anecdotally).
Data Type: Date

Time Start

Definition: The typical time of day which the speeding issues begin or increase in frequency (anecdotally).
Data Type: Time

Time End

Definition: The typical time of day which the speeding issues end or begin to subside (anecdotally).
Data Type: Time

Surface Type

Definition: The surface type of the segment.
Geometry Type: Line
Data Type: Coded

- Asphalt
- Concrete
- Crushed Aggregate or Gravel
- Bituminous Surface Treatment
- Improved Native Material
- Native Material

Additional Fields

Additional supporting data include:

Pavement Width

Definition: Width of paved surface (if applicable).
Unit Type: Feet

Traffic Operation

Definition: Indication of traffic operations as either bidirectional (i.e., two-way) or one-way of travel.
Geometry Type: Line
Data Type: Coded

- One-way
- One-way as part of a divided highway
- Two-way
- Unknown

Truck Escape Ramp

Definition: The presence of a truck escape ramp or lane along roadside that enables trucks with braking problems to safely stop.

Geometry Type: Point

Data Type: Coded:

- Yes
- No
- Unknown

Unpaved Condition

Definition: Surface condition associated with unpaved roads.

Geometry Type: Point

Data Type: Coded

- Crown
- Loose Aggregate
- Washboarding/Rutting
- Drainage
- Potholes

Vehicle Prohibition

Definition: Type of vehicle prohibited from using a particular section of roadway (i.e., closed to passenger vehicles).

Geometry Type: Point

Data Type: Coded

- Passenger Vehicle and Other Low Clearance Vehicles
- Van and Van Based Bus
- Pickup or Single-Unit Truck
- Truck Tractor
- Bus
- Motorcycle

Alternate Modes

This section documents variables related to alternate modes of travel. This could include pedestrians, (e-)bicycles, off-highway vehicles (OHVs), and equestrian users among others. **NOTE:** All data elements can be represented by independent geometry OR data elements can be stored as event layers to be referenced as part of an overall LRS.

Bicycle Count

Definition: The total daily bicycle flow (i.e., count) in both directions along the roadway (unless directional segment).
Geometry Type: Point
Data Type: Long integer
Unit Type: Number of bicyclists

Additional Fields

Additional supporting data include:

Date Start

Definition: The date bicycle count started
Data Type: Date

Date End

Definition: The date bicycle count ended.
Data Type: Date

Time Start

Definition: The time bicycle count started.
Data Type: Time

Time End

Definition: The time bicycle count ended.
Data Type: Time

Marked Crossing

Definition: Indicator of a marked pedestrian or other non-motorist crossing.
Data Type: Coded

- Yes
- No
- Unknown

Additional Fields (Applicable to Marked Crossings)

Additional supporting data include:

Durable Pavement Markings

Definition: Indicator that durable pavement markings of any type are present (e.g., Waterborne, epoxy, thermoplastic, etc.).

Data Type: Coded:

- Yes
- No
- Unknown

High Visibility Crosswalk Marking

Definition: Crosswalk is a high visibility type.

Data Type: Coded:

- Yes
- No
- Unknown

Lighting

Definition: Indicator that lighting is present.

Data Type: Coded:

- Yes
- No
- Unknown

Parking Restriction

Definition: Indicator that parking is restricted prior to crossing area.

Data Type: Coded:

- Yes
- No
- Unknown

Curb Extension

Definition: Indicator that a curb extension is present.

Data Type: Coded:

- Yes
- No
- Unknown

Advance Stop/Yield Sign

Definition: Presence of advanced stop/yield sign (W11-2 and W16-7P).

Data Type: Coded:

- Yes
- No
- Unknown

Advance Stop/Yield Line

Definition: Presence of advanced stop/yield line.

Data Type: Coded:

- Yes
- No
- Unknown

In-street Stop/Yield Sign

Definition: Indicator of in-street stop/yield sign present (R1-6).

Data Type: Coded:

- Yes
- No
- Unknown

Pedestrian Refuge Island

Definition: Indicator that a raised median island that is intended as a pedestrian refuge is present on the approach.

Data Type: Coded:

- Yes
- No
- Unknown

Raised Crosswalk

Definition: Indicator that a raised crosswalk is present.

Data Type: Coded:

- Yes
- No
- Unknown

Pedestrian Signal

Definition: Type of pedestrian signal present.

Data Type: Coded

- Pedestrian Hybrid Beacon (PHB)
- Rectangular Rapid Flashing Beacon (RRFB)

Motorcycle Flow

Definition: Daily count of motorcyclists

Geometry Type: Point

Data Type: Short Integer

Unit Type: Number of motorcyclists

Motorized Mixed Use

Definition: Off-highway vehicles (OHV) are personal recreation vehicles that may be motorized. OHVs can include all-terrain vehicles (ATVs), 4-wheel-drives (4WDs), and trail bikes.
Geometry Type: Point
Data Type: Short Integer
Unit Type: Number of off-highway vehicles (OHVs)

Additional Fields

Additional supporting data include:

OHV Trails/Crossings

Definition: Presence of off-highway vehicle (OHV) trails/crossings.
Data Type: Coded:

- Yes
- No
- Unknown

OHV Signage

Definition: Presence of off-highway vehicle (OHV) warning signage.
Data Type: Coded:

- Yes
- No
- Unknown

OHV on Shoulder

Definition: Presence of off-highway vehicles (OHVs) observed on road shoulder.
Data Type: Coded:

- Yes
- No
- Unknown

Non-Motorized Crossing Warning

Definition: Presence of signage in advance of a non-motorized crossing that warns motorists of that upcoming crossings
Geometry Type: Coded

- Yes
- No
- Unknown

Additional Fields

Additional supporting data include:

Dynamic

Definition: "Dynamic" signs will have flashing lights or dynamic electronic text.
Data Type: Coded

- Yes
- No
- Unknown

Pedestrian Count

Definition: The total daily pedestrian flow (i.e., count) in both directions along the roadway (unless directional segment).
Geometry Type: Point
Data Type: Long integer
Unit Type: Number of pedestrians

Additional Fields

Additional supporting data include:

Date Start

Definition: The date pedestrian count started.
Data Type: Date

Date End

Definition: The date pedestrian count ended.
Data Type: Date

Time Start

Definition: The time pedestrian count started.
Data Type: Time

Time End

Definition: The time pedestrian count ended.
Data Type: Time

Pedestrian Signals

Definition: Type of pedestrian signal present.
Geometry Type: Point
Data Type: Coded

- Pedestrian Hybrid Beacon (PHB; figure 111)
- Rectangular Rapid Flashing Beacon (RRFB; figure 112)

Source: FHWA

Figure 111. Photograph. Example of a PHB.

Source: FHWA

Figure 112. Photograph. Example of an RRFB.

Additional Fields

Additional supporting data include:

High Visibility Crosswalk Marking

Definition: Presence of high visibility crosswalk marking.

Data Type: Coded:

- Yes
- No
- Unknown

Lighting

Definition: Presence of lighting.

Data Type: Coded:

- Yes
- No
- Unknown

Parking Restriction

Definition: Presence of parking restrictions.

Data Type: Coded:

- Yes
- No
- Unknown

Curb Extension

Definition: Presence of curb extension.

Data Type: Coded:

- Yes
- No
- Unknown

Pedestrian Refuge Island

Definition: Presence of pedestrian refuge island.

Data Type: Coded:

- Yes
- No
- Unknown

Raised Crosswalk

Definition: Presence of a raised crosswalk.

Data Type: Coded:

- Yes
- No
- Unknown

Sidepath

Definition: A bidirectional shared use path located immediately adjacent and parallel to a roadway.
Geometry Type: Line
Data Type: Coded:

- Yes
- No
- Unknown

Additional Fields

Additional supporting data include:

Width

Definition: Width of sidepath.
Data Type: Short Integer
Unit Type: Feet

Physical Separation

Definition: Presence of physical separation (i.e., physical distance or barrier between sidepath and motor vehicle travel way).
Data Type: Coded:

- Yes
- No
- Unknown

Sidewalk

Definition: A paved path, typically concrete or inlayed brick, that serves walking pedestrians and is aligned along the side of a street.
Geometry Type: Line
Data Type: Coded:

- Yes
- No
- Unknown

Additional Fields

Additional supporting data include:

Width

Definition: Width of sidewalk.
Data Type: Short Integer
Unit Type: Feet

Physical Separation

Definition: Presence of physical separation (i.e., physical distance or barrier between sidewalk and motor vehicle travel way).

Data Type: Coded:

- Yes
- No
- Unknown

Transit Stop

Definition: Physical stop associated with fixed route transit that operates during some portion of the day.

Geometry Type: Point

Data Type: Coded:

- Local Bus
- Regional Bus
- Commuter Bus
- Street Car
- Light Rail
- Heavy Rail
- Commuter Rail

Type of Bicycle Lane

Definition: Type of on-street bicycle lane; this should include unmarked, wide paved shoulders.

Geometry Type: Line

Data Type: Coded:

- None
- Wide curb lane with no bicycle markings
- Wide curb lane with bicycle markings (e.g., sharrows)
- Marked bicycle lane
- Separate parallel bicycle path
- Signed bicycle route only (no designated bicycle facility)
- Other

Additional Fields

Additional supporting data include:

Physical Separation

Definition: Presence of physical separation (i.e., physical buffer or barrier between bicycle and motor vehicle travel way).

Data Type: Coded:

- Yes
- No
- Unknown

Unmarked Crossing

Definition: Indicator of an unmarked pedestrian or other non-motorist crossing.

Data Type: Coded

- Yes
- No
- Unknown

Additional Fields (Applicable to Unmarked Crossings)

Additional supporting data include:

Desire ("Goat") Paths

Definition: Presence of an informal "desire" or "goat" path created by frequent use by non-motorist users.

Data Type: Coded:

- Yes
- No
- Unknown

Horseback/Equestrian Users

Definition: Indicator that crossing is used by horseback or equestrian users (figure 113).

Data Type: Coded:

- Yes
- No
- Unknown

Source: FHWA

Figure 113. Photograph. Signage indicating potential equestrian crossing.

Project

This section documents past or upcoming projects performed by FLH, FLMAs, or other partner agencies.

Project Point

Definition: Spot projects, such as individual intersections, that can be represented by a single point and milepost. Plans can also be represented by a point if applicable. Unique project names or other identifiers should be used to track projects over time.

Geometry Type: Point

Data Type: Text

Additional Fields

Additional supporting data include:

Project Type

Definition: Project type.

Data Type: Coded:

- Long Range Plan
- Safety Action Plan
- Intersection Evaluation
- Corridor Study
- Road Safety Audit
- Other Safety Evaluation

Documentation

Definition: Web page or central storage drive that contains a project description and project documentation.

Data Type: Text

Units Type: URL

Project Line

Definition: Linear projects, such as corridor studies and road safety audits (RSAs), that can be represented by a single line and beginning/ending mileposts. Unique project names or other identifiers should be used to track projects over time.

Geometry Type: Line

Data Type: Text

Additional Fields

Additional supporting data include:

Project Type

Definition: Project type.

Data Type: Coded:

- Long Range Plan
- Safety Action Plan
- Intersection Evaluation
- Corridor Study
- Road Safety Audit
- Other Safety Evaluation

Documentation

Definition: Web page or central storage drive that contains a project description and project documentation.

Data Type: Text

Units Type: URL

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FHWA-FLH-23-006

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