Photographic Data Extraction Feasibility and Pilot Study in Support of Roadside Safety and Roadway Departure Research

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FOREWORD

The Federal Highway Administration (FHWA) has identified roadway departure as a focus area because roadway departure crashes consistently contribute to more than half of the fatal crashes on U.S. roadways. Access to relevant data is critical to understanding the causes of roadway departure and mitigating the consequences. This study seeks to maximize available vehicle and infrastructure crashworthiness data sources and repurpose them to answer questions of interest to FHWA, such as the identification of barrier types and end treatments subjected to specific crash conditions previously unreported in the crashworthiness datasets.

This study is part of a series of low-cost in-house efforts to make full use of existing data resources to understand the roadway departure problem. Existing data will be extrapolated and interpolated to determine reliable results and identify missing data. This report represents an ongoing effort in roadway departure analysis.

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16. Abstract
This work represents the first phase of an ongoing low-cost in-house effort to perform data analysis, optimize internal data gathering in an informed fashion, make data requests to organizations, and obtain needed information. The work also calls on the definition of "roadway departure" prepared by a 2008 working group assembled by the Federal Highway Administration (FHWA) Office of Safety. The group provided a verbal and data definition in order to extract data and relate the data to the fatal crash population.

Many applications exist for crashworthiness data and untapped resources from previously unqueried sources.(1) The FHWA roadway departure definition provided a Fatality Analysis Reporting System data approach; however, other National Highway Traffic Safety Administration datasets exist with real-time or near real-time data.(2) One such dataset is the National Motor Vehicle Crash Causation Study (NMVCCS).(3,4) The present work pursues photographic data extracted from the NMVCCS. This report provides further discussion regarding the surrogates adopted in framing roadway departure.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^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)

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LIST OF ABBREVIATIONS

CDS	Crashworthiness Data System
EAR	Exploratory Advanced Research
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
GM®	General Motors®
HBA	Hinged breakaway
LBSS	Longitudinal Barrier Special Study
NASS	National Automotive Sampling System
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NMVCCS	National Motor Vehicle Crash Causation Study
SGT	Single guardrail terminal
SKT	Sequential kinking terminal
TAS	Terminal anchor section

CHAPTER 1: INTRODUCTION

BACKGROUND

The research team undertook the photographic data extraction pilot study in response to the 2008 revision of the Fatality Analysis Reporting System (FARS), releasing geographical positioning system coordinates.(2) Subsequently, the National Highway Traffic Safety Administration (NHTSA) released the geographical coordinates for previous crash years in an independent file format for 1999 and 2000 and revision of the FARS files from 2001 through 2007. Using the Federal Highway Administration (FHWA) roadway departure definition to filter crashes of interest, events involving guardrails, concrete barriers, and impact attenuators were reviewed from 2004 to 2009.(5) From the pilot study, it was determined that barrier type and placement might provide useful information at low acquisition costs. The missing element, however, was post-crash condition. To obtain that information, it was necessary to review on-scene crash data. The current study considered the on-scene photography captured through the National Motor Vehicle Crash Causation Study (NMVCCS).(4) NMVCCS was a congressionally mandated special study compiled under the National Automotive Sampling System (NASS) architecture from 2005 through 2007, with a primary objective to provide pre-crash and crash causation information.(3,4)

In 2008, the NASS Crashworthiness Data System (CDS), providing a sample of tow-away crashes occurring on public roadways in the United States, showed marked improvement in roadside crash photography, possibly modeled after NMVCCS photography.(6) Data collection for these crashes, however, continued to be near-crash time, with NASS researchers arriving to the crash scene within days or weeks. Prior NASS CDS efforts included the 1982 Longitudinal Barrier Special Study (LBSS), which was a collaborative effort with NHTSA.(7) However, the photographs and crash data were filed in paper medium and electronic records unavailable to FHWA. To date, no NHTSA crashworthiness dataset has provided a suitable level of coded roadway environment data for FHWA analysis.

This study sought to complement the coded datasets by extracting new information from photographic images. NMVCCS data were selected owing to their temporal association with the crash and quality of photographs taken. Further, the pilot study initially attempted to classify the types of barriers involved, but the lack of temporal association limited the data extraction to an inventory confirming coded FARS attributes. The ability for researchers to assess the types of damage was considered useful as data inputs for future modeling tasks, thereby validating the immediate use of NMVCCS to feed the codification of a supplementary roadside element dataset.

National Cooperative Highway Research Program (NCHRP) projects have used photographic analysis to expand the understanding of uncoded elements, specifically NCHRP projects 17-11, 17-22, and 22-15.(8–10) NCHRP projects 17-11 and 17-22 sought to identify impact conditions for run-off-road crashes, while project 22-15 considered the compatibility of the vehicle fleet with existing barrier types. The three studies compiled previously unavailable data from photographs and synthesized relevant test and real-world data.

Table 1 summarizes the means of harmonizing the coded and uncoded data. Historically, two broad types of data have existed: basic and crash. Basic data provided basic vehicle characteristics (e.g., make, model, and assessment of components) and occupant demography (e.g., observational and hospital discharge data). Crash data have generally provided post-crash vehicle disposition (e.g., tow away status and full deformation measurements) and geographical location (e.g., explicitly stated or sanitized scene photographs absent of geographical location information serving as a surrogate). Codified details have depended on the collection mandate of the dataset. It has been understood that in the absence of naturalistic data on each crash occurring, precise vehicle trajectory will be unavailable. However, the identification of roadside elements and descriptions of roadside environment have been available in crash photographs for several years. Currently, photographic data extraction is a labor-intensive task; however, in the future, roadside element extraction might benefit from automated data extraction based on the work of the FHWA Exploratory Advanced Research (EAR) Program.

Table 1. Traditional and supplemental data acquisition approaches.

Data Type	Data Elements		
	Codified	**Unavailable**	**Uncodified Photographic**
Basic	Basic vehicle data		
	Basic occupant demography		
Crash	General vehicle contacts	Precise vehicle trajectory	Specific type of element
	Geographical location		Roadway and roadside description

Note: Blank cells indicate data elements outside the scope of the data types.

The authors of this report advocate additional roadside element acquisition from the NMVCCS dataset. For FARS, a means of digitally extracting roadside element information from panoramic view software images is being assessed separately in tandem with findings of concurrent and related EAR projects. If NMVCCS and FARS data extraction methodologies are found to be acceptable for safety research, then a combination of these techniques will be applied to extract data from NASS CDS images.

OBJECTIVES

This study seeks to enhance the understanding of roadway element data from collected but uncodified information. This report seeks to perform the following tasks:

- Outline the findings of the photographic data extraction feasibility study.
- Describe the findings of the photographic data extraction pilot study to date.
- Provide recommendations for future photographic data extraction efforts.

CHAPTER 2: RESULTS OF THE PHOTOGRAPHIC DATA EXTRACTION FEASIBILITY STUDY

Geographical coordinates found in FARS are a valuable resource to the roadside safety researcher. The limited roadway environment data were able to be assessed using panoramic view software, which provided an image of the crash scene according to geographical coordinates. Although the crash scene images were temporally discontinuous, they provided insight into the type and placement of the barrier cited in the crash data.

Traditional data acquisition has been inadequate to address the needs of FHWA. The photographic analysis sought to enhance the few relevant coded variables and limited attributes for those variables. However, issues exist in photographic analysis, such as unknown crash locations and inconsistent levels of detail, which require the activation of several operative assumptions.

CANDIDATE DATASETS

During the course of the pilot study, the researchers considered all relevant NHTSA datasets for supplementary data acquisition. FARS provided secondary access to crash scene images. The geographical coordinates were supplied to third-party panoramic view software, yielding images that were temporally discontinuous with the crash. NASS CDS provided near-crash time photographs, while NMVCCS provided on-scene crash photography.

The research team summarized the process for data filtering, photographic capture, and possible data codification parameters in table 2. The principal difference in filtering rested with the FHWA roadway departure definition applicable only to FARS. Owing to privacy protocol observed in NASS CDS and NMVCCS, variables and attributes necessary to apply the roadway departure definition were not reported. As a surrogate for the proper roadway departure definition, impacts occurring in the first event involving guardrails, concrete barriers, and impact attenuators were accepted as quasi-roadway departure crashes. FARS required a two-step process for extracting the geographical coordinates from the data files and then inputting the coordinates into panoramic view software to observe the crash location during some point in time not coinciding with the crash. NMVCCS provided the photographs linking the vehicle to the crash scene and final disposition, suggesting trajectory after impacting the roadside element. Finally, NASS CDS provided crash location photographs within days or weeks of the crash as well as post-crash vehicle conditions for vehicles accessible at the tow yard.

Table 2. Extraction of photographic data by dataset.

Dataset	Relevant Attributes	Parameters of Extracted Data
FARS	Temporally non-concurrent first event roadway departure	• Panoramic view software interface • Crash location
NVMCCS	On-scene first event roadside element impact	• Post-crash • Vehicle final rest serving as geographical coordinate surrogate
NASS CDS	Near crash time first event roadside element impact	• Days or weeks after crash • Crash location images serving as geographical coordinate surrogate • Vehicle towed from scene

OPERATIVE ASSUMPTIONS

For the initial review of FARS images, the research team adopted the following assumptions to facilitate image review:

- If the image pre-dated the crash, the barrier would be the one found at the time of the crash.
- If the image was taken after the crash, the barrier would have been replaced with a similar barrier.
- In obvious cases of miscoded geographical coordinates, the following hierarchy would be applied to ascertain the crash location:
    1. Review of all vehicle crash events by scrolling along roadway segments.
    2. Consult street, cross street, and mile post information, especially in the case of elevation.

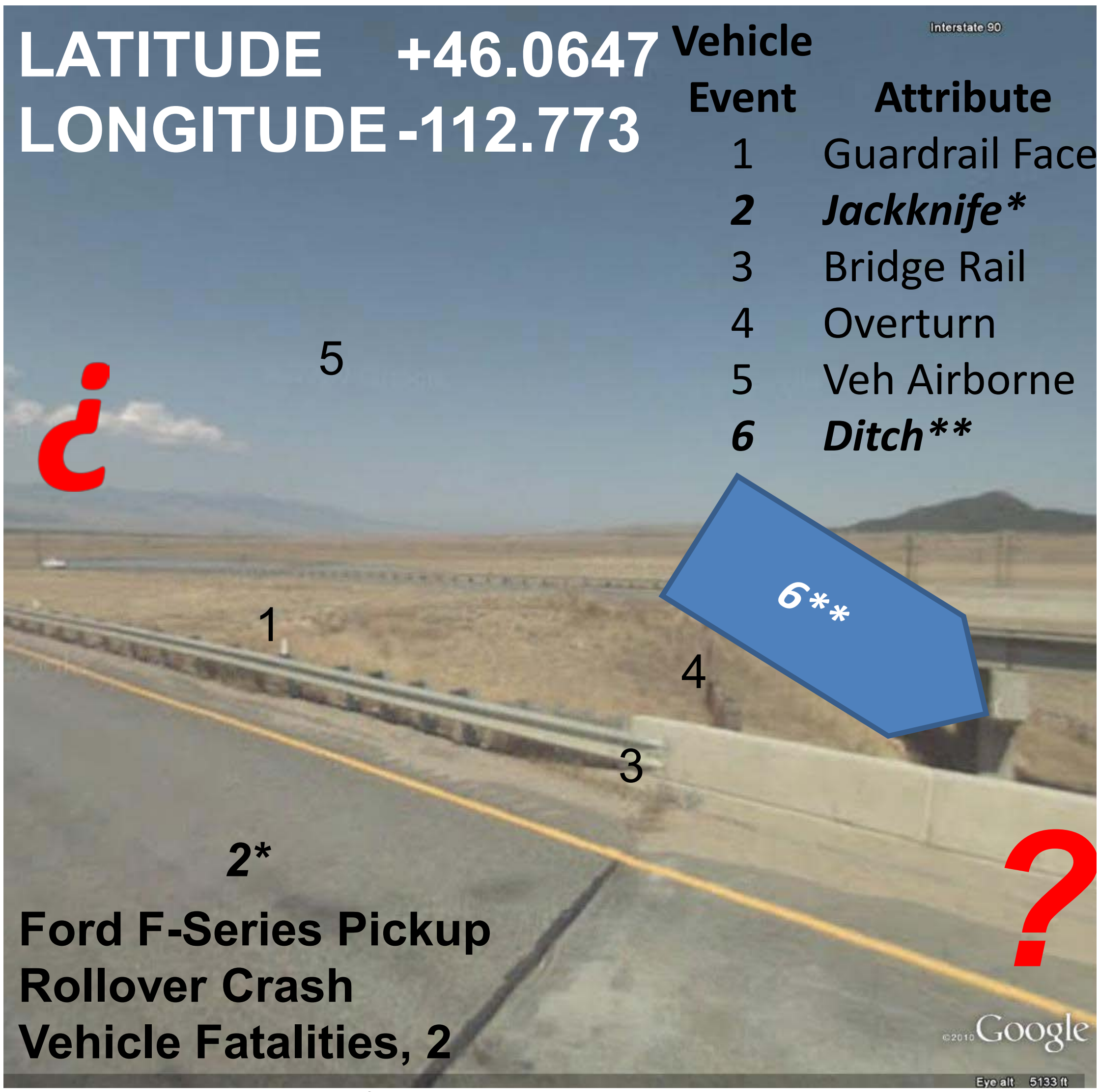
EXAMPLES OF CANDIDATE CRASH SELECTION FINDINGS

The research team filtered FARS, NASS CDS, and NMVCCS to compile a roadway departure dataset. They also entered the geographical coordinates into panoramic view software while using crash scene photographs as geographical coordinate surrogates for the datasets governed by privacy protocols.

FARS Dataset

With the publication of geographical coordinates in 2008 and retroactive provision for prior crash years by NHTSA, possible crash trajectories could be conceived. Starting in 2004, FARS started to disaggregate the crash into vehicle event units, which was previously only done in NASS CDS.[6,11] With the coded vehicle events and the crash locations, it became possible for researchers to envision at least one crash trajectory, whereas previously, the crash scene was unknown to data analysts.

Figure 1 provides one possibility with respect to crash progression. From similar images, it became possible for practitioners and researchers to have a discussion relevant to roadway vernacular. For example, a police accident report may cite the involvement of a ditch, but a roadway designer may have posited the presence of an embankment. Additionally, questions with the coded data existed regarding the application of a jackknife condition to a pickup truck. Unknowns also existed, with respect to the precise location of impact and Terhune scale rollover classification, but the general environment in which the vehicle was operating was better described.



Original image: ©Google Earth®. (See Acknowledgements section for trajectory overlay.)

Figure 1. Illustration. FARS data acquisition example showing possible vehicle trajectory.[2,12]

NMVCCS Dataset

Although NHTSA did not provide geographical coordinates in the NMVCCS dataset, the on-scene photography generally superseded the need for such flexibility, as seen in figure 2. Generally, from using one photograph, researchers were able to extract information relevant to the vehicle final disposition, vehicle damage, and roadside element damage. From this information, it was possible to postulate the path and interactions leading to post-crash vehicle final resting position. As the photographs were taken on scene, the roadside damage, if present, was readily evident and could be linked to specific coded elements like vehicle paint color and paint transfers to the roadside element. An additional boon to the study was the presence of measurement rods, which were used previously in NASS CDS to quantify vehicle damage. In NMVCCS, the measurement rods were used to highlight elements in photographs and unintentionally provided the barrier height, damage height, and damage width. This emphasis had a secondary effect of providing much needed roadside element measurement details. As this was not mandated in the NMVCCS photography protocols, these measurements were available inconsistently throughout the dataset. The other available attribute was the damage to the barrier and its components, seen visually and generally created by those unaware of roadside design precepts.

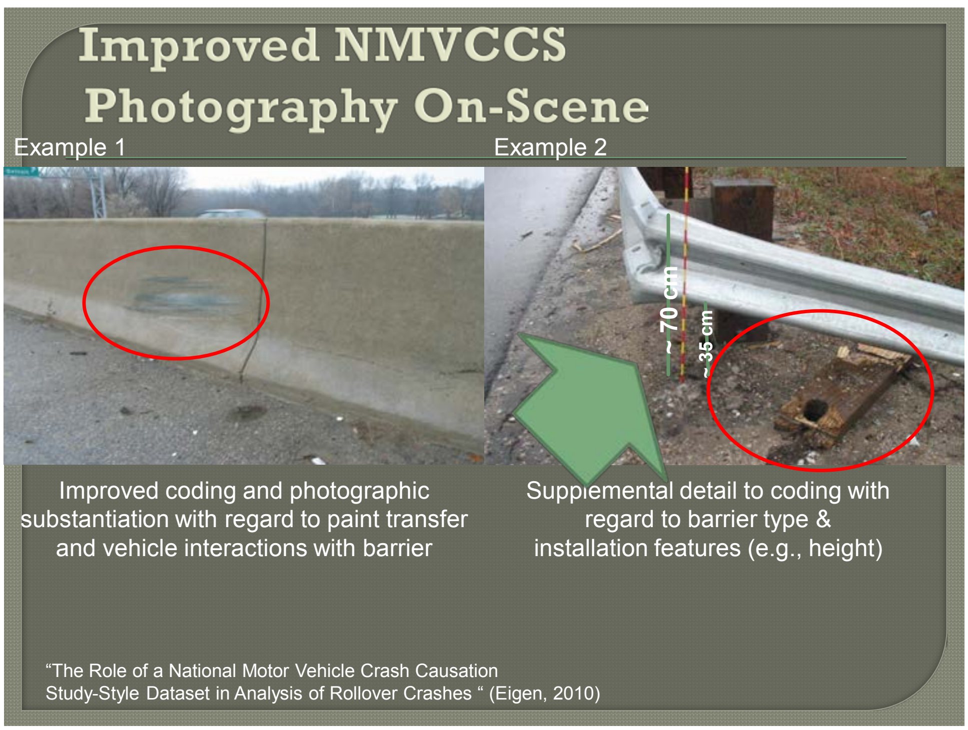


Figure 2. Illustration. NMVCCS photographic data acquisition example.[1,4]

NASS CDS Dataset

NASS CDS data were the final dataset considered.[6,11] The photographic image capture had the unintended benefit of improvement after the publication of the NMVCCS data. NASS CDS images before NMVCCS focused on the vehicle and the occupant interaction with the vehicle, but after the on-scene NMVCCS experience, the crash environment images improved markedly from an FHWA perspective. Although the photographs were taken within days or weeks of the crash, a benefit existed in knowing the precise crash location. Based on the vehicle events recorded, the crash location and vehicle damage photographs might provide information relevant to possible trajectory.

NASS CDS photographic analysis required a two-step process to understand the crash scene and infrastructure as well as the vehicle damage and its possible interaction with the roadside environment. Most vehicles carried quantitative damage measurements conforming to Society of Automotive Engineering standards. These were also the same type of measurement rods that were repurposed in the NMVCCS dataset.

Figure 3 provides a summary of data relevant to the roadside element study extracted from NASS CDS Case 2007-09-013.(6) The left image provides the roadside element, the deformed metal guardrail. The vehicle damage can be discerned from the center and right images. In this case, the front of the vehicle made contact with the barrier, followed by a subsequent impact with the barrier, culminating in a one-quarter turn driver-side rollover. The rollover was identified as a climb-over probably associated with the guardrail damage shown in the left image. In this case, the vehicle scaled the barrier, causing the vehicle to roll to the opposite side of the barrier.

Figure 3. Illustration. NASS CDS data acquisition example showing damaged roadside elements (left, W-beam strong post) and vehicle damage (center, back/left oblique and right, front with measurement rods).(6)

FEASIBILITY STUDY DATASET SELECTION

FARS was the first dataset considered because the availability of geographical coordinates allowed for a wide range of panoramic view image options.

FHWA has been a limited user of the NHTSA dataset, especially in problem identification, as in the case of the roadway departure data definition.(5) Details relevant to developing crash testing protocols and roadside design parameters have been unavailable. It is believed that at minimum, the photographic data might provide valuable modeling inputs associated with different crash types. The supplemental data acquisition was developed based on the initial inventory style identification through FARS and was refined to include roadside element damage, vehicle damage, and vehicle trajectory.

For purposes of this current study, FARS and NMVCCS crashes were selected for consideration from a pool of crashes filtered using the FHWA roadway departure definition for FARS and the first event roadside element impact surrogate for NMVCCS. The images were reviewed per table 3. The case review process was outlined in *Leveraging New Technologies to Capture Infrastructure Data to Supplement Roadside Crash Analyses.*(13)

Table 3. FARS crash panoramic view image classification.

Major Classification Rubric	Photographic Classification
Generally useable	Accurate identification
	Possible supplementation to accurately coded data
Possibly useable	Absence of elevation data
	Contact found at proximate geographical coordinates
Miscoded	Attribute absent from geographical coordinates image
	Coded misidentification
External to codification	Geographical location could not be resolved
	Unresolved photographic quality
Missing data	Coordinates not provided

The FARS photographs fell into five major classification rubrics, translating into the photographic classification (see table 3). Upon reviewing the NMVCCS crashes, these were further simplified into a color usability classification system (green, yellow, and red).

The FARS green category included the generally useable classification, the yellow category contained the possibly useable classification, and the red category comprised the remaining rubrics (see table 4). Additionally, green was merited if the coded roadway element was confirmed by crash scene image, with at least one scenario emerging for modeling. Yellow was assigned if the coded roadway element was confirmed at proximate coordinates or confirmed by traffic way identifiers permitting the update of a coded roadway element, thereby improving the roadside element description based on coded location information or suggesting at least one scenario for modeling. Finally, red was assigned if geographical coordinates were unpublished, images were overexposed, or the street view was unavailable, as in the case of international border crossings.

Table 4. FARS candidate crashes by frequency and usability.

Usability Classification	FARS						Usability by:	
	2004	2005	2006	2007	2008	2009	Classification	Acceptability
Green	131	90	66	57	55	36	53 percent	71 percent
Yellow	12	25	32	25	22	30	18 percent	
Red	61	38	35	30	46	26	29 percent	

Note: The blank cell indicates that the data were deemed unusable.

The same categories were applied when assessing NMVCCS crashes (see table 5). It was found that 71 percent of the first event roadway departure FARS crashes were classified as green and yellow collectively (table 4), and 100 percent of the NMVCCS crashes were classified as green (table 5). The FARS green and yellow aggregation and the NMVCCS green crashes were deemed suitable for consideration in the photographic data extraction pilot study as candidate results for the supplementary dataset.

Table 5. NMVCCS candidate crashes by frequency and usability.

Usability Classification	NMVCCS						Usability by:	
	2004	2005	2006	2007	2008	2009	Classification	Acceptability
Green	0	101	139	147	0	0	100 percent	100 percent
Yellow	0	0	0	0	0	0	0 percent	
Red	0	0	0	0	0	0	0 percent	

Note: Blank cells indicate absence of cases. No cases were classified as yellow or red.

FINDINGS OF THE FEASIBILITY STUDY

The goal of this study was to confirm the presence of coded roadside elements and determine their placement. It provided greater detail for the limited coded attributes, including uncoded roadside element type, and related them to the coded crash events. Finally, it provided insight into uncoded data with external images with full panoramic scene views for crashes with geographical location as well as NHTSA images with damage detail as a surrogate for datasets disallowing the provision of precise crash scene locations. These findings suggested the efficacy of the feasibility study and warranted continuation in the form of a pilot study.

CHAPTER 3: RESULTS OF THE PHOTOGRAPHIC DATA EXTRACTION FEASIBILITY PILOT STUDY

DESCRIPTIVE SUMMARY STATISTICS

For each case, through visual observation of the photographs, different pieces of information were collected and stored as variables. This section provides the general procedure of how these variables were collected and a brief explanation of the variables used. It also provides some statistics that summarize the data collected in those variables.

General Data Extraction Process

The NMVCCS database groups all of its information by crash case. Each crash case has a narrative that explains how the crash happened and its possible causes. The analyst must review this narrative and answer the following questions to obtain a general idea of how the crash happened:

- If several vehicles experienced any type of collision, which vehicle was the first to present abnormal behavior (such as skidding, departing abruptly from its lane, etc.)? (The answer indicates the vehicle that will be selected for consideration in the analysis.)

- In which direction was the vehicle driving and on which part of the roadway?

- Did the vehicle depart from the roadway and run into a shoulder or barrier? (If this is the case, the analyst only considers the first time this event happens and on which side of the road (left or right).)

- Were there one or several physical elements on the roadway that were presumed to be factors in the occurrence of the crash?

- What were precipitation conditions at the moment of the crash?

The second and third questions are especially important to understand the location of the barrier and the shoulder that might have been involved in the crash. The location information is stored as variables, allowing readers to better understand how the crash happened by just consulting the information from the variables.

After answering the questions, the analyst must observe the crash photographs and try to draw all the necessary information from the photographs. The fourth question helps the analyst avoid missing other important aspects in the road. With this help and with an element of discretion, the analyst assumes that most of the characteristics of the roadway that appear in the photographs, such as contamination and surface anomalies, should be stored in the variables.

The fifth question is directly stored in the variables. There is a variable labeled “Reported Precipitation” that is used to indicate the precipitation conditions at the moment of the crash.

Lastly, the analyst must determine if the photograph was taken at the moment of the crash or after the crash. Information such as contamination and the damage caused to the road should only be used from photographs taken at the moment of the crash. However, geometric characteristics can be obtained from photographs that happened after the crash. While NMVCCS provides some indication on when the photograph was taken, the analyst must make that determination, either on-scene or sometime after the crash. Although NMVCCS was conceived as on-scene data, some crash scenes might have been complicated by roadway traffic, in the absence of closure, limited closure time, or some such access impediment. In these cases, the researcher might have opted to review less time-critical aspects of the crash scene within hours of the crash once crash victims had been transported and vehicles towed from scene.

After following the approach, the analyst must describe the crash using the elements in table 6 and store the corresponding information.

Variables and Attributes

The variables used to capture the information are classified into four groups according to what part of the road they describe: shoulder; roadway, barrier, and precipitation. They can also be classified into four groups according to the type of technical expertise needed to identify the information: pavement characteristics and contamination, geometric characteristics, damage caused, and precipitation. Most of the variables contain information associated to pre-specified attributes. The variables are explained in table 6.

Table 6. Supplementary variables and their attributes.

<table>
<tr><th>Part of the Road Described</th><th>Type of Information</th><th>#</th><th>Variable</th><th>Attributes</th><th>Observations</th></tr>
<tr><td rowspan="3">Shoulder</td><td rowspan="3">Geometry and physical elements</td><td>1</td><td>Location of the first shoulder involved</td><td>• No shoulder involved.
• Left side of road.
• Right side of road.
• Other.
• Unknown.</td><td>“No shoulder involved” indicates that either the road has no shoulders or the vehicle did not leave the roadway during the crash.</td></tr>
<tr><td>2</td><td>Representative paved shoulder width</td><td>• No shoulder involved.
• No paved shoulder.
• Less than 4 ft.
• 4 to 8 ft.
• More than 8 ft.
• Indistinguishable from photos.
• Unknown location of first shoulder involved.</td><td>The observation of the first variable also applies here. “Unknown location of first shoulder involved” should be selected if the value of the first variable is unknown.</td></tr>
<tr><td>3</td><td>Representative unpaved shoulder width</td><td>• No shoulder involved.
• No unpaved shoulder.
• Less than 4 ft.
• 4 to 8 ft.
• More than 8 ft.
• Indistinguishable from photos.
• Unknown location of first shoulder involved.</td><td>The observations of the first and second variables apply here.</td></tr>
</table>

Part of the Road Described	Type of Information	#	Variable	Attributes	Observations
		4	Major variations in paved shoulder width	• No shoulder involved. • No paved shoulder. • Yes. • No. • Indistinguishable from photos or other sources. • Unknown location of first shoulder involved.	If the length in the second variable varies significantly, then the attribute "yes" should be selected here. The observations of the first and second variables apply here.
		5	Major variations in unpaved shoulder width	• No shoulder involved. • No unpaved shoulder. • Yes. • No. • Indistinguishable from photos or other sources. • Unknown location of first shoulder involved.	If the length in the third variable varies significantly, then the attribute "yes" should be selected here. The observations of the first and second variables apply here.
		6	Roadway to paved shoulder drop-off	• No shoulder involved. • No paved shoulder. • Yes. • No. • Indistinguishable from photos. • Unknown location of first shoulder involved.	The observations of the first and second variables apply here.
		7	Presence of rumble strips	• No shoulder involved. • No paved shoulder. • Yes. • No. • Indistinguishable from photos. • Unknown location of first shoulder involved.	The observations of the first and second variables apply here.
	Pavement properties and contamination	8	Paved shoulder contamination	• No shoulder involved. • No paved shoulder. • Ice or slush. • Snow. • Mud. • Loose sand or stone. • Grass, leaves, or sticks. • Water. • Oil. • Other. • Several of the above. • Indistinguishable from photos. • None. • Unknown location of first shoulder involved.	The observations of the first and second variables apply here.
Roadway	Geometry and physical elements	9	Pavement marking quality	• Visible. • Decayed. • Indistinguishable from photos.	"No shoulder involved" indicates that either the road has no shoulders or the vehicle did not leave the roadway during the crash.

Part of the Road Described	Type of Information	#	Variable	Attributes	Observations
	Pavement properties and contamination	10	Roadway pavement type	• Asphalt • Concrete • Other: specify • Indistinguishable from photos	
		11	Apparent macro-texture	• Yes, due to visible coarse texture from tining or grooves in concrete surface or exposed surface or exposed coarse aggregate in asphalt or concrete surface. • No. • Indistinguishable from photos.	Selecting "yes" requires having a very good photograph that effectively indicates that the road has an apparent macrotexture.
		12	Rutting	• Yes, per puddled or other surface water in ruts, low spots, or flat areas. • No. • Indistinguishable from photos.	Selecting "yes" requires having a very good photograph that effectively indicates that the road has rutting.
		13	Pavement contamination	• Ice or slush. • Snow. • Mud. • Sand. • Gravel. • Water. • Oil. • Other. • Several of the above. • Indistinguishable from photos. • None.	
		14	Gross pavement irregularities	• None. • Very rough. • Big pothole(s). • Large dips or bumps. • Concrete pavement blow-up. • Excessive patching/settlement. • Large cracks. • Large longitudinal gaps pavement to shoulder or between lanes. • Under construction conditions. • Drop-off between lanes during construction of overlays. • Other. • Indistinguishable from photos.	
Barrier	Geometry and physical elements	15	Location of the first compromised barrier	• No barrier compromised. • Left side of road. • Right side of road. • Other. • Indistinguishable from photos. • Unknown location.	

Part of the Road Described	Type of Information	#	Variable	Attributes	Observations
		16	Barrier type	• No barrier compromised. • Aesthetic timber barrier/wood guardrail. • Box beam. • Bridge rail. • Constant slope barrier (UK equivalent, concrete step barrier). • F-shaped barrier. • General Motors® (GM®) barrier shape. • High-tension cable guardrail systems. • Impact attenuators. • Jersey barrier. • Low-tension cable guardrail. • Median barrier steel guardrail. • Median strip. • Steel-backed timber guardrail. • Temporary impact attenuators. • Thrie beam. • Thrie beam strong post. • Water- and sand-filled barriers. • W-beam strong post. • W-beam weak post. • Weak post box beam. • Weathering steel (Corten®) guardrail. • Other: specify. • Indistinguishable from photos. • Unknown location of first barrier compromised.	

Part of the Road Described	Type of Information	#	Variable	Attributes	Observations
Barrier	Geometry and physical elements	17	Barrier end treatment type	• Outside the road segment of analysis. • Bull nose end treatment. • Guardrail bridge attachment. • Rock fence. • Rounded terminal buffer (shape of a question mark). • Single guardrail terminal (SGT) (sequential kinking terminal (SKT)-350) types I, II, and III, hinged breakaway (HBA) (installation instructions drawing). • Terminal anchor section (TAS or "turndown" roll-over end section). • Terminal end sections (boxing glove). • Thrie beam terminal connector shoe (end shoe). • Trail end guardrail sections. • W-beam terminal connector shoe. • Jersey barrier end treatment type F. • Impact attenuators. • Other. • Indistinguishable from photos.	
		18	Barrier post material	• No barrier compromised. • Wood. • Metal. • Indistinguishable from photos. • N/A (i.e., Jersey barrier). • Unknown location of first barrier compromised.	
		19	Barrier block-out material	• No barrier compromised. • Wood. • Plastic. • Metal. • Indistinguishable from photos. • No block-out material. • N/A (i.e., Jersey barrier). • Unknown location of first barrier compromised.	
		20	Location of crash with respect to barrier	• Along the barrier. • At the end of the barrier. • No barrier involved.	
		21	Location of crash with respect to guardrail	• Along the guardrail. • At the end of the guardrail. • No guardrail involved.	

Part of the Road Described	Type of Information	#	Variable	Attributes	Observations
		22	Ground to barrier face, measure-ment rods	N/A	Sometimes the people in charge of the photographs put a rod in front of the barrier. This rod has very visible marks that allow an approximate measurement of the distance between the ground and the beginning of the barrier face.
		23	Vertical barrier face, measure-ment rods	N/A	The observation of the 20th variable also applies here.
		24	Horizontal damage barrier face, measure-ment rods	N/A	Although the expectation was that the people on the ground would put a rod for measuring this length on the damage, there were no photographs with this aiding rod.
		25	Damage height from ground, measurement rods	N/A	The observation of the 21st variable also applies here.
	Damage caused	26	Ground to barrier, Google Earth®	N/A	These variables are analogous to variables 20–23. Nonetheless, the measurement would not be taken by looking at a possible rod on the picture but by using Google Earth®. These variables were not actually used for the NMVCCS database but for another database (i.e., this was a flexible data entry meant to accommodate FARS as well as NMVCCS data as well).
		27	Vertical barrier face, Google Earth®	N/A	
		28	Horizontal damage barrier face, Google Earth®	N/A	
		29	Damage height from ground, Google Earth®	N/A	
		30	Barrier condition	• No barrier compromised. • No visible damage. • Scuffing and scraping. • Breakage barrier face. • Breakage component. • Compromised location. • Indistinguishable from photos. • Unknown location of first barrier compromised. • Unknown since photos were taken before crash. • Unknown since photos were taken more than 1 month after crash.	
Precipitation	Precipitation	31	Reported precipitation	• Liquid. • Freezing. • Frozen. • None. • Not reported.	As mentioned previously, this variable did not come from the photographs but from the narrative of the NMVCCS database.

Note: Blank cells in observations denote an absence of special instructions for the referenced rubric.
N/A = Not applicable.

SUMMARY STATISTICS

Figure 4 through figure 7 summarize some of the information captured in the variables in table 6. A comprehensive count of the information obtained can be found in appendix C.

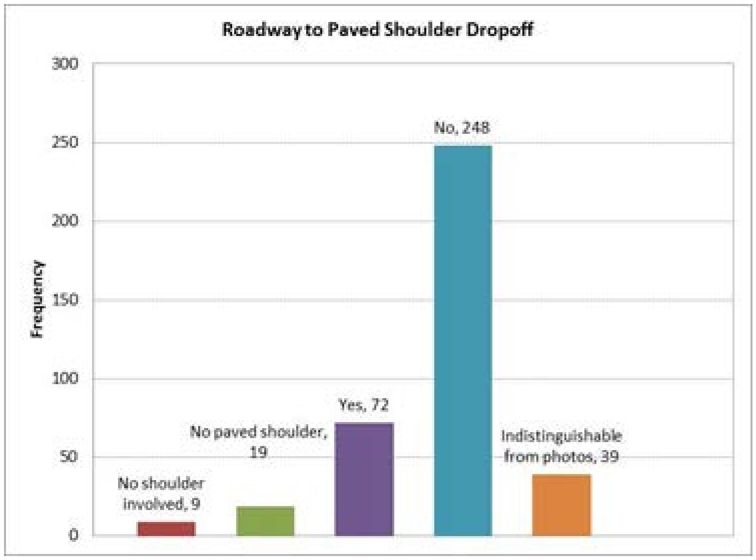


Figure 4. Graph. Attributes observed in the roadway to paved shoulder drop-off variable.

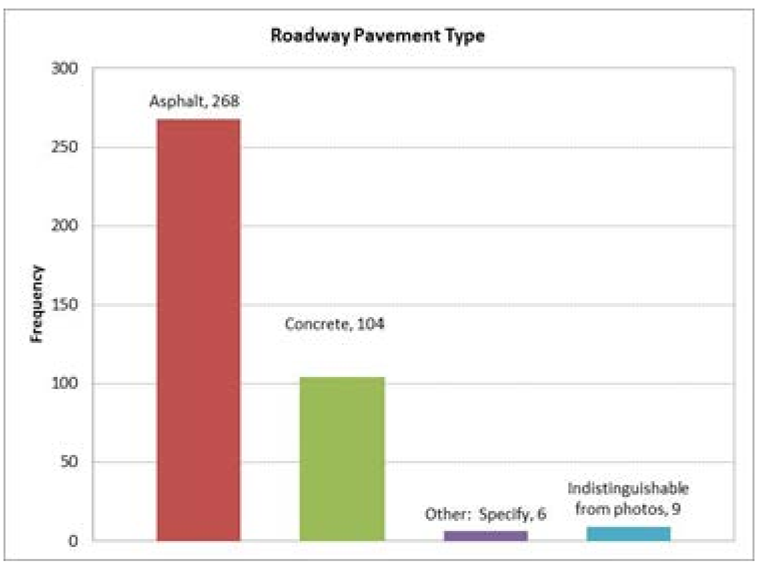


Figure 5. Graph. Attributes observed in the roadway pavement type variable.

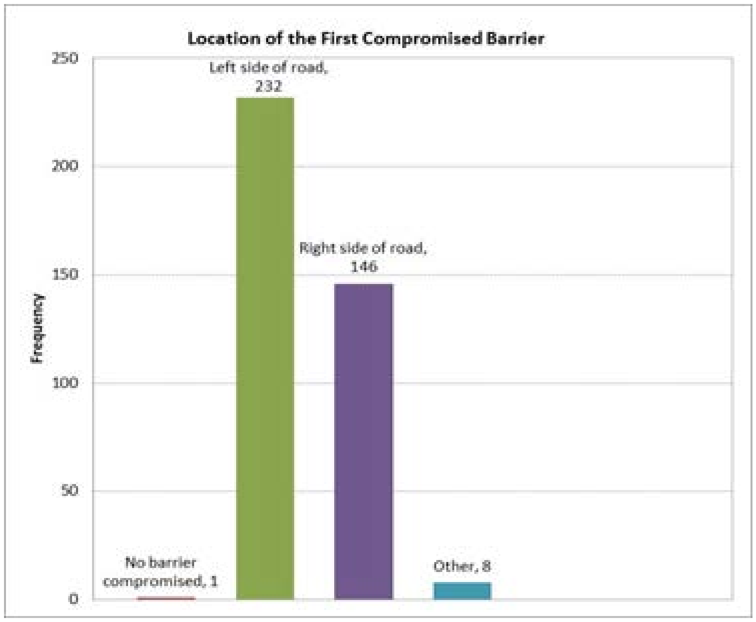


Figure 6. Graph. Attributes observed in the location of the first compromised barrier variable.

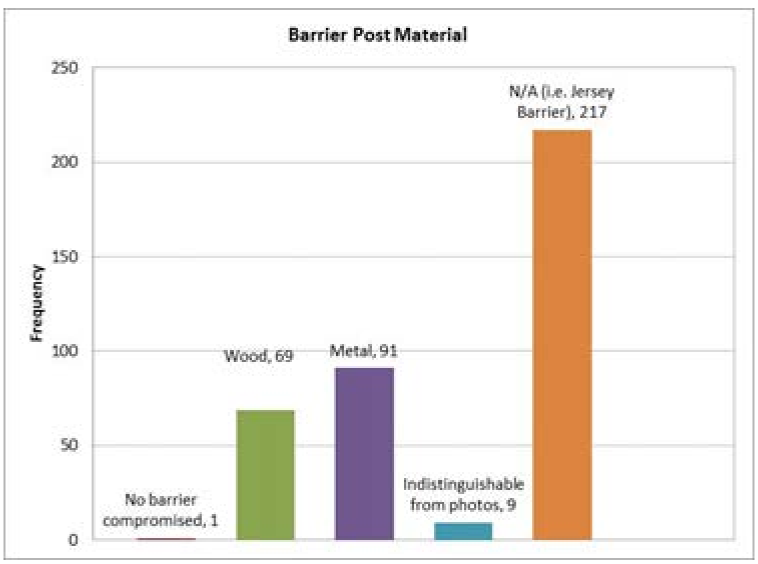


Figure 7. Graph. Attributes observed in the barrier post material variable.

PHOTOGRAPHIC EXAMPLES

The previous section presented the procedure that should be followed to perform data extraction. This section illustrates that procedure followed by an explanation of how a catalog was used to identify different road elements in the case studies. These road elements include types of barriers and barrier end treatment types. Finally, cases in which difficulties were experienced are presented for capturing information from the photographs.

Typical Case

The example presented here corresponds to Case No. 2005079486822 from the NMVCCS database and follows the procedure explained in the previous section. The following variables are not mentioned in this example: paved shoulder contamination (8), apparent macrotexture (11), rutting (12), pavement contamination (13), and gross pavement irregularities (14). Those variables presented challenges for the analyst and are mentioned in the subsection "Challenging Aspects."

The narrative presented in NMVCCS provides the following information (hereafter referred to as observations):

1. It was a single-vehicle crash.
2. The vehicle was heading northbound.
3. The driver drove off the roadway into the left shoulder and then hit the barrier.
4. The main factor for the vehicle's departure did not seem to be caused by a feature in the road or pavement but by the behavior of another vehicle.
5. There was no precipitation at the time of the crash.

Observations 2, 3, and 5 provide an immediate answer to the question of which attributes assign to the following variables:

- Location of the first shoulder involved: Left side (1).
- Location of the first compromised barrier: Left side (15).
- Reported precipitation: None (31).

The photographs in figure 8 and figure 9 from the NMVCCS database indicate the following values to the variables corresponding to the shoulder:[4]

- Representative paved shoulder width: More than 8 ft (2).
- Representative unpaved shoulder width: No unpaved shoulder (3).
- Major variations in paved shoulder width: No (4).
- Major variations in unpaved shoulder width: No unpaved shoulder (5).
- Roadway to paved shoulder drop-off: No (6).
- Presence of rumble strips: No (7).

Figure 8. Photo. First view of Case No. 2005079486822 showing the point of impact.

Figure 9. Photo. Second view of Case No. 2005079486822 showing the point of impact.

Variables 2 and 3 require the judgment of the analyst to indicate a length range for the shoulder. Figure 8 shows a pickup parked on the shoulder. Since a standard lane has a length of 12 ft, is assumed that the shoulder is longer than 8 ft. Variables 4 and 5 have a “yes” value if the shoulder varies considerably from the point where the vehicle hits the barrier to upstream. Because the photographs in figure 8 and figure 9 do not provide a good perspective for an answer to variable 4, the analyst needs to look at other photographs of the case, such as the photograph in figure 10 to confirm the “no” value. From figure 8 through figure 10, the analyst can confirm that the shoulder has no rumble strips (variable 6). They also allow the analyst to confirm that there is no drop-off between the roadway and the shoulder.

Figure 10. Photo. Case No. 2005079486822 look back from point of impact.

Regarding characteristics on the roadway, figure 8 through figure 10 indicate the following values for the listed variables:

- Pavement marking quality: Asphalt (9).
- Roadway pavement type: Visible (10).

Regarding characteristics of the barrier, figure 8 through figure 10 indicate the following values for the listed variables:

- Barrier type: Jersey barrier (16).
- Barrier end treatment type: Outside the road segment of analysis (17).
- Barrier post material: Not applicable (i.e., Jersey barrier) (18).
- Barrier block-out material: Not applicable (i.e., Jersey barrier) (19).
- Barrier conditions: Breakage of barrier face (30).

It is important to note that variables 18 and 19 only apply to guardrails such as aesthetic timber barrier/wood guardrail, median barrier steel guardrail, Thrie beam, Thrie beam strong post, W-beam strong post, W-beam weak post, weak post box beam, and weathering steel (Corten®) guardrail. Variable 17 has a value of "outside the road segment of analysis" in this example because the crash did not happen at the end of a barrier.

An important question to ask is whether the vehicle had a hit along the barrier or at its end. This is answered through the photographs and allows determining the value for the location of crash with respect to the barrier. A similar variable is "location of crash with respect to guardrail." This variable only looks at those barriers that are guardrails. In this specific example, those two variables have the following values:

- Location of crash with respect to barrier: Along the barrier (20).

- Location of crash with respect to guardrail: No guardrail involved (21).

Finally, the analyst should consider if there is information in the photographs that provides values for the following variables: ground to barrier face, measurement rods; vertical barrier face, measurement rods; horizontal damage barrier face, measurement rods; and damage height from ground, measurement rods. In the case analyzed in this example, there were no photographs that provide an estimate for these measurements. In some few cases, the people in charge of collecting the data put a rod next to the scene of the crash. A case with this information is provided in the subsection "Challenging Aspects."

Examples of Other Road Elements Presented in the Crash Cases

This section presents the original motivation for photographic data extraction feasibility and pilot studies with examples of different road elements. These road elements include the variables barrier type and barrier end treatment type. The analysts relied on a photograph catalog (shown in appendix A) to identify these road elements. Table 7 presents the road element for each example, while figure 11 through figure 16 show the corresponding photographs.

Table 7. Identification of road elements in some cases.

Case No.	Barrier Type Element	Barrier End Treatment Type Element
2005049602183	W-beam strong post	Energy absorbing
2005049602403	High-tension cable guardrail systems	Outside the road segment of analysis
2005012696122	Thrie beam strong post	Non-energy absorbing (slotted rail terminal)
2005082626081	W-beam strong post	Impact attenuators

Figure 11. Photo. Case No. 2005049602183 post-crash W-beam strong post (left) contrasted with comparative catalog image (right).(4,14)

Figure 12. Photo. Case No. 2005049602183 post-crash W-beam strong post highlighting energy absorbing end treatment.[4,14]

Figure 13. Photo. Case No. 2005049602403 post-crash high-tension cable guardrail systems (left) contrasted with comparative catalog image (right).[4,15]

Figure 14. Photo. Case No. 2005012696122 post-crash Thrie beam strong post (left) contrasted with comparative catalog image (right).[4,16]

Figure 15. Photo. Case No. 2005012696122 post-crash Thrie beam strong post (left) highlighting non-energy absorbing slotted rail terminal contrasted with comparative catalog image (right).[4,14]

Figure 16. Photo. Case No. 2005082626081 post-crash impact attenuator (left) in advance of W-beam strong post (center) contrasted with comparative catalog image (right).[4,14]

Challenging Aspects

In response to colleagues studying pavement performance issues, this study was extended to identify variables related to pavement properties and contamination (see table 6). A pavement pilot study was initiated within the photographic data extraction pilot study. One of these variables was the macrotexture (11) of the pavement. The objective of this variable was to identify whether the road surface was in optimal condition (case in which the variable would have a "no" value) or whether it had features on the surface that highlighted some type of macrotexture. Figure 17 through figure 21 present photographs used to identify this variable. Experts in the field determined that these pictures are not of high enough quality to establish with assurance if the road surfaces present an identifiable macrotexture. For this reason, this variable was dropped and does not appear in the statistics of this study.

Figure 17. Photo. Photograph 1 used for identifying macrotexture in Case No. 2005012695244.

Figure 18. Photo. Photograph 2 used for identifying macrotexture in Case No. 2005012695244.

Figure 19. Photo. Photograph 3 used for identifying macrotexture in Case No. 2005012695244.

Figure 20. Photo. Photograph 1 used for identifying macrotexture in Case No. 2007075702347.

Figure 21. Photo. Photograph 2 used for identifying macrotexture in Case No. 2007075702347.

Another variable that was included at the beginning of the study was rutting (variable 12). Figure 22 shows a probable case of rutting. After submitting this photograph to experts in the field, it was determined that it could not be used to determine rutting. As a result, this variable was dropped from the study. Due to similar reasons, the following other variables were dropped: paved shoulder contamination (8), pavement contamination (13), and gross pavement irregularities (14).

Figure 22. Photo. Photograph used for identifying rutting in Case No. 2007075702347.

Finally, obtaining values for the following variables was challenging: ground to barrier face, measurement rods; vertical barrier face, measurement rods; horizontal damage barrier face, measurement rods; and damage height from ground, measurement rods. In very few cases, such as the one shown in figure 23, these measurements were possible to obtain.

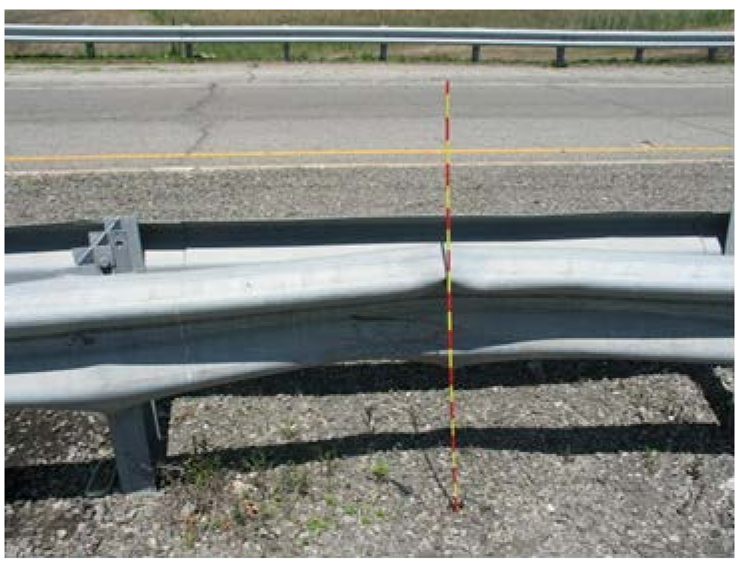


Figure 23. Photo. Photograph from Case No. 2005073438121 in which measurements were obtained using rods.

DISCUSSION

Although a great deal of new information has been identified through the study of NMVCCS images, several limiting factors must be acknowledged. First, the roadway departure problem comprised over half the crash fatalities.(1) However, the sample size is relatively small for researcher-investigated crashes benefitting from on-scene NMVCCS or near-crash time NASS

CDS photography. FARS, while rich in data, provides limited details. This discussion section considers the data acquired from NMVCCS on-scene photography.

Data Enhancements Sought

The supplementary dataset was envisioned to provide more roadside information than previously coded. The data were expected to have a uniform core of relevant variables and attributes. Finally, a systematic approach was to be devised through the feasibility and pilot studies to streamline data extraction.

Height of Barrier and Damage

The pilot study yielded unexpected results. Several roadside elements were highlighted by measurement rods that were originally used to take vehicle damage measurements for NASS CDS cases. NMVCCS photography protocols did not contemplate the roadside environment, as did LBSS in the early 1980s, with only known NASS classification of variables using a limited number of attributes. In the model of the NCHRP studies, all photographic data were considered.(8–10) The measurement rods, when available, provided insight into the height of the barrier from the ground, the height from where the measurement rods were placed in the photograph to damaged barrier location, and, occasionally, the width of the damage. It was found that most roadside element photographs were absent of measurement rods, leaving very small cell sizes from which to draw conclusions. With added sample size, the benefit would involve assessing variations in barrier height owing to maintenance and vehicle compatibility with barriers.

Damage Location

Another critical feature involved locating the precise damage location(s) along the roadside element. Damage and injury patterns might vary depending on impact with the end terminal, post, or length of need (i.e., adequate distance in advance of the hazard to keep the vehicle safe from impact and redirected back on the roadway). Even amidst the small sample sizes, this was deemed a potentially important data element.

Shoulder Width

Although the data acquisition was meant to be fact-based and require no estimation, pavement engineers suggested that estimating the shoulder width might be useful with an assessment of pavement type and quality. While the photographs carried insufficient resolution to provide the details required for pavement assessments, the shoulder width estimation was retained. The photographic data coder estimated in increments of 4 ft. This may be an effective qualitative means for understanding the roadway departure and vehicle trajectory before reaching final rest.

Roadside Element Classification

The purpose of the feasibility study was to assess the viability of viewing photographs, confirming the installed hardware coded in a crashworthiness dataset, and supplementing the component materials. A catalog of existing barrier technologies was compiled for easy comparison by the data coder. Furthermore, the type of barrier, its post, and end treatment were identified based on the catalog of photographs. This was intended to provide information missing since the LBSS performed by NHTSA for FHWA. Since the LBSS predated the electronic data releases, it has been lost to paper archives and potentially of minimal relevance owing to the changes in vehicle fleet over the past 30 years.

Through iterations of photographic review, refinements proposed by three reviewers, and inclusion of supplemental data sources, a labor-intensive process has been improved by developing a review methodology. With improvements in data capture, some of the human intervention can be replaced by digital identification of roadside elements. Currently, the military has partnered with reality television to improve the processing and screening of drone footage, which might benefit the identification of roadside elements in still and video image and facilitate extraction of this data into an analysis ready data format. Several more iterations of human reviews will be required to determine the conditions, such as lighting, clarity, and element types, under which these digital identifications might take place.

Future Refinements

These additional insights will be useful to modelers filling important gaps of understanding as well as to roadway designers in understanding how the vehicle and occupant interact with the roadside environment. The previously mentioned variables are a small subset of the data acquired from the photographic review and deemed important to the pilot study on roadway departure. In the way that NMVCCS was originally intended to serve as a behavioral crash causation dataset and not envisioned to provide valuable roadside information, other data elements extracted from the photographs might be useful to other users. For this reason, appendix B outlines the data collected and the relevant attributes, and appendix C contains the full data extraction.

CHAPTER 4: FUTURE CONSIDERATION AND PILOT STUDY SUMMARIZATION

Based on the precedent of successful NCHRP studies, the review of photographs was deemed an appropriate means of extending the current understanding of roadway departure crashes. The results of using crashworthiness data collected for different purposes were mixed and exceeded expectations. Presently, first event roadside element crashes have been reviewed, and the photographic data have been extracted. A proposed outline of the remaining datasets with their perceived impact and limitations has been compiled in the following sections.

FUTURE REVIEWS: IMPACT AND LIMITATIONS

Subsequent iterations of this study will continue to focus on FARS, NASS CDS, and NMVCCS. The census quality of FARS will provide many panoramic photographs from which to extract data but which are less relevant to the crash event. NASS CDS will provide near crash time photographic evidence predicated upon the strength of the photography and identification of salient roadside elements. Finally, NMVCCS photography has yielded the highest-quality and most crash-relevant information.

FARS Crashes

In deference to the on-scene crash photographs, the identified FARS crashes were assessed and set aside during the pilot study. During the next phase, it is envisioned that panoramic view software will be consulted to provide an image of the crash scene at a temporally discontinuous time with the crash. The benefit will be to understand roadside element placement and potential crash trajectory. The type of roadside element will be assumed to be static, with damaged elements being replaced with the same type of technology. The limitation exists in confirming the precise location of impact and forfeiting important post-crash damage condition data.

NASS CDS Dataset

This dataset is caught in the middle of FARS and NMVCCS, with rich data but scant roadside element detail, captured weeks after the crash scene has been cleared. NASS CDS crashes after 2008 will be consulted by applying the NMVCCS filter for first event roadside element impacts. This will be the surrogate for the FARS data definition of roadway departure. As the precise crash location will have been photographed by the researcher, location identification has been assured. As this will have been near-crash time photography, many damage clues may have disappeared or the element might have been replaced by the time of investigation. Although this database may be able to provide information on roadside element type and its components, more subtle measurements and crash evidence might be lost to the meteorological vagaries of the area.

NMVCCS Dataset

Beyond the first event roadside element impacts, many secondary events involving roadside elements exist. The rationale for excluding secondary impacts is that the most crash sensors were designed as first event technologies and are disabled upon first impact, rendering the technology inactive, as it cannot be triggered in the absence of a functioning sensor. Premature deployment might have been with good reason; however, graduated technologies deploying in stages such as airbags would have the most compatibility with reviewing subsequent roadside element events. For purposes of enlarging the dataset, additional secondary event crashes will be reviewed to determine whether they provide insight into to the roadway departure problem.

Data Collection via Photographic Reviews

Based on the success of the pilot study, the Highway Safety Information System Laboratory may be asked to supply additional graduate student support. These students are preparing for graduate degrees in civil engineering, generally specializing in roadway transportation. This skill set makes them aware of design issues and capable of providing insights into matching the case photographs to the catalog. Even with the most accomplished engineering student, human error, limited hardware experience, and photographic clarity might affect proper codification. For this reason, the supplemental dataset produced in the pilot study will be reviewed by subject-matter experts.

As new students will be undertaking this task and learning the data extraction methodology, they will be subjected to a learning curve, similar to the one encumbering the early pilot study data acquisition. Student adaptation was not found to be an impediment to the study.

Future Technologies

As mentioned previously, adoption of digital data capture is one goal for this project. As a result, results of the FHWA EAR Program are being monitored for information exchange.

Planned Future Activities

Planned future activities include the following:

- Submit supplemental dataset produced in pilot study to subject-matter expert review.
- Codify geographical locations from FARS cases, 2004 to the present, using panoramic view software.
- Codify NASS CDS first event roadside element impact crashes.
- Identify applicable NMVCCS secondary roadside element impact crashes.
- Promote the need for more on-scene data collection.

PILOT STUDY SUMMARIZATION

Photographic extraction was used to understand the composition and placement of roadway elements. As the feasibility study progressed, more elements were found to be extractible from the photographs. Similarly, as the pilot study progressed, extended roadway data were collected beyond the realm of safety.

Findings of the Photographic Data Extraction Feasibility Study

The value of the data extraction pilot study was marketed to various stakeholders by means of committee briefings, working papers, and conference publications. The pilot study also sought to highlight the value of on-scene crash photography. Within this publication, the pilot study identification of candidate crashes and the filtering methodology was discussed. The crashes deemed suitable for subsequent review were classified with respect to data extraction value.

Findings of the Photographic Data Extraction Pilot Study To Date

The development of the supplementary dataset began with the pilot study. Reviewing NMVCCS crash scene photographs, the variables and attributes were refined and augmented. It is understood that an on-scene data collector completely versed in roadside element design, placement, and construction would be the best data compiler. However, this would be cost prohibitive, and uniformity would vary. As a result, a photographic review model was adopted.

Summary statistics were prepared that illustrated the unexpected types of information available from photographic review and highlighted sample size issues. The extracted data are expected to benefit modelers in understanding the vehicle interactions with the roadside beyond the information acquired to date from vehicle sensors, which are generally disabled after the first off-road crash event.

Recommendations for the Future of the Photographic Data Extraction Efforts

In addition to the cases reviewed in the pilot study, additional subsequent event NMVCCS crashes as well as FARS and CDS crashes have been identified for subsequent review. The methodology will vary for temporally discontinuous images, but the basic identifying information should remain constant. Issues of damage will not be assessed, as damage cannot be tied conclusively to the reviewed crash. Consideration will also be given to the synthesis of data for on-scene, near crash time, and temporally discontinuous crashes. Finally, continued encouragement will be given to data compiling organizations to revive on-scene crash data collection.

APPENDIX A: PHOTOGRAPHIC CATALOG OF ROADSIDE ELEMENTS

This appendix presents the photographs that were used as a reference when classifying two types of roadside elements: barrier type and barrier end treatment type.

Figure 24 through figure 48 present the different types of barriers that were used as a reference for the variable barrier type. Each type corresponds to one attribute in the variable. Other attributes used to describe this variable were no barrier compromised, other: specify, indistinguishable from photos, and unknown location of first barrier.

Figure 24. Photo. Barrier type 1—aesthetic timber barrier/wood guardrail.[17]

Figure 25. Photo. Second image of barrier type 1—aesthetic timber barrier/wood guardrail.[18]

Figure 26. Photo. Barrier type 2—box beam.[19]

Figure 27. Photo. Barrier type 3—bridge rail.[20]

Figure 28. Photo. Second image of barrier type 3—bridge rail.[20]

Figure 29. Photo. Third image of barrier type 3—bridge rail.[20]

Figure 30. Illustration. Barrier type 4—constant slope barrier.[20]

Figure 31. Photo. Barrier type 5—F-shaped barrier.[20]

Barrier type 6 is a GM® barrier shape. An image for this barrier shape was not available for the publication but can be viewed with an online search.

Figure 32. Photo. Barrier type 7—high-tension cable guardrail system.[15]

Figure 33. Photo. Barrier type 8—Jersey barrier.[20]

Figure 34. Photo. Second image of barrier type 8—Jersey barrier.[20]

Figure 35. Photo. Barrier type 9—low-tension cable guardrail.[21]

Figure 36. Photo. Barrier type 10—median barrier steel guardrail.[15]

Figure 37. Photo. Barrier type 11—median strip.[22]

Figure 38. Photo. Barrier type 12—steel-backed timber guardrail.[17]

Figure 39. Photo. Barrier type 13—Thrie beam.[20]

Figure 40. Photo. Barrier type 14—Thrie beam strong post.[16]

Figure 41. Photo. Barrier type 15—W-beam strong post.(14)

Figure 42. Photo. Barrier type 16—W-beam weak post.(14)

Figure 43. Photo. Barrier type 17—weak post box beam.(23)

Figure 44. Photo. Barrier type 18—weathering steel (Corten®) guardrail.(14)

Figure 45. Photo. Barrier type 19—impact attenuator.(4)

Figure 46. Photo. Second image of barrier type 19—impact attenuator.(4)

Figure 47. Photo. Third image of barrier type 19—impact attenuator.(24)

Figure 48. Photo. Fourth image of barrier type 19—impact attenuator.[4]

Figure 49 through figure 58 present the different types of treatments on the barrier ends that were used as a reference for the variable "barrier end treatment type." Each treatment corresponds to one attribute in the variable. Other attributes used to describe this variable were outside the road segment of analysis, other, and indistinguishable.

Figure 49. Photo. Barrier end treatment type 1—bull nose end treatment.[25]

Figure 50. Photo. Barrier end treatment type 2—guardrail bridge attachment.[14]

Figure 51. Photo. Barrier end treatment type 3—rock fence.(26)

Figure 52. Photo. Barrier end treatment type 4—rounded terminal buffer ("question mark").(14)

Barrier end treatment type 5 was SGT (SKT 350) types I, II, and III, HBA. An image for this barrier end treatment was not available for the publication but can be viewed with an online search.

Figure 53. Photo. Barrier end treatment type 6— "turndown" roll-over end section.(14)

Figure 54. Photo. Barrier end treatment type 7—terminal end sections (boxing glove).[14]

Figure 55. Photo. Barrier end treatment type 8—Thrie beam terminal connector shoe ("end shoe").[20]

Barrier end treatment type 9 was a trail end guardrail section. An image for this barrier shape was not available for the publication but can be viewed with an online search.

Figure 56. Photo. Barrier end treatment type 10—W-beam terminal connector shoe.[14]

Barrier end treatment type 11 was a Jersey barrier end treatment type F. An image for this barrier shape was not available for the publication but can be viewed with an online search.

Figure 57. Photo. Barrier end treatment type 12—impact attenuators.[27]

Figure 58. Photo. Barrier end treatment type 12—temporary impact attenuators.[4]

APPENDIX B: DATA EXTRACTION SPREADSHEET

This appendix presents the spreadsheet that was used to extract the data. The spreadsheet is shown in figure 59 and figure 60. The figures allow researchers to determine which variables had a limited set of attributes and which ones were not restricted to a set of attributes.

As observed in the figures, each color represents the part of the roadway that is being described. In figure 59, the seven center orange columns concern the shoulder, and the six columns in white (shown in bottom columns) correspond to the roadway. In figure 60, the 12 columns in purple (seven columns in top columns, five columns in center graphic) correspond to the barrier, the column in teal (figure 59, top column) corresponds to the precipitation, and the remaining columns in white (figure 60, bottom columns) correspond to additional information.

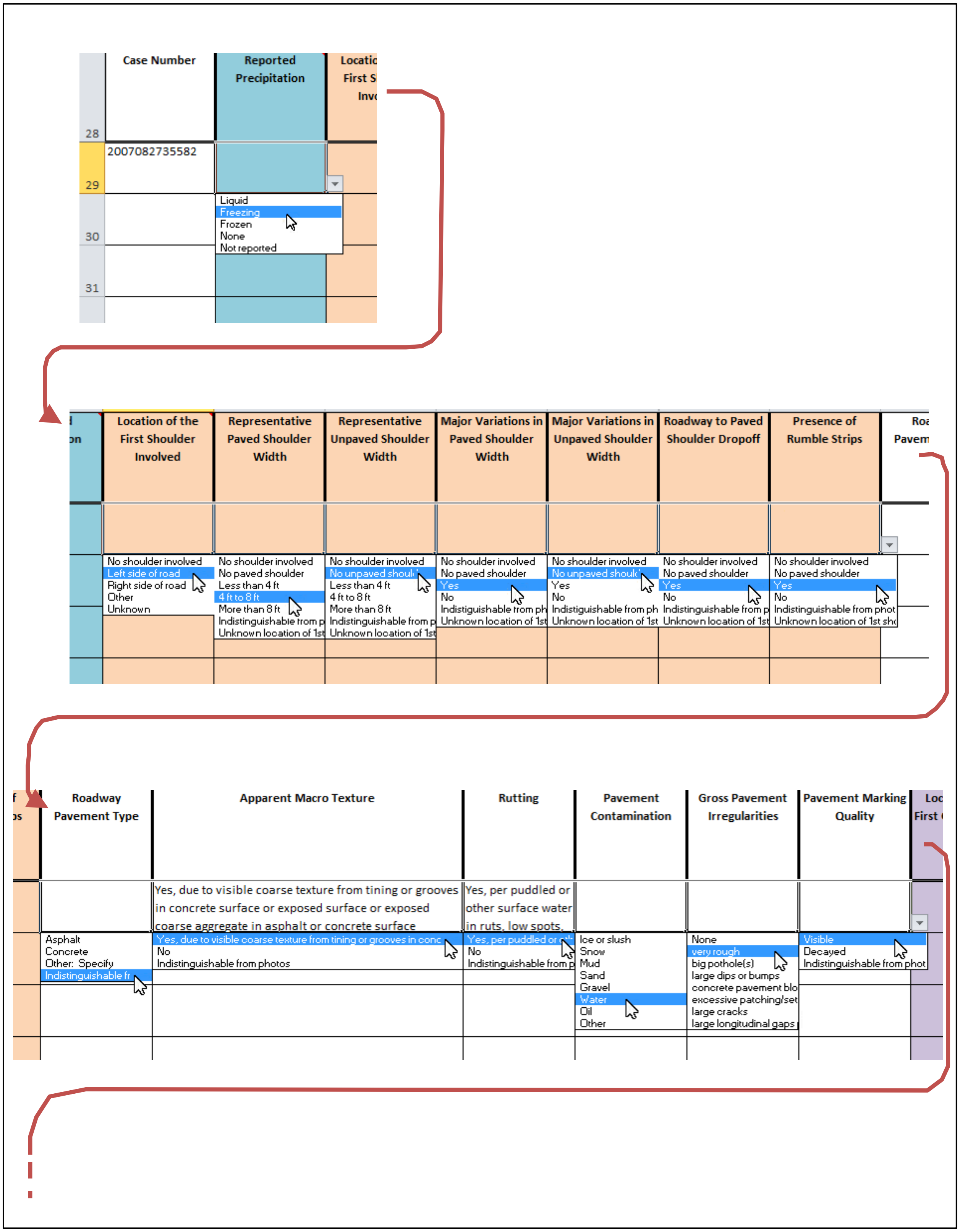


Figure 59. Illustration. Spreadsheet employed for data extraction (first 15 columns).

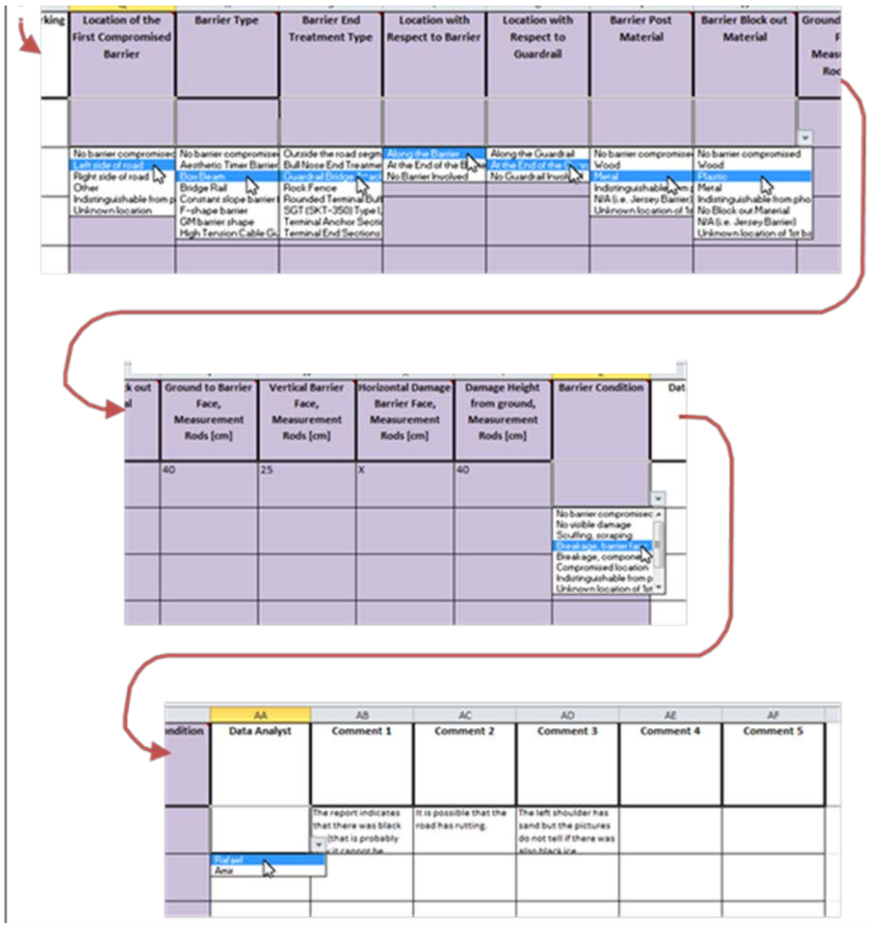


Figure 60. Illustration. Spreadsheet employed for data extraction (last 18 columns).

APPENDIX C: COMPLETE SUMMARY STATISTICS

This appendix presents all the attributes found in the data extraction process, as seen in table 8 through table 25. Due to its completeness, this appendix presents only the number of attributes and their percentage for each of the variables. Some of these values were already presented in the "Descriptive Summary Statistics" section.

Table 8. Reported precipitation.

Attribute	Count	Percent
Liquid	63	16.3
Freezing	0	0.0
Frozen	20	5.2
None	278	71.8
Not reported	26	6.7

Table 9. Location of the first shoulder involved.

Attribute	Count	Percent
No shoulder involved	7	1.8
Left side of road	229	59.2
Right side of road	148	38.2
Other	3	0.8
Unknown	0	0.0

Table 10. Representative paved shoulder width.

Attribute	Count	Percent
No shoulder involved	8	2.1
No paved shoulder	21	5.4
Less than 4 ft	104	26.9
4 to 8 ft	98	25.3
More than 8 ft	140	36.2
Indistinguishable from photos	16	4.1
Unknown location of first shoulder involved	0	0.0

Table 11. Representative unpaved shoulder width.

Attribute	Count	Percent
No shoulder involved	8	2.1
No unpaved shoulder	285	73.6
Less than 4 ft	54	14.0
4 to 8 ft	13	3.4
More than 8 ft	13	3.4
Indistinguishable from photos	14	3.6
Unknown location of first shoulder involved	0	0.0

Table 12. Major variations in paved shoulder width.

Attribute	Count	Percent
No shoulder involved	9	2.3
No paved shoulder	19	4.9
Yes	39	10.1
No	303	78.3
Indistinguishable from photos or other sources	17	4.4
Unknown location of first shoulder involved	0	0.0

Table 13. Major variations in unpaved shoulder width.

Attribute	Count	Percent
No shoulder involved	8	2.1
No unpaved shoulder	274	70.8
Yes	34	8.8
No	53	13.7
Indistinguishable from photos or other sources	18	4.7
Unknown location of first shoulder involved	0	0.0

Table 14. Roadway to paved shoulder drop-off.

Attribute	Count	Percent
No shoulder involved	9	2.3
No paved shoulder	19	4.9
Yes	72	18.6
No	248	64.1
Indistinguishable from photos	39	10.1
Unknown location of first shoulder involved	0	0.0

Table 15. Presence of rumble strips.

Attribute	Count	Percent
No shoulder involved	7	1.8
No paved shoulder	15	3.9
Yes	76	19.6
No	260	67.2
Indistinguishable from photos	29	7.5
Unknown location of first shoulder involved	0	0.0

Table 16. Roadway pavement type.

Attribute	Count	Percent
Asphalt	268	69.3
Concrete	104	26.9
Other: specify	6	1.6
Indistinguishable from photos	9	2.3

Table 17. Pavement marking quality.

Attribute	Count	Percent
Visible	375	96.9
Decayed	8	2.1
Indistinguishable from photos	4	1.0

Table 18. Location of the first compromised barrier.

Attribute	Count	Percent
No barrier compromised	1	0.3
Left side of road	232	59.9
Right side of road	146	37.7
Other	8	2.1
Indistinguishable from photos	0	0.0
Unknown location	0	0.0

Table 19. Barrier type.

Attribute	Count	Percent
No barrier compromised	1	0.3
Aesthetic timber barrier/wood guardrail	1	0.3
Box beam	3	0.8
Bridge rail	0	0.0
Constant slope barrier (UK equivalent concrete step barrier)	1	0.3
F-shaped barrier	0	0.0
GM® barrier shape	2	0.5
High-tension cable guardrail systems	4	1.0
Impact attenuators	8	2.1
Jersey barrier	190	49.1
Low-tension cable guardrail	1	0.3
Median barrier steel guardrail	0	0.0
Median strip	1	0.3
Steel-backed timber guardrail	0	0.0
Temporary impact attenuators	0	0.0
Thrie beam	0	0.0
Thrie beam strong post	15	3.9
Water- and sand-filled barriers	1	0.3
W-beam strong post	127	32.8
W-beam weak post	6	6
Weak post box beam	0	0
Weathering steel (Corten®) guardrail	0	0
Other: specify	21	21
Indistinguishable from photos	5	5
Unknown location of first barrier compromised	0	0

Table 20. Barrier end treatment type.

Attribute	Count	Percent
Outside the road segment of analysis	270	69.8
Bull nose end treatment	2	0.5
Guardrail bridge attachment	8	2.1
Rock fence	0	0.0
Rounded terminal buffer (“question mark”)	14	3.6
SGT (SKT-350) types I, II, and III, HBA	21	5.4
TAS or “turndown” roll-over end section	3	0.8
Terminal end sections (boxing glove)	10	2.6
Thrie beam terminal connector shoe (“end shoe”)	1	0.3
Trail end guardrail sections	4	1.0
W-beam terminal connector shoe	2	0.5
Jersey barrier end treatment type F	4	1.0
Impact attenuators	11	2.8
Other	22	5.7
Indistinguishable from photos	15	3.9

Table 21. Barrier post material.

Attribute	Count	Percent
No barrier compromised	1	0.3
Wood	69	17.8
Metal	91	23.5
Indistinguishable from photos	9	2.3
Not applicable (i.e., Jersey barrier)	217	56.1
Unknown location of first barrier compromised	0	0.0

Table 22. Barrier block-out material.

Attribute	Count	Percent
No barrier compromised	2	0.5
Wood	83	21.4
Plastic	12	3.1
Metal	29	7.5
Indistinguishable from photos	29	7.5
No block-out material	7	1.8
Not applicable (i.e., Jersey barrier)	224	57.9
Unknown location of first barrier compromised	0	0.0
None	1	0.3

Table 23. Location of crash with respect to barrier.

Attribute	Count	Percent
Along the barrier	270	69.8
At the end of the barrier	116	30.0
No barrier involved	1	0.3

Table 24. Location of crash with respect to guardrail.

Attribute	Count	Percent
Along the guardrail	254	65.6
At the end of the guardrail	95	24.5
No guardrail involved	38	9.8

Table 25. Barrier condition.

Attribute	Count	Percent
No barrier compromised	2	0.5
No visible damage	23	5.9
Scuffing, scraping	174	45.0
Breakage, barrier face	74	19.1
Breakage, component	35	9.0
Compromised location	35	6.5
Indistinguishable from photos	54	14.0
Unknown location of first barrier compromised	0	0.0
Unknown since photos were taken before crash	0	0.0
Unknown since photos were taken more than 1 month after crash	0	0.0

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The original map image in figure 1 was created using Google Earth®. Google, Inc. owns the copyright of the original image. As a part of this study, the Google Earth® image was modified with a photo overlay depicting a possible car rollover crash trajectory.

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