APPENDIX D

IN-SERVICE PERFORMANCE EVALUATION PROCEDURES MANUAL

NCHRP Project 22-13(2)

IN-SERVICE PERFORMANCE EVALUATION PROCEDURES MANUAL

CONTRACTOR'S FINAL DRAFT

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CHAPTER ONE

INTRODUCTION

While there is almost universal agreement on the importance of in-service performance evaluations (ISPEs) of roadside safety appurtenances, the process that should be used has never been formalized. The purpose of this manual is to describe the process and procedures to be used for evaluating the performance of a roadside safety feature. These recommendations have been developed largely by examining prior in-service evaluations and identifying characteristics and techniques that either did or did not result in a meaningful examination of the performance of an appurtenance.

These procedures were developed with the assumption that in-service evaluation data collection will normally be performed by DOT maintenance workers with support from DOT headquarters engineers, researchers, and consultants. These procedures are *not* intended to be in-depth collision reconstruction activities. Reconstruction implies a greater level of detail and sophistication that can only be achieved using highly specialized and trained reconstructionists. While in-depth reconstructions and investigations are useful evaluation tools for roadside hardware research and development, they generally demand greater resources than a typical state could devote to the long-term systematic study of a specific roadside hardware system. These procedures, on the other hand, are intended to be simple, straightforward, routine and therefore easily implementable by any highway professional with basic technical skills. The objective of an in-service performance evaluation, as described herein, is to observe, measure and record the performance of the hardware in a wide variety of circumstances, not to reconstruct a specific collision.

These procedures can be used to perform a specific evaluation of a roadside feature or for continuous monitoring of several types of features. Since a successful ISPE requires a large amount of data, it is most effective when data collection efforts are incorporated into routine maintenance and repair procedures. If data collection is ongoing, the ISPE can be a long-term part of a safety management system. In many states, the maintenance supervisor fills out a one-page form documenting labor and material costs required to repair a barrier. An effective ISPE might require filling out a couple more pages of information that could be forwarded to the group in charge of safety management. Using this data, the effectiveness of roadside hardware could be continuously monitored to detect emerging problems. Such data would provide a valuable database for making decisions about when and what hardware should be upgraded and what hardware should be left alone. On the other hand, a State may have a more specific objective in performing an ISPE. Perhaps the DOT is contemplating upgrading a specific device that has been used in that State for many years. An ISPE can be performed to answer specific questions about the performance of the device. There are, then, many ways to integrate ISPEs into the routine operations of a DOT.

Figure 1 is a flow-chart summarizing the steps involved in performing an ISPE. There are three major phases in the in-service evaluation process: planning and preparation (Chapter 2), data collection (Chapters 3 and 4) and analysis (Chapters 5 and 6). Planning and preparation for an ISPE involves eleven specific steps, as shown in Figure 1, and is described in Chapter 2. Each of the steps in the planning and preparation process is explained in a section in Chapter 2. Data collection procedures are presented in Chapters 3 and 4. Chapter 3 describes the process of obtaining and coding information from official sources like police collision reports or DOT maintenance reports. Chapter 4 presents data collection and measurement procedures for collecting data during field site visits. Methods for analyzing the data are presented in Chapter 5 and methods for storing and quality checking the data are presented in Chapter 6.

Appendix A of this manual is a workbook of forms for use in an ISPE. The forms are included and discussed in the following chapters and are also available on the Internet at http://www.wpi.edu/Academics/Depts/CEE/Roadsafe/ISPE/procedures.html. These forms cover all aspects of planning, performing and analyzing the data from an ISPE. States will, no doubt, want to modify and specialize these forms. They are included here to provide a basis for the development of data collection materials that will be suitable for a broad range of ISPEs.

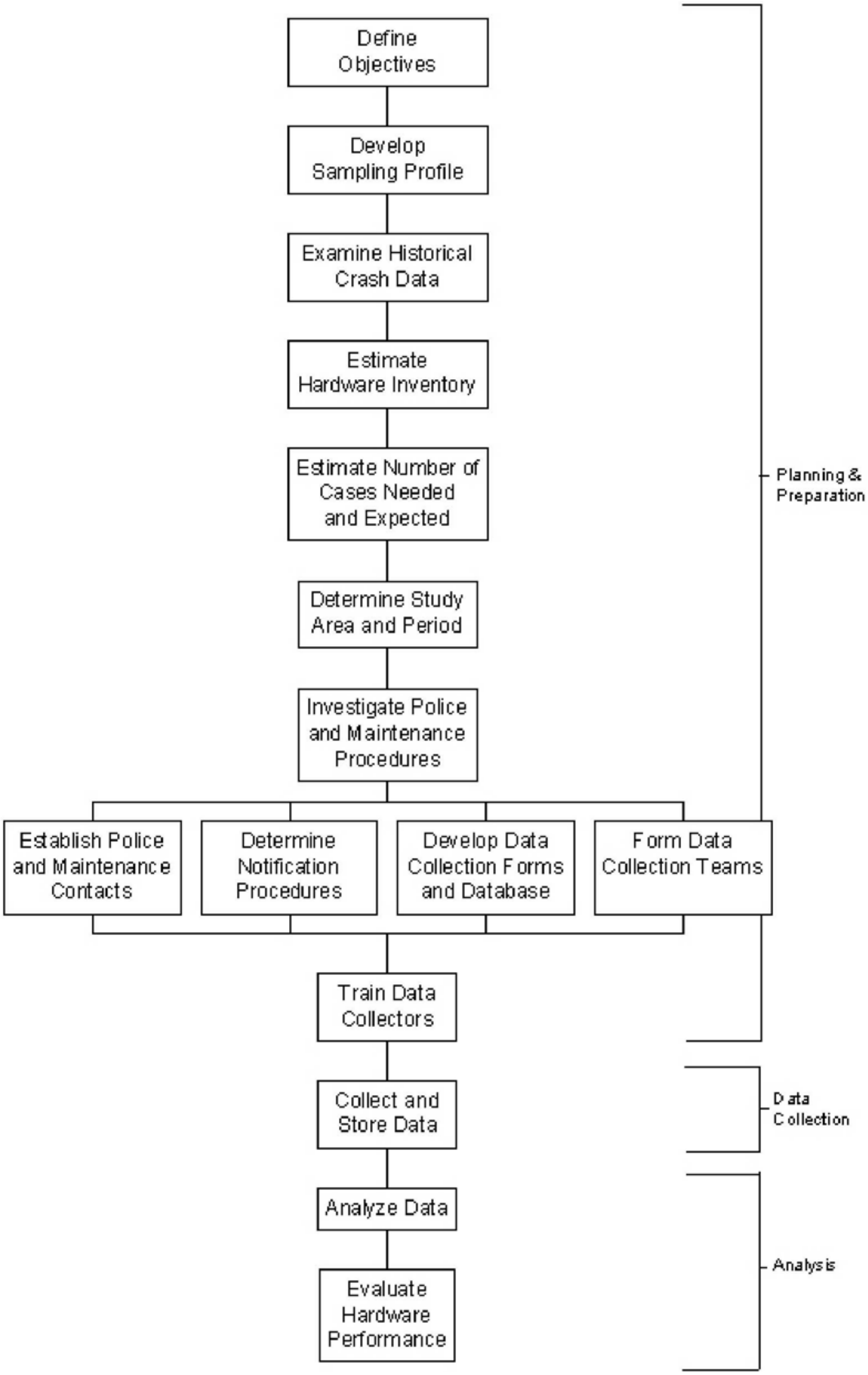


Figure 1. Flow chart of the ISPE process.

The purpose of this manual is to provide the basic procedures and methods for performing an ISPE. Example forms are included to represent the types of data that should be collected. Specific data collection procedures are presented for making specific types of measurements. Calculations of volume and inventory-adjusted collision rates are explained in order to provide a common basis for comparing data among States. This manual is a resource for State DOTs and anyone else interested in performing an ISPE of a roadside feature.

CHAPTER TWO

PLANNING & PREPARATION

PLANNING

A great deal of planning and organizing is required before data collection can begin in an in-service performance evaluation (ISPE) project, as shown in Figure 1 in the previous chapter. Careful planning and realistic expectations will help ensure a successful ISPE project. The “Planning” form in the ISPE Workbook in Appendix A can be used to help in this process. It includes sections for documenting the project objectives and data requirements, developing a sampling profile, estimating the number of collisions that can be expected, and recording police and maintenance personnel contact information. Other useful documents should be attached to this form, such as a map of the study area(s), sample police report, and sample maintenance repair/cost report.

Personnel

An in-service performance evaluation requires the active participation of an evaluation team. A team normally will consist of the following members:

- A principal investigator
- An analyst
- A database manager
- Lead field data collectors
- Field data collectors

Good data starts with well-trained, careful field data collectors. The field procedures discussed in this manual can be easily executed by two people. Each data collection effort is organized into data collection teams. Each team is responsible for a specific geographical area like a State DOT Maintenance District. Each team should have at least two field data collectors that have been trained and are thoroughly familiar with the data collection effort although having three or four trained data collectors provides more flexibility to accommodate other activities. One person in each data collection area should be designated as the lead data collector for that area. This person serves as the main point of contact for the data collection efforts and is responsible for making sure there is always a data collection team available. If the data collection is being performed by DOT maintenance staff, the Maintenance Supervisor in each garage is a good choice for the lead data collector.

Once the data has been collected it must be entered into the electronic database. This may be done by the field data collectors using e-mail or the internet or it may be done by at a central location. A database manager is responsible for building and maintaining the electronic database. The database manager may also be responsible for managing the paper files generated in the field. The paper files contain the original data collection forms, copies of documents like police and maintenance reports, field sketches and photographs of the site. While there are usually several data collection teams there should be only one central database managed by a single database manager. In addition to adding data to the electronic database, the database manager also performs quality control checks on both the hardcopy and electronic data to detect any coding errors or inconsistencies.

The analyst is responsible for analyzing the electronic data as described in Chapter 5. The analyst and the database manager roles can often been accomplished by the same individual since the database manager is most active during the planning and data collection phase whereas the analyst is most active after the data has been collected. Knowledge of statistical methods and database programs is important for both the database manager and the analyst.

The principal investigator is the person in the team who is responsible for the overall coordination of the project. The principal investigator is generally the person who plans the study, makes the arrangements with police and maintenance personnel and answers any questions of objectives and procedures that come up during the data collection. The principal investigator should try to gain a good understanding of the role of the other members of the team. For example, the principal investigator should accompany the field data collectors periodically in order to become familiar with the details of how data is collected and stored. If the principal investigator has interest or skills in managing and analyzing data he or she could also serve as the data manager and the analyst.

The in-service evaluation team can be staffed in a variety of ways. Using State DOT maintenance garage personnel as data collectors is particularly efficient since they are also responsible for the repair of damaged hardware. The team could be selected completely within the DOT or aspects of the data collection could be contracted out. For example, the principal investigator, database manager and analyst might be consultants from a local engineering firm or a research team from a nearby University while the data collection is performed by State personnel. Likewise, the whole in-service evaluation process could be contracted out to an engineering firm or University. While the arrangements can be very flexible, it is important that specific individuals be identified who are responsible for the three main activities: planning and overall project direction, data storage and analysis and field data collection.

Define Evaluation Objectives

A review of in-service evaluations that have been reported in the literature reveals that often in-service evaluation projects encounter difficulties because the designers of the study did not determine in advance the specific objectives. ISPEs can have different focuses and objectives. For example, one project may attempt to find installation and maintenance problems and costs for new devices, while another may be meant to determine the collision performance of an existing installed device (i.e., collision frequency, occupant injury, etc.). The following are some possible quantifiable objectives for an in-service evaluation of a traffic barrier:

- To find the fatal and severe injury collision rate,
- To find the collision rate,
- To find the average installation cost, and
- To find the average repair cost.

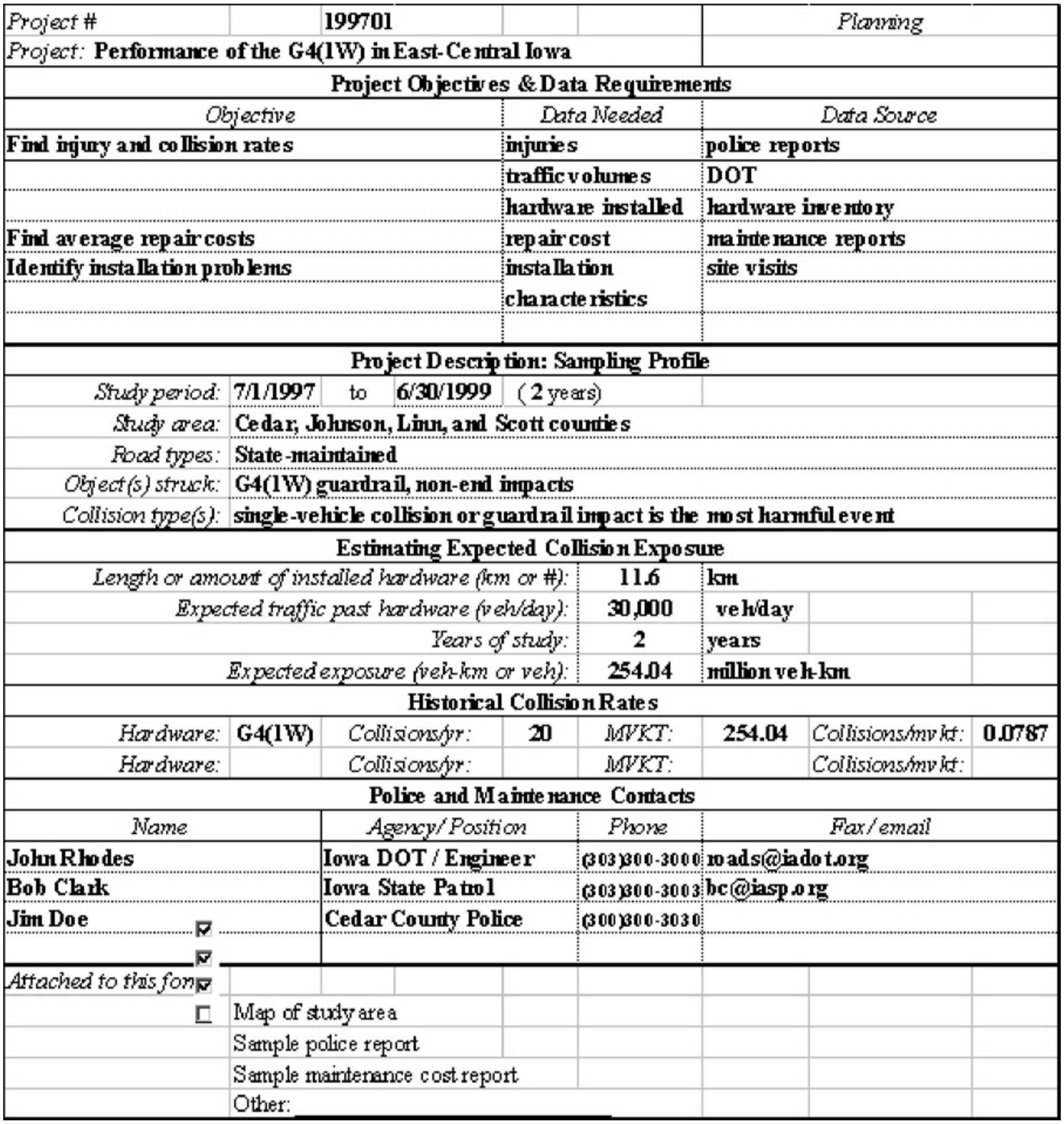
In addition to the quantifiable objectives listed above, there are other equally important but less easily quantified objectives such as identifying:

- Construction and installation problems,
- Maintenance or repair problems,

- Barrier failure mechanisms,
- Collision performance problems, and
- Modifications that would reduce costs or increase efficiency.

All these objectives or any combination may be addressed in an in-service evaluation project. Identifying them early in the project planning is important so that sources of data can be identified that will provide the information needed to meet the objectives. For example, if an analyst is interested in the effect of soil conditions on the failure mechanisms for wood guardrail posts, a source of data characterizing the soil conditions would have to be identified. Clearly such information would not be contained in a police report or a maintenance repair report so the data would have to be collected by investigators in the field.

Figure 2 shows an example of the ISPE planning form for a study performed in Iowa. The title of the study is “Performance of the G4(1W) in East-Central Iowa” as shown in the figure. The first section of the form provides a space to list the objectives. Several objectives are listed including the calculation of collision rates and the calculation of repair costs. Next to each objective, all the types of data required to fulfill the objective are listed. For example, collision severity data, traffic volume data and guardrail inventory data are needed to calculate the collision rates. The possible source of the data is listed next to each data element. For example, collision severity would be collected from the police report and inventory information would be collected from the appropriate Area Engineers. This list of data elements and sources provides a shopping list of data elements and potential sources. The next step is to see if the right kind of information can be obtained from the sources listed.



Project #	**199701**	*Planning*
Project: **Performance of the G4(1W) in East-Central Iowa**		

Project Objectives & Data Requirements

Objective	*Data Needed*	*Data Source*
Find injury and collision rates	**injuries**	**police reports**
	traffic volumes	**DOT**
	hardware installed	**hardware inventory**
Find average repair costs	**repair cost**	**maintenance reports**
Identify installation problems	**installation characteristics**	**site visits**

Project Description: Sampling Profile

Study period:	**7/1/1997**	to	**6/30/1999**	(2 years)
Study area:	**Cedar, Johnson, Linn, and Scott counties**			
Road types:	**State-maintained**			
Object(s) struck:	**G4(1W) guardrail, non-end impacts**			
Collision type(s):	**single-vehicle collision or guardrail impact is the most harmful event**			

Estimating Expected Collision Exposure

Length or amount of installed hardware (km or #):	**11.6**	**km**
Expected traffic past hardware (veh/day):	**30,000**	**veh/day**
Years of study:	**2**	**years**
Expected exposure (veh-km or veh):	**254.04**	**million veh-km**

Historical Collision Rates

Hardware:	**G4(1W)**	*Collisions/yr:*	**20**	*MVKT:*	**254.04**	*Collisions/mvkt:*	**0.0787**
Hardware:		*Collisions/yr:*		*MVKT:*		*Collisions/mvkt:*	

Police and Maintenance Contacts

Name	*Agency/ Position*	*Phone*	*Fax/ email*
John Rhodes	**Iowa DOT / Engineer**	**(303)300-3000**	**roads@iadot.org**
Bob Clark	**Iowa State Patrol**	**(303)300-3003**	**bc@iasp.org**
Jim Doe ☑	**Cedar County Police**	**(300)300-3030**	
☑			

Attached to this forn ☑

☐ Map of study area

Sample police report

Sample maintenance cost report

Other: ____________________

Figure 2. Planning Form.

The most important general-purpose measure of the performance of a device is the collision and injury rate normalized by traffic volume. Table 1 shows the data elements that must be collected to perform such calculations, along with the likely source of that information.

Table 1. Data needed for calculating rates normalized by volume.

	Police Report	**DOT Traffic Data**	**Hardware Inventory**
No. of A+K collisions	X		
No. of B+C collisions	X		
No. of PDO collisions	X		
Traffic volumes		X	
Quantity of hardware			X

If these data are available, the calculations are straightforward. For example, a study area has 1.5 km of roadside G1 cable guardrail with a one-way average annual ADT of 50,000 vpd traveling past the guardrail installations. During one year of monitoring the study area, one A+K collision, eight B+C collisions, and fifty PDO collisions occurred. The yearly rate of injury collisions per vehicle-km traveled past a G1 guardrail could be calculated as:

$$\frac{(1+8)}{(50{,}000vpd \times 365days \times 1.5km)} = 3.29\text{E-}7 \text{ collisions/veh-km} = 0.3288 \text{ collisions/ million veh-km}$$

or in other words, one injury collision occurred for each

$$(50{,}000vpd \text{ x } 365days \text{ x } 1.5km) \div (1 + 8) = 3{,}041{,}667 \text{ veh-km traveled past a G1 guardrail.}$$

Calculating volume and inventory-adjusted rates is very important. Proportions of police-reported collisions (e.g., an occupant is killed or severely injured in 1.5 percent of police-reported collisions in the above example) do not account for differences between States in reporting thresholds or differences in exposure to collisions. Normalizing the number of severe collisions by the traffic volume and quantity of hardware helps to make the calculated rates more transportable. Volume and inventory-adjusted collision rates can be compared across regions and among states because the two biggest factors (e.g., volume and quantity of hardware) have been normalized.

There may, of course, be other factors that make comparisons inappropriate. Geometric characteristics of roadways, for example, may affect the frequency of collisions. If geometric data are available for the sites of the hardware installations, it is useful to consider these effects. Chapter 7 explains how to adjust rates using Accident Modification Factors to account for roadway geometry. Characteristics such as lane width, shoulder width and type, median width, grade, horizontal curvature, and superelevation need to be collected in order to make such adjustments.

Normalizing collision rates by the volume and quantity of hardware and adjusting for the effects of roadway geometry will make the results of the study much more meaningful.

Develop a Sampling Profile

One method for identifying the objectives of the study is to develop a sampling profile that identifies exactly what type of collisions will be investigated. The sampling profile is a list of criteria that each case must meet in order to be included in the in-service evaluation database. It is important to identify the criteria for cases that will be included to avoid unintentionally compromising the database with inconsistently sampled cases. Some prior in-service evaluations have degraded the quality of the database by not following any specific sampling strategy and thereby creating a hodge-podge of cases without statistical importance. The following was the sampling profile for an in-service evaluation of strong-post W-beam guardrails in eastern Iowa:

Period:	1 July 1997 to 30 June 1999,
Location:	Cedar, Johnson, Linn and Scott Counties,
Road types:	State maintained roads,
Object struck:	Non-end impacts with G4(1W) strong-post W-beam guardrail, and
Collision type:	Single-vehicle collisions or collisions where the guardrail impact was the most harmful event.

This information is entered into the planning form as shown in Figure 2.

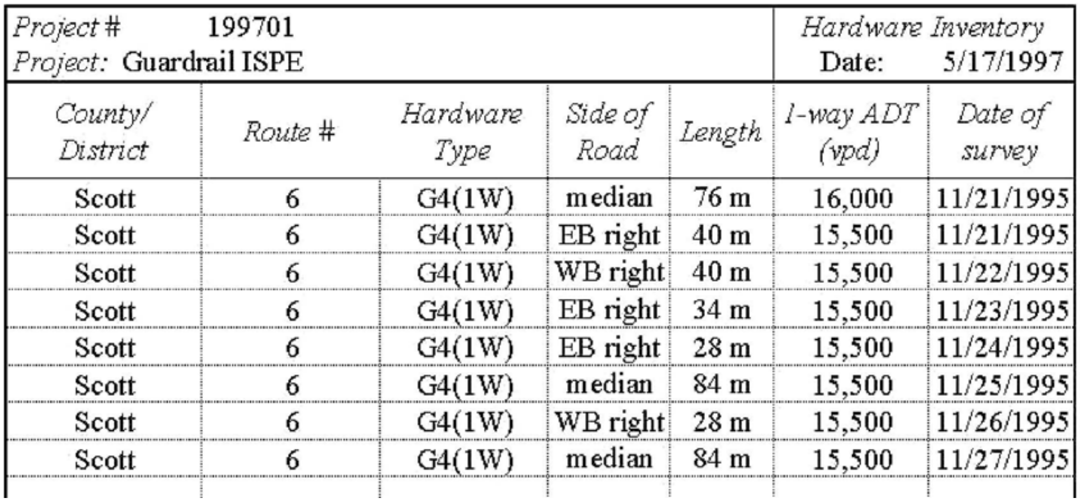
Examine Historical Data

The next step is to obtain actual crash data for the areas that may be included in the ISPE study. The state or local police are generally the sources of this information. From the collision data, the number and severity of collisions involving roadside hardware in the prospective data collection area should be determined over several years. The cases should fit the sampling profile as closely as possible. Often it is difficult to determine what type of traffic barrier was involved from the police reports alone but the values obtained will at least provide an upper bound on the number of police-reported collisions that can be expected in any given period. Traffic volume data are also needed for the same time period as the crash data for calculating exposure-adjusted rates.

Estimate Hardware Inventory

Estimating the quantity of hardware to be studied is an often-neglected aspect of performing in-service evaluations. While calculating severe and major injury (A+K) proportions of all reported collisions is useful, it can be a deceptive measure of performance. For example, assume that 10 Type A guardrail terminals and 100 Type B guardrail terminals are installed on similar roadways with similar operating conditions. After one year of collecting collision data both types of terminals experienced five reported collisions. Only one A+K collision was observed for the Type A terminal whereas two were observed for the Type B terminal. These data might suggest that the Type A terminal is better since its A+K rate is half that of the Type B terminal (leaving aside for the moment the issue of statistical significance and small sample size). If, however, the reason that there were only five collisions on the Type B terminals was that it was very effective in stopping or redirecting vehicles without damage and therefore without a police report being filed, the Type B terminal would be ten times more effective than the Type A terminal. This overly simple example illustrates the importance of being able to estimate the number of opportunities for a collision. The number of opportunities is a function of (1) the amount of roadside hardware in place and (2) the traffic volume passing the hardware.

Few states have roadside hardware inventory information. The emergence of safety management systems may eventually increase the number of states that use inventories to manage their roadside hardware infrastructure but at present states with inventories are the exception rather than the rule. The inventory need not be complicated to be useful. Figure 3 shows a portion of a guardrail inventory from Scott County, Iowa. The inventory simply lists the route, type of guardrail, length, and the date the site was last examined by DOT maintenance personnel. The form used in Figure 3 is provided in the ISPE Workbook.



Project # 199701
Project: Guardrail ISPE

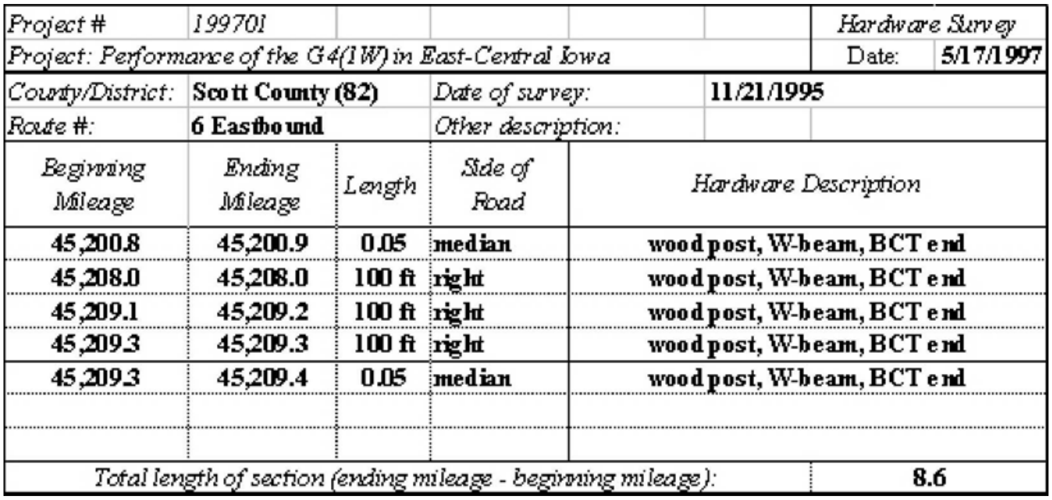
Hardware Inventory
Date: 5/17/1997

County/ District	Route #	Hardware Type	Side of Road	Length	1-way ADT (vpd)	Date of survey
Scott	6	G4(1W)	median	76 m	16,000	11/21/1995
Scott	6	G4(1W)	EB right	40 m	15,500	11/21/1995
Scott	6	G4(1W)	WB right	40 m	15,500	11/22/1995
Scott	6	G4(1W)	EB right	34 m	15,500	11/23/1995
Scott	6	G4(1W)	EB right	28 m	15,500	11/24/1995
Scott	6	G4(1W)	median	84 m	15,500	11/25/1995
Scott	6	G4(1W)	WB right	28 m	15,500	11/26/1995
Scott	6	G4(1W)	median	84 m	15,500	11/27/1995

Figure 3. Partial Hardware Inventory from Scott County, Iowa.

Nearly every state maintains either photologs or videologs of all the state-maintained roadways. In principle these could be viewed by a data collector who could record the type and quantity of roadside hardware by route and milepost. Aside from the obvious tedium of watching them, videologs rarely include a wide enough field of view to show the roadside hardware. The hardware may be visible in the distance but as it gets closer it will move quickly out of the picture frame. Distinguishing subtle differences, for example identifying a MELT versus a BCT or an ET2000 versus a FLEAT, would be quite difficult with videologs. Unless kept up-to-date, video and photologs may also not be a good reflection of the true state of the roadways. While there are problems with using video and photologs to estimate hardware quantities, they may be the only method of obtaining inventory data short of performing an actual inventory.

Another method of obtaining inventory information is to actually perform an inventory prior to the start of data collection. A sample of typical roadways in each functional class can be inventoried to estimate the quantities of traffic barriers in the data collection area. The sample must have a sufficient length of roads in each functional classification to allow for an accurate estimate. An example “drive-by hardware survey” form is shown in Figure 4 and a blank form is included in the appendix.



Project # 199701 Hardware Survey
Project: Performance of the G4(1W) in East-Central Iowa Date: 5/17/1997
County/District: **Scott County (82)** Date of survey: **11/21/1995**
Route #: **6 Eastbound** Other description:

Beginning Mileage	Ending Mileage	Length	Side of Road	Hardware Description
45,200.8	**45,200.9**	**0.05**	**median**	**wood post, W-beam, BCT end**
45,208.0	**45,208.0**	**100 ft**	**right**	**wood post, W-beam, BCT end**
45,209.1	**45,209.2**	**100 ft**	**right**	**wood post, W-beam, BCT end**
45,209.3	**45,209.3**	**100 ft**	**right**	**wood post, W-beam, BCT end**
45,209.3	**45,209.4**	**0.05**	**median**	**wood post, W-beam, BCT end**

Total length of section (ending mileage - beginning mileage): **8.6**

Figure 4. Hardware Survey Form.

The data collector should record the odometer reading at the beginning and ending of each route and the beginning and ending points of each section of guardrail. Short sections (e.g., 150-200 feet) must be estimated since odometers only record distance to the nearest 0.1 mile. The number of posts could also be counted since the nominal post spacing for each type of guardrail is known. The length of the guardrail could then be calculated by multiplying the number of guardrail posts by the nominal post spacing.

After the inventory data is collected, the number of guardrail terminals per km of roadway or the number of km of guardrail per km of roadway can be calculated as shown in Table 2. The quantity of guardrails and terminals can then be estimated by extrapolating the sample data using the total length of roadways in each functional class in the data collection area. While not particularly precise, the method does provide a quick, reasonably accurate measure of the quantity of hardware.

Table 2. Estimated quantity of guardrails and W-beam guardrail terminals on State-maintained roads in a four-county data collection area in Iowa.

Element		Interstate	US/State	Total
Guardrail				
G1	9.8km	9.4km	19.2km	
G4(1W)		12.9km	11.6km	24.5km
Total	22.7km	21.0km	43.7km	
Terminals				
Bullnose end		158	115	273
BCT	510	942	1,452	
W-Beam Anchor		48	190	238
MELT	51	0	51	
Total	609	1,132	1,741	

Estimate the Crash Exposure

Determining the amount of crash exposure needed to obtain useful information is the next critical step in planning an in-service evaluation. Crash exposure is the number of opportunities for a collision with the type of roadside hardware under study, described in terms of vehicle-kilometers traveled past the particular type of hardware. A target number of vehicle-kilometers should be identified that will provide enough data to allow for the calculation of meaningful statistics, proportions and rates. From this number, the geographic size of the data collection area and the length of the data collection period can be determined. Collisions are rare events so data collection areas will tend to be large and the data collection period may be quite long.

Statistical significance refers to well-defined statistical tests that can be performed on a data set to determine if trends apparent in the data are a reflection of physically meaningful differences in the data or random variation typical of any physical phenomena. In general, statistical significance requires a large number of sampled cases. A population refers to all instances of a particular type of event whereas a sample is some smaller subset selected according to some sampling plan. For an in-service evaluation, the data collection sampling technique should attempt to collect *all* collisions that occur in the data collection region that fit the sampling profile during the data collection period. This will result in a database of the population of collisions (e.g., all collisions) fitting the sampling profile. Collecting, for example, all collisions for one year in four Counties in Iowa that involve a strong-post W-beam guardrail would constitute the entire population of such collisions in that region during that time. Conclusions made on the data set would not be subject to potential bias that may occur if all collisions were not collected. For example, if data were collected only for collisions on rural roads, information about the performance on high-volume, high-speed interstates would be lost.

Estimating the exposure that will be needed to meet the objectives of the study is a critical step in the design of a successful in-service evaluation. The following simple example illustrates how the necessary exposure can be estimated using historical collision and traffic data and estimated hardware inventory. Assume that an in-service evaluation is being considered to determine the rate of reported collisions with strong-post W-beam guardrails that result in injuries. Prior collision data indicate that over a period of two years, 47 injury collisions with strong-post W-beam guardrails were reported in the proposed data collection area. The average traffic volume on the road network in the area during that time period was 26,000 veh/day. The hardware inventory shows that an estimated 95 km of strong-post W-beam guardrail was installed in the area. The expected injury collision rate would be calculated as:

$$rate=\frac{47coll.}{(26,000veh/day)(365day/yr)(2yr)(95km)}=0.0267coll./mill.veh-km$$

In other words, the expected rate would be 0.0267 injury collisions per million vehicle-kilometers traveled past a strong-post W-beam guardrail. How many vehicle-kilometers would be required to ensure that the injury collision rate could be calculated with 90 percent confidence to within +/- ten percent? The confidence interval for the injury collision rate, p, can be calculated as follows:

$$confidence[(\hat{p}-w)\leq p\leq(\hat{p}+w)]=(1-\alpha)\times 100\%$$

where $(1-\alpha)$ = the confidence level,

$2w$ = the desired interval width (i.e., precision), and

$\hat{p}$ = a point estimate of the actual rate, p.

If a normal approximation to the binomial distribution is assumed, the half-width *w* can be expressed as a function of the sample size or exposure, *N*:

$$w=\sqrt{Z^{2}_{(1-\alpha/2)}\times\frac{\hat{p}(1-\hat{p})}{N}}$$

where $Z_{(1-\ /2)}$ = percentile of the two-sided standard normal distribution for the given confidence level. $Z_{(1-\ /2)}$ for 90 percent confidence is 1.645.

Solving this expression for *N* yields: $N=\frac{Z^{2}_{(1-\alpha/2)}\hat{p}(1-\hat{p})}{w^{2}}$

For the example discussed above, if the point estimate ($\hat{p}$) of the injury collision rate based on historical data is 0.0267 collisions/million veh-km, the desired confidence level (1-α/2) is 90 percent and the desired precision (*w*) is 10 percent, then the exposure (millions of veh-km traveled) required can be calculated as follows:

$$N_{reqd}=\frac{Z^{2}_{(1-\alpha/2)}\hat{p}(1-\hat{p})}{w^{2}}=\frac{1.645^{2}\times0.0267\times(1-0.0267)}{(0.1\times0.0267)^{2}}=9{,}864 mill.veh-km$$

The hardware inventory in the data collection area would have to be large enough and the data collection period long enough so that at least 9,864 million vehicle-kilometers would be traveled past strong-post W-beam guardrails during the data collection. For an average traffic volume of 26,000 vehicles/day and a data collection period of three years, the data collection area would need to contain 346 kilometers of guardrail. If the analyst is interested in comparing the A+K rate for cases when the impacting vehicle penetrated the rail (i.e., a subset of the original sample) to those where there was no penetration the exposure required would increase.

When comparing two different systems or reporting the results, the analyst must be very careful to keep the precision of the calculated values in mind. For example, if an in-service evaluation of one guardrail terminal indicated that the injury collision rate was 0.0267 collisions/million veh-km and the rate for another terminal was 0.0367 collisions/million veh-km, the difference would only be significant if the calculated precision was better than 0.005, half the difference between the values. If the precision, w, were for example 0.007, the differences between the two terminals could be due to the random variation and the small sample sizes and there would not be a statistically significant difference between the two samples. Such results would only be able to provide anecdotal information about the performance of the traffic barrier and general trends. If the exposure that can be expected in a particular region is not large enough to satisfy the in-service evaluation objectives, the data collection area, data collection period or both must be expanded until the proper balance between the desired precision and the expense of the data collection is achieved.

Determine the Study Period

While ideally the study period should be determined by the amount of exposure required, agencies are often interested in obtaining answers quickly. Unfortunately, in-service evaluations cannot be rushed and if obtaining quick answers is a priority a large data collection area may be required to preserve the validity of the study while minimizing the data collection time. In fact, in-service evaluations are better viewed as continuous processes rather than “one-shot deals” where a quick answer is obtained and then the device is forgotten. Data collection efforts should generally be planned in one-year increments so that the poor-weather months are not unintentionally over or under-sampled. If data collections are planned in full-year increments, then the effect of weather should not bias the sample. This is particularly important in northern states that experience regular snowfall.

Identify the Study Area

Like determining the length of the study, the location and geographical size of the data collection area is determined primarily by the amount of exposure that is required and the area where this exposure can reasonably be expected. As discussed above, average traffic volumes and hardware inventory can be used to calculate yearly collision exposure in a particular geographical area. If the desired exposure is known, the exposure for a variety of geographical areas can be compared to identify the best data collection area. Generally, areas with larger traffic volumes will be best but care must be taken to ensure that roads of a variety of functional classifications are included if the objectives are to be valid across a range of functional classifications.

The upper bound for the area size will be determined by the area that can reasonably be managed from one data collection center. The travel time to the farthest point in the data collection area should, in general, be less than two hours. If the project boundaries have to be extended beyond a two or three hour wide area in order to increase the amount of available data, adding another data collection team may have to be considered. DOT maintenance areas are usually a convenient size for data collection efforts. An ISPE may involve five or six maintenance garages in contiguous areas.

The selection of a data collection area should also take into account the areas covered by local roadway maintenance agencies and police departments. The data collection area should agree with the boundaries that these agencies use as much as possible to simplify notification procedures and reduce errors from mis-communications. If it is possible to concentrate the data collection area such that most of the cases come from just a few police and maintenance agencies, it will be much easier to establish good working relationships with these agencies and receive prompt notification about traffic barrier collisions.

Investigate Police Procedures

There will be several police agencies in most typical data collection areas. State Highway Patrols, County Sheriffs, and City Police Departments all share the responsibility for responding to traffic collisions. Generally, the State Police or State Highway Patrol cover relatively large areas and are responsible for the interstate highways and other major routes in the data collection area where traffic volume is concentrated and as such will often generate the largest number of accident reports.

Most states have a uniform police accident report form that is used by all law enforcement agencies. This greatly simplifies collecting and interpreting data since the same basic set of information will be available on the police accident form regardless of the police agency that collected the data.

Perhaps the most important aspect of setting up a data collection effort is establishing cordial and cooperative relationships with police agencies. Generally maintenance agencies will be interested in the project objectives and will therefore be inclined to be helpful. Police officers, on the other hand, may not fully understand the objectives of the study or even appreciate the value of traffic barriers. Making the accident reports available to data collectors may appear to the desk personnel at the police agency as “busy work” with no real value. Data collectors should attempt to put as little responsibility as possible on the police desk personnel. Most people, including police personnel, will be much more interested in being helpful if the data collectors explain the objectives, purpose and importance of the study. Establishing good working relationships with police and maintenance agencies is a very important first step that will dramatically affect the quality of the data collection effort.

If possible it will usually be most efficient to have a single point of contact in each agency. While the initial contact will probably be with a watch captain or some higher-level police officer, the day-to-day task of filing accident reports is usually the responsibility of a desk officer or clerical worker. This is the person that the data collectors will deal with on a regular basis and any effort focused on developing a good working relationship with that person will be worthwhile. The ISPE team must learn how police reports are processed and who in the agency accomplishes each step. Once an appreciation of the process is obtained, the most efficient method of collecting police reports can be determined.

The following list illustrates the types of questions that should be asked of the police agencies:

- Whom should the data collectors call on a routine basis to find out if any cases of interest have been filed? Could a desk officer call the data collection team if a case of interest occurs? How many desk officers would need to be informed about the project for this to work?

- Can the police department provide copies of the collision report to the data collection team? Are police reports public documents in this State? Are there any restrictions on the use of the collision report?

- Who receives the collision report form after the investigating officer is finished with it?

- Is there a log book of recent or pending collision reports? If so, would data collectors be allowed to look through the log?

- Is there a special accident investigation team in this State (or District)? What types of collisions do they investigate? Could the data collectors contact the accident investigation team directly?

Privacy Issues

Privacy issues should be carefully considered when contemplating the use of police collision reports or, for that matter, maintenance repair reports. Information that would allow the identity of a motorist to be determined should be carefully excluded from the data. Each item to be used on the police report should be considered in the light of privacy and what exactly is needed. For example, police reports always include the date and time of the collision. While it may be useful for the data collector to know how many collisions occurred in, say, April, it is of little relevance to record the specific day of the month. Likewise, it is useful to know whether the collision occurred during the daylight hours or at night, but the precise hour and minute are not generally of value. The important information (e.g., the month, the lighting conditions, etc.) can be captured in a less specific, less intrusive way such that privacy is preserved. Names, addresses, license numbers, license plate numbers, specific dates, and specific times should never be included in the in-service data. They are unlikely to have any particular use in the analysis and including them exposes the data collection unnecessarily to the litigation process.

Even if these precautions are taken, there may be instances where the identity of individuals can be deduced by matching all the characteristics in the database. In designing the data collection forms and database, only information that will be used should be collected.

Investigate Maintenance Procedures

Establishing a good working relationship with maintenance personnel is also essential for developing efficient data collection techniques. As is the case with police agencies, the initial contact with the maintenance agency will probably be with a State DOT area engineer, a County Engineer or a City Engineer. While these people are important in setting up the procedures, the day-to-day tasks of scheduling work, obtaining materials and repairing roadside hardware are usually the responsibility of a maintenance supervisor. Maintenance supervisors will be the best points-of-contact since they are in charge of the daily activities of the maintenance crews. These people also have extensive local knowledge about hardware inventory, high-collision locations, and local procedures that will be very valuable to the data collection team. The team should endeavor to understand the procedures for repairing and maintaining traffic barriers so that the most effective method for notification is determined.

The following list illustrates the types of questions that should be asked of the maintenance agencies:

- How does the maintenance garage find out when hardware needs to be repaired? Do police agencies notify the maintenance garage? Does the maintenance supervisor periodically survey the area?
- Do the work crews maintain work logs? Can these logs be looked at by the data collectors to find dates/locations of guardrail repairs? What is the code for guardrail repair?
- Is a report filed for each guardrail repair? Is the report associated with a police crash report? Is the report a public document that the data collection team can copy? Where does the report go after it is completed at the maintenance garage (e.g., is it submitted to some central office)?
- Are DOT personnel allowed to give copies of police reports to the public (i.e., the data collection team)?
- Are repair costs tracked? What costs are tabulated: labor, equipment, materials, total cost? Are the parts used to repair the barrier tabulated?
- What linear referencing system is used to identify locations (e.g., a milepost system or distance from major intersections)?
- Is there an inventory of roadside hardware? Who maintains the inventory? How often is it updated? Is it available to the data collection team?

If the DOT maintenance garage personnel are involved in the data collection, most of these questions will be obvious. This list does, however, serve to illustrate the important procedures that should be examined while planning the in-service evaluation.

PREPARING DATA COLLECTION MATERIALS

The second major step in performing an in-service performance evaluation is preparing data collection materials and integrating information available from the State DOT and law enforcement agencies into the data collection forms.

In general, two forms will need to be filled out for each collision sampled in an in-service performance evaluation: a general information form (i.e., the general form), and a hardware-specific form that documents the site characteristics, pre-impact installation details, barrier damage and collision results (i.e., the installation and damage form). The general form includes information collected from the police, DOT maintenance garages and DOT traffic data. The installation and damage form requires a visit to the collision site.

Data should be saved in (1) paper files and (2) an electronic database. The purpose of the electronic files is to allow for statistical analysis of the data. The purpose of the paper files is to provide a method for quality control and data checking if questions arise during the analysis. The paper file should contain copies of the police crash report, the DOT maintenance cost recovery report, photographs, sketches, the hand filled-out forms and any other information that might be useful in examining the case. The information on the data collection forms should be entered into an electronic database to facilitate quality control checking and analysis when the data collection is complete. In the sample Microsoft Access database (located at http://www.wpi.edu/Academics/Depts/CEE/Roadsafe/ISPE/procedures.html), data can be entered directly into the electronic version of the data collection forms, which are exactly the same as the paper forms. The data are then automatically stored in various tables in the database.

Data Collection Forms

Regardless of the source of the information (e.g., police reports, maintenance reports, roadway characteristics data or site visits), all the information must be recorded on data collection forms. Data collection forms used in prior in-service evaluations have sometimes been as simple as a single page or as complicated as the 41-page NASS CSS forms.*(1)* The forms should be limited to only information that is likely to be used in the analysis. Ideally, the forms should be brief and simple enough to require only a short time to complete yet long enough to contain all the information needed to assess the performance of the hardware.

The ISPE workbook in Appendix A contains several data collection forms for use in ISPEs of a variety of roadside hardware. A general form such as the one shown in Figure 5 and also included in the appendix should always be used in order to standardize the type of information collected in all in-service evaluation projects. The National Governors Association (NGA) and NHTSA have produced a set of model minimum uniform crash criteria (MMUCC) that they encourage states to use on their police collision reports.*(2)* The following data elements included in the MMUCC may be useful to collect in an in-service evaluation:

Crash Data Elements
Crash Case Identifier
Crash Date and Time
Crash County
Crash City/Place
Crash Roadway Location (Route #, coord. or MP)
Source of Information (police agency)
Weather Condition
Road Surface Condition
Contributing Circumstances, Environment
Contributing Circumstances, Road
Work Zone Related (in or near a workzone, and which part of it)

Vehicle Data Elements
Vehicle Configuration (type)
Total Occupants in Vehicle
Vehicle Authorized Speed Limit
Direction of Travel Before Crash
Point of Impact (on vehicle)
Sequence of Events
Most Damaged Area
Extent of Damage

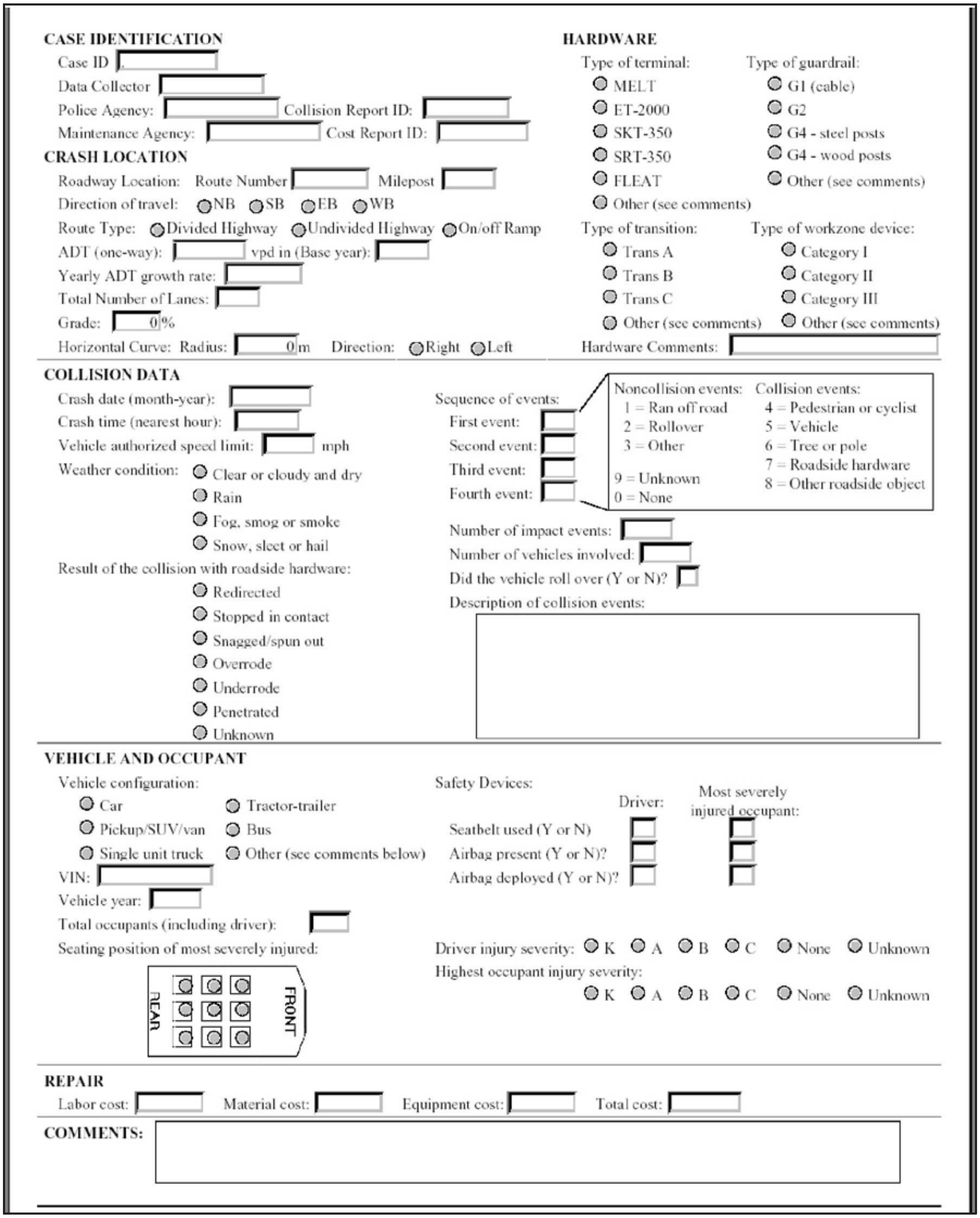
Person Data Elements
Injury Status
Seating Position
Occupant Protection System Use (seatbelts)
Air Bag Deployed
Ejection
Contributing Circumstances, Driver
Driver Condition
Cited

Derived Data Elements
Crash Severity
Number of Vehicles
VIN
Vehicle Model Year
Vehicle Body Type

Linked Data Elements
Horizontal Alignment
Grade
Functional Classification of Highway
Lanes
Annual Average Daily Traffic
Trafficway Description
Average Widths of the Shoulder(s) and Lane(s)
Average Width of Median

Definitions and possible values of these elements are discussed in Appendix B. The sample forms in the Workbook contain many of these data elements, and others could be added as needed.

Several hardware-specific forms in the Workbook capture installation and damage characteristics for various types of hardware. In some cases, additional information may be desired or some data elements may not be collected. The forms may be altered to suit the individual project, as long as the procedures used to collect the data follow the methods discussed in Chapters Three and Four. If a project is being planned to study a hardware device that is not represented by one of the hardware-specific forms shown in the appendix, the project team may need to develop their own form. A library of forms can also be found on the world wide web at http://www.wpi.edu/Academics/Depts/CEE/Roadsafe/ispe.html.



CASE IDENTIFICATION

Case ID ☐

Data Collector ☐

Police Agency: ☐ Collision Report ID: ☐

Maintenance Agency: ☐ Cost Report ID: ☐

CRASH LOCATION

Roadway Location: Route Number ☐ Milepost ☐

Direction of travel: ○NB ○SB ○EB ○WB

Route Type: ○Divided Highway ○Undivided Highway ○On/off Ramp

ADT (one-way): ☐ vpd in (Base year): ☐

Yearly ADT growth rate: ☐

Total Number of Lanes: ☐

Grade: 0 %

Horizontal Curve: Radius: 0 m Direction: ○Right ○Left

HARDWARE

Type of terminal:
- ○ MELT
- ○ ET-2000
- ○ SKT-350
- ○ SRT-350
- ○ FLEAT
- ○ Other (see comments)

Type of guardrail:
- ○ G1 (cable)
- ○ G2
- ○ G4 - steel posts
- ○ G4 - wood posts
- ○ Other (see comments)

Type of transition:
- ○ Trans A
- ○ Trans B
- ○ Trans C
- ○ Other (see comments)

Type of workzone device:
- ○ Category I
- ○ Category II
- ○ Category III
- ○ Other (see comments)

Hardware Comments: ☐

COLLISION DATA

Crash date (month-year): ☐

Crash time (nearest hour): ☐

Vehicle authorized speed limit: ☐ mph

Weather condition:
- ○ Clear or cloudy and dry
- ○ Rain
- ○ Fog, smog or smoke
- ○ Snow, sleet or hail

Result of the collision with roadside hardware:
- ○ Redirected
- ○ Stopped in contact
- ○ Snagged/spun out
- ○ Overrode
- ○ Underrode
- ○ Penetrated
- ○ Unknown

Sequence of events:
- First event: ☐
- Second event: ☐
- Third event: ☐
- Fourth event: ☐

Noncollision events:	Collision events:
1 = Ran off road	4 = Pedestrian or cyclist
2 = Rollover	5 = Vehicle
3 = Other	6 = Tree or pole
	7 = Roadside hardware
9 = Unknown	8 = Other roadside object
0 = None	

Number of impact events: ☐

Number of vehicles involved: ☐

Did the vehicle roll over (Y or N)? ☐

Description of collision events: ☐

VEHICLE AND OCCUPANT

Vehicle configuration:
- ○ Car
- ○ Pickup/SUV/van
- ○ Single unit truck
- ○ Tractor-trailer
- ○ Bus
- ○ Other (see comments below)

VIN: ☐

Vehicle year: ☐

Total occupants (including driver): ☐

Seating position of most severely injured:

REAR ○ ○ ○ / ○ ○ ○ / ○ ○ ○ FRONT

Safety Devices:

	Driver:	Most severely injured occupant:
Seatbelt used (Y or N)	☐	☐
Airbag present (Y or N)?	☐	☐
Airbag deployed (Y or N)?	☐	☐

Driver injury severity: ○ K ○ A ○ B ○ C ○ None ○ Unknown

Highest occupant injury severity: ○ K ○ A ○ B ○ C ○ None ○ Unknown

REPAIR

Labor cost: ☐ Material cost: ☐ Equipment cost: ☐ Total cost: ☐

COMMENTS: ☐

Figure 5. General Form

Data Sources

Police Collision Reports

Most of the collisions studied in an in-service evaluation will be first identified through local or state police agencies and documented on a police collision report. The police report is useful in obtaining basic information regarding crash date, time, location, injury severity and collision sequence. The narrative and sketch provide additional understanding of the crash dynamics and summarize the impact event. While useful, data from the police report are necessarily limited and must be supplemented with other data collected at the scene. For example, the police report may indicate that a vehicle struck a guardrail but rarely provides any detail about the type of guardrail struck. A trip to the scene of the collision will have to be made to determine if the crash fits the sampling profile for the study and warrants full scale data collection.

Police reports contain much information that is not useful for analysis and should be kept private, as discussed earlier. The general data collection form (Figure 5) contains only data relevant to the study. Data elements that are recorded include:

- Route number, type (divided highway, undivided highway, or on/off ramp), milepost, and direction;
- Month, year and time of the collision;
- Number of vehicles involved;
- Whether the vehicle rolled over;
- Posted speed limit;
- Weather conditions;
- Description of collision events: number of impact events, sequence of events, result of the collision (redirection, penetration, etc.), and narrative and/or sketch
- Vehicle configuration (car, pickup/SUV/van, truck, etc.), VIN, and year;
- Number of occupants and seating position of most injured occupant;
- Safety devices used by the driver (seatbelt, airbag) and most injured occupant; and
- Severity of injuries to the driver and the highest injury severity to any occupant.

Maintenance Cost Report

The maintenance and repair information normally collected by DOTs does not usually include information about the crash itself, the severity of the collision, or the sequence of collision events. Instead, maintenance information generally consists of labor and materials costs required to repair a traffic barrier after it has been damaged in a collision. The information often will include a detailed list of parts that were replaced and the types of labor and equipment required to repair the barrier. This information is useful for documenting (1) the cost of repairing the barrier and (2) the type of damage sustained to the barrier components. The police accident report form is usually either attached to or referenced on the maintenance report form so that it is possible to connect a specific collision event to a particular damaged traffic barrier. This provides a useful check on how efficient the notification process is between the police and maintenance agencies. The maintenance report may also contain private information, so only data relevant to the study is recorded on the general data collection form, usually consisting of labor, material, equipment and total repair costs.

Traffic Operations Data

Each state maintains a computerized database of traffic operational information on all state-maintained roads. Information like the average daily traffic, traffic mix, and 85th percentile speeds are contained in this database. The data collection team should gain access to this data since it provides another important source of information on the characteristics of the roadway. In general this information is only updated periodically so, for example, the traffic volumes may be two years old but this will still give a good indication of the traffic conditions on the roadway. Most states publish booklets with volume counts on the State roadway network. The traffic operational information needed for the study and pertinent to the data collection area should be obtained for use during the data collection.

Roadway Geometry Data

Some states also maintain a database of geometric characteristics of roadways. Important factors that may affect collision rates include the median width, lane width, shoulder width, grade, radius of horizontal curve or degree of curvature, length of horizontal curve, and superelevation. If available, these data should be merged with the hardware inventory data to identify geometric characteristics at each hardware installation.

CHAPTER THREE

DATA COLLECTION - OFF-SITE

Collecting data is the central activity in an in-service performance evaluation. As discussed in Chapter Two, information comes from a variety of sources including police reports, traffic data, maintenance and repair data and site visits. This chapter describes the process of collecting data from various official sources (e.g., police, maintenance garages, etc.). Data collection at the collision site is discussed in the next chapter.

FIELD PROCEDURES

Collision Notification

The first step in the data collection procedure is notification. There are several methods that can be used by a data collection team to receive notification that a collision has occurred. Notification can be obtained either through the law enforcement agencies, the maintenance agencies or both.

Method One

The first method is to describe to the desk personnel in each agency the types of collisions that are being investigated. The sampling plan described in Chapter Two can also be provided to the desk personnel. When a collision matching the description is filed, the desk personnel faxes or mails a copy of the report to the data collection team. The advantage to this method is that data collectors are simply notified whenever a possible case occurs. The disadvantage is that it requires the cooperation of many different desk personnel, some of whom will be diligent and others who will not, some of whom will understand the type of collision being sought and others who will not. This method also relies on the ability of the desk staff to recognize exactly the type of case of interest to the study team. This method is not recommended since it is likely to result in missed cases that the desk staff do not recognize as fitting the sampling profile.

Method Two

The second method has worked well in other types of collision data collection activities like the National Accident Sampling System (NASS) pole and narrow bridge studies.*(2)(3)* Most police and maintenance agencies maintain a log book of pending activities including traffic collisions or barrier repairs. With the permission of the agency, the data collectors look through the log books (sometimes called crew logs in maintenance garages) and identify any cases that may involve the hardware being studied. The reports for these cases are then duplicated by the data collectors. The advantages to this method are: (1) the agency is a passive participant so little additional work is required of it, and (2) the data collectors and not the agency personnel make the decision about which cases fit the study profile. The disadvantages of this method are that (1) it requires a visit to each agency by the data collector and (2) there may be a delay for the report to be entered into the log. The time interval between visits can probably be increased for smaller agencies by calling ahead to see if there is anything new or potentially interesting in the pending-log. Larger police agencies like the Highway Patrol, State Police, or DOT maintenance garages should be visited weekly.

Method Three

Method three is a variation on method two where the data collector calls each agency each week and asks if there are any cases fitting the sampling profile. If there are, the reports can be faxed to the data collectors for review to determine if they fit the sampling profile. If this method is used, data collectors should still visit the agency every month or two to review all case and crew logs to be sure that all appropriate cases are being collected.

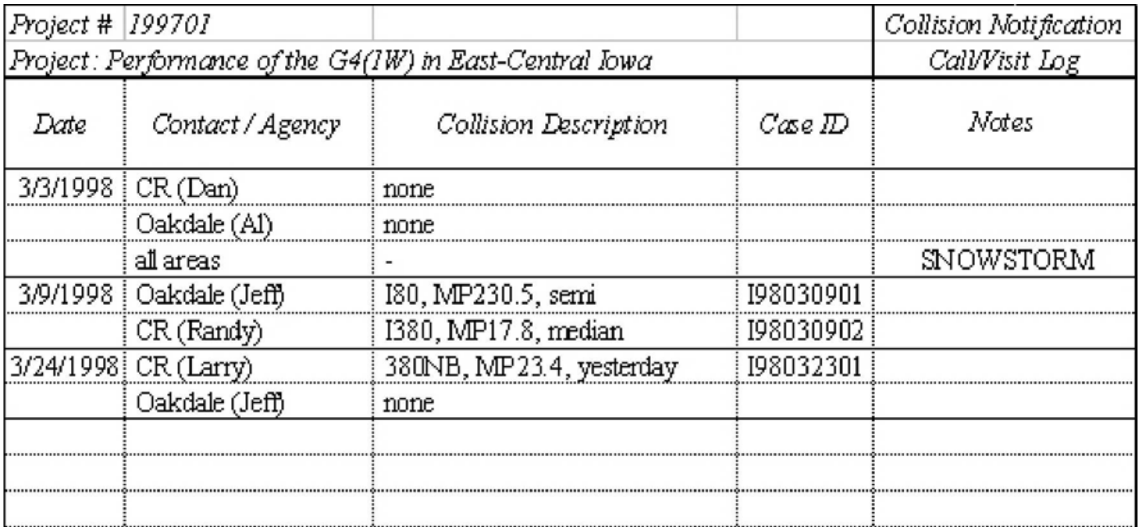
Other more novel methods may also be appropriate. Automatic notification devices like Energy Absorption System's Impact Monitoring System (IMS) can be used when only a small number of devices are installed for study. The IMS contains motion sensors (i.e., mercury switches) that alert maintenance crews when the device is disturbed, allowing them to respond and repair the installation. Continuous-loop video cameras have been used on occasion to monitor specific sites. The video camera can be set to continuously record the site. An impact will trigger a sensor that will capture the last few seconds thereby recording the impact.

The exact notification procedure used will depend on a variety of factors including the public availability of police and DOT reports and the level of access to be allowed for data collectors. Police reports have different legal status in each different State. Some States allow the release of the police report to the public immediately and without restriction whereas other states have waiting periods and restrictions. The data collection team will have to comply with whatever restrictions are imposed by law and try to adjust their procedures such that they obtain the information they need. For example, some DOT and police departments cannot allow the police report to be copied but they will allow data collectors to view the report and make notes on the individual entries. Some States only allow the police report to be copied when the case is complete, meaning all police investigations are complete.

The more severe the collision, the more difficult it will be to obtain the police report. Most State Police Departments have special accident investigation teams for investigating severe collisions. For example, if fatalities are involved the accident investigation team will usually be in charge of the investigation rather than regular patrol officers. The accident investigation team usually does a much more detailed investigation involving scene measurements, witness interviews and review of hospital and emergency room records. These investigations take time so it may take weeks or even months to finalize and officially file the accident report. It is a good idea for the data collection team to make contact with the State Police accident investigation team in the area to explain the project objectives and establish lines of communication. Most officers attached to the accident investigation unit will be cooperative and provide the information needed for the in-service evaluation project before the official report is complete if their state laws allow them to do so. In fact, officers on the accident investigation team are excellent contacts in the police agencies since they can more easily appreciate the importance of collecting in-service performance information about roadside hardware collisions.

A similar process should be established with each maintenance garage in the data collection area. Once a week a data collector should visit the garage supervisor and examine the work plans for the coming week. In most States the police notify the maintenance garage if a traffic barrier has been damaged in an collision. There may, however, be significant lag time between the time the collision is reported to the police and the time that the police report the damage to the maintenance garage. There may be additional lag time between when the maintenance garage is notified and when repairs can actually be accomplished. In general, the police agencies should have the information before the maintenance agencies but the contact should be made to make sure that no cases are missed and to be sure that the site is visited before the maintenance supervisor schedules the traffic barrier for repair. The best approach will generally be to contact both the police agencies and maintenance agencies on a weekly basis and also request desk officers and maintenance supervisors to call the data collection team when collectable cases occur. In principle this is redundant, but it is better to receive notification about a collision case twice than to occasionally miss a case that is not reported through the primary notification link. Getting notification from both the maintenance and police agencies is an excellent way to ensure that all reported collisions are being properly sampled. In an in-service evaluation performed in Iowa where the maintenance garage was the primary means of notification, about ten percent of the cases were not reported to the maintenance garage and were sampled through contacts with the police departments alone. One typical reason for not reporting the collision to the maintenance personnel was that the police officer considered the barrier damage to be inconsequential and therefore it was not necessary to bother the DOT with the case.

The third form in the ISPE workbook is a “collision notification call/visit log” to be used to document all calls or visits to police or maintenance agencies. Figure 6 shows a partially completed collision notification log. It is important for data collectors to record contacts with each agency in the log. First, it provides a quality check to be sure that notification calls are being made regularly and systematically. Second, it provides a means of recording important events like snow storms, floods or power outages that may result in an unusually large case load.

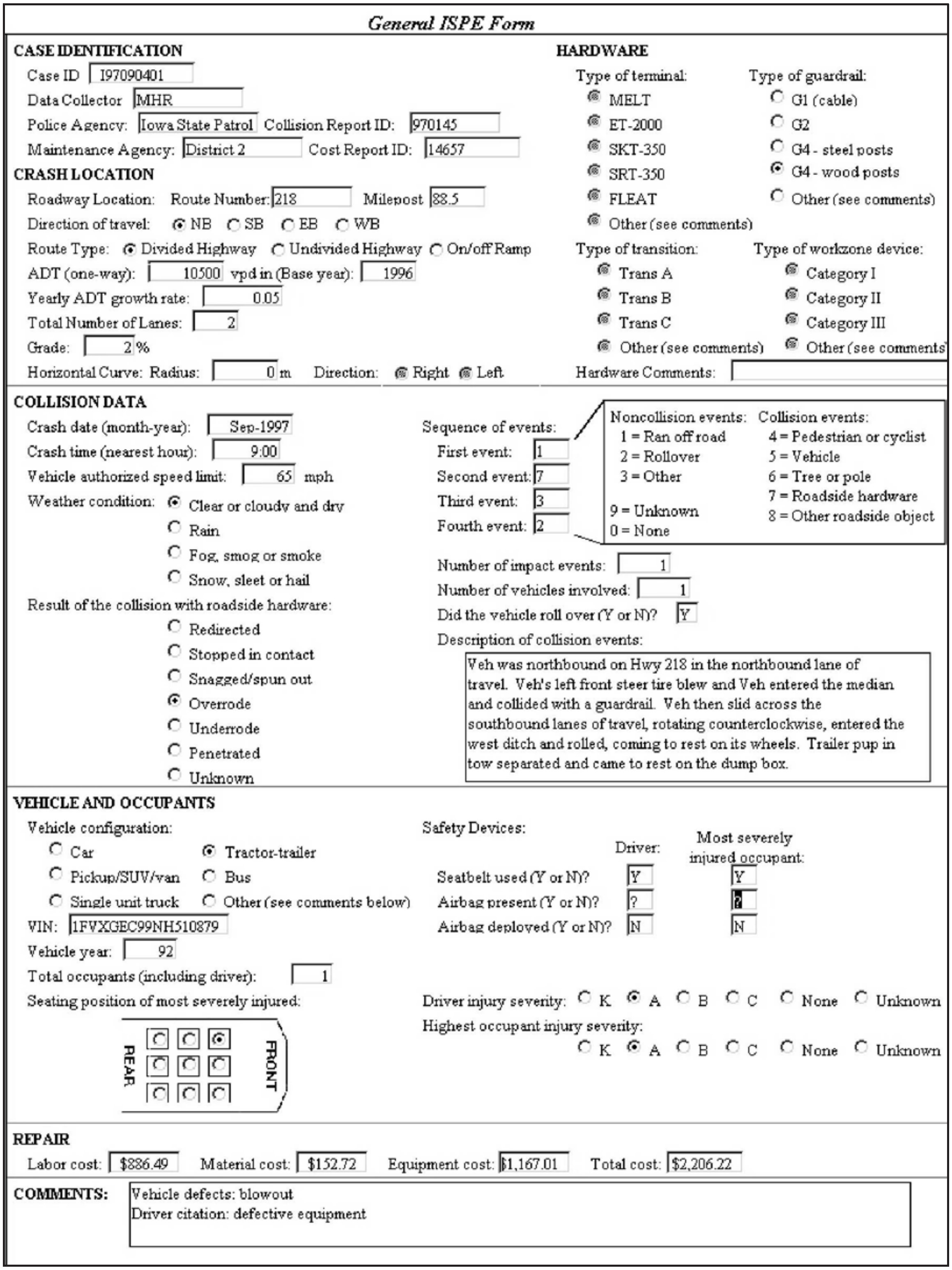


Project #	199701			Collision Notification
Project : Performance of the G4(1W) in East-Central Iowa				Call/Visit Log
Date	Contact / Agency	Collision Description	Case ID	Notes
3/3/1998	CR (Dan)	none		
	Oakdale (Al)	none		
	all areas	-		SNOWSTORM
3/9/1998	Oakdale (Jeff)	I80, MP230.5, semi	I98030901	
	CR (Randy)	I380, MP17.8, median	I98030902	
3/24/1998	CR (Larry)	380NB, MP23.4, yesterday	I98032301	
	Oakdale (Jeff)	none		

Figure 6. Part of a Notification Log.

Gathering General Case Information

After notification of a collision, the first step is to record general information about the collision. A sample General Information Form is shown in Figure 7, and a blank form is included in the ISPE Workbook. The top section of the form focuses on case identification and description.



General ISPE Form

CASE IDENTIFICATION

Case ID: I97090401

Data Collector: MHR

Police Agency: Iowa State Patrol Collision Report ID: 970145

Maintenance Agency: District 2 Cost Report ID: 14657

CRASH LOCATION

Roadway Location: Route Number: 218 Milepost: 88.5

Direction of travel: ● NB ○ SB ○ EB ○ WB

Route Type: ● Divided Highway ○ Undivided Highway ○ On/off Ramp

ADT (one-way): 10500 vpd in (Base year): 1996

Yearly ADT growth rate: 0.05

Total Number of Lanes: 2

Grade: 2 %

Horizontal Curve: Radius: 0 m Direction: ○ Right ○ Left

HARDWARE

Type of terminal:
- ○ MELT
- ○ ET-2000
- ○ SKT-350
- ○ SRT-350
- ○ FLEAT
- ○ Other (see comments)

Type of guardrail:
- ○ G1 (cable)
- ○ G2
- ○ G4 - steel posts
- ● G4 - wood posts
- ○ Other (see comments)

Type of transition:
- ○ Trans A
- ○ Trans B
- ○ Trans C
- ○ Other (see comments)

Type of workzone device:
- ○ Category I
- ○ Category II
- ○ Category III
- ○ Other (see comments

Hardware Comments:

COLLISION DATA

Crash date (month-year): Sep-1997

Crash time (nearest hour): 9:00

Vehicle authorized speed limit: 65 mph

Weather condition:
- ● Clear or cloudy and dry
- ○ Rain
- ○ Fog, smog or smoke
- ○ Snow, sleet or hail

Result of the collision with roadside hardware:
- ○ Redirected
- ○ Stopped in contact
- ○ Snagged/spun out
- ● Overrode
- ○ Underrode
- ○ Penetrated
- ○ Unknown

Sequence of events:
First event: 1
Second event: 7
Third event: 3
Fourth event: 2

Noncollision events:	Collision events:
1 = Ran off road	4 = Pedestrian or cyclist
2 = Rollover	5 = Vehicle
3 = Other	6 = Tree or pole
	7 = Roadside hardware
9 = Unknown	8 = Other roadside object
0 = None	

Number of impact events: 1

Number of vehicles involved: 1

Did the vehicle roll over (Y or N)? Y

Description of collision events:

Veh was northbound on Hwy 218 in the northbound lane of travel. Veh's left front steer tire blew and Veh entered the median and collided with a guardrail. Veh then slid across the southbound lanes of travel, rotating counterclockwise, entered the west ditch and rolled, coming to rest on its wheels. Trailer pup in tow separated and came to rest on the dump box.

VEHICLE AND OCCUPANTS

Vehicle configuration:
- ○ Car
- ● Tractor-trailer
- ○ Pickup/SUV/van
- ○ Bus
- ○ Single unit truck
- ○ Other (see comments below)

VIN: 1FVXGEC99NH510879

Vehicle year: 92

Total occupants (including driver): 1

Seating position of most severely injured:

REAR				FRONT
	○	○	●	
	○	○	○	
	○	○	○	

Safety Devices:

	Driver:	Most severely injured occupant:
Seatbelt used (Y or N)?	Y	Y
Airbag present (Y or N)?	?	?
Airbag deployed (Y or N)?	N	N

Driver injury severity: ○ K ● A ○ B ○ C ○ None ○ Unknown

Highest occupant injury severity: ○ K ● A ○ B ○ C ○ None ○ Unknown

REPAIR

Labor cost: $886.49 Material cost: $152.72 Equipment cost: $1,167.01 Total cost: $2,206.22

COMMENTS:
Vehicle defects: blowout
Driver citation: defective equipment

Figure 7. General Information Form.

Assign Case Numbers

A unique case identification number (ID) must be assigned to each collision case. The case ID is used to link different forms and data elements together. Any numbering method can be used as long as the cases are uniquely identified. One method that has been used is to form the case ID from a letter representing the state followed by eight numbers representing the date and sequence of the collision. For example, a case number of I97090201 indicates the first reported collision that occurred in a data collection area in Iowa on September 4, 1997.

Identify Data Collector

Record the data collector's name or initials. This allows the data collection team to work backwards to verify information at a later date. This is also important for quality assurance purposes. For example, data collector MHR may have misunderstood the procedure for measuring slopes. The analyst can contact MHR at a later date to clarify any dubious information that comes to light during the analysis. This data element will make finding all the errors made by MHR easier if there was some systematic error in the way this data collector recorded information.

Identify the Crash Location and Characterize the Roadway

The crash site is identified by route number and milepost or coordinates. One location descriptor that is often used is the milepost nearest the collision location. This method is useful if the roadways have frequent mileposts such as every 0.1 mile. If the state has mileposts only at structures or overpasses, using the milepost as a locator can make the site very difficult to find. Global positioning systems (GPS) are widely available and inexpensive vehicle-mounted systems can be used to record the latitude and longitude of collision sites.

From the most recent DOT route volume data, determine the average annual daily traffic (AADT) passing the location. Identify whether the AADT is for one or two directions of travel. Most States publish volume counts on State roads periodically (e.g., often every two years). The data collection team should obtain the route volume books from the DOT and use them to record the AADT at or near each collision site, the year the AADT was measured (the base year), and the yearly growth rate. From this information, the one-way AADT for the year the collision occurred in can be estimated as:

$$(\text{AADT in volume book}) \times (1 + \text{Yearly growth rate})^{[(\text{Year of collision}) - (\text{Year of AADT})]}$$

For example, if a collision occurred in 2000 at a certain location, the one-way AADT at that location was 16,700 vehicles per day (vpd) in 1998, and the yearly growth rate was 3.4 percent, the one-way AADT in 2000 would be estimated as: $(16{,}700\text{vpd}) \times (1.034)^{(2000-1998)} = 17{,}855 \text{ vpd}$

If geometric data are available for the roadway, the grade and horizontal curvature at this location should also be recorded. Other important characteristics of the roadway are the number of lanes, whether it is divided, and what types of hardware systems were involved in the collision. These characteristics are usually easily observed during the site visit.

Collecting Data from a Police Collision Report

The second section of the general form shown in Figure 7, "collision data," contains information taken from the police collision report that may be relevant to the in-service performance evaluation. For example purposes, Figures 8a and 8b show a completed motor vehicle accident report from the Iowa State Patrol that was used to complete the general form shown in Figure 7. Police accident reports vary among states, so the exact procedure for completing this part of the form will need to be adjusted slightly to accommodate each state's uniform police report. Most of the data elements in this part of the form conform to the National Governors' Association's recommended "Model Minimum Uniform Crash Criteria."*(2)*

Record Date and Time of Collision

The date and time of the collision are found on the second line of the Iowa State Patrol report, labeled in Figure 8a as A and B respectively. Note that the time is given in military (24-hour) format. On the data collection form, there are entries for the date (month and year) and the time, rounded to the nearest hour.

Record Vehicle Information

The number of vehicles involved in the collision is also found on the second line of the Iowa State Patrol report, labeled in Figure 8a as C. Farther down, the police collision report describes the vehicles. Use the information about the primary vehicle that collided with the roadside appurtenance, including vehicle configuration or type (labeled D). For purposes of the study, the vehicle configurations should be grouped into categories such as passenger car, pickup/sport-utility vehicle (SUV), bus, truck or other. The Iowa State Patrol uses 22 vehicle type codes as shown in Table 3. Motorcycles, bicycles, trains, and mopeds should not be included in most in-service evaluations of roadside hardware; "passenger car" would include codes 01 and 02, "pickup" would include codes 03 through 06, "bus" would include codes 13 and 14, "truck" would include codes 07 through 11, and "other" would include the rest of the codes. Notice that it is unclear how a sport utility vehicle like a Ford Explorer or an Isuzu Trooper would be coded on the Iowa police report.

Table 3: Iowa Police Report Vehicle Type Codes

01	Passenger car
02	Car and trailer
03	Panel truck
04	Pickup truck
05	Pickup and trailer
06	Pickup camper
07	Straight truck
08	Truck tractor
09	Truck tractor / semi
10	Double bottom truck
11	Tow truck / wrecker
12	Motor home
13	Bus
14	School bus
15	Farm veh / equip
16	Motorcycle
17	Bicycle, etc.
18	Recreation veh.
19	Maint / const veh
20	Train
21	Other (describe)
22	Moped

Other vehicle characteristics are the VIN (labeled E in Figure 8a), vehicle year (labeled F), and number of occupants (labeled G). Any vehicle defects (labeled H) should also be noted in the "comments" section of the form.

Record Speed Limit

Record the posted speed limit if it is included on the collision report. In Figure 8a, the speed limit is labeled as I. If this information is not on the collision report, it should be possible to collect it during the site visit.

Record Driver Citations

Any driver citations, labeled as J in Figure 8a, should be noted in the "comments" section of the form. This information is helpful in identifying human factors contributing to the severity of the collision.

Describe Environment

The bottom part of the first page of the accident report, labeled as K in Figure 8a, describes the environment and circumstances of the collision. Record the weather conditions, using the most severe if two conditions are indicated. Examine the circumstances and roadway characteristics for clues to factors contributing to the severity of the collision and note them in the "comments" section of the form.

Describe Vehicle Occupants

The top part of the second page of the accident report (Figure 8b) describes the injured occupants of the vehicle. Record information about the driver and the most severely injured occupant of the vehicle, including whether they were using a seatbelt (codes 2 or 3 under "protective devices," labeled as L) and whether the airbags were deployed (code 4 under "protective devices"), as well as the severity of their injuries (labeled as M). Also record the seating position (labeled as N) of the most severely injured occupant. This information is the most important data on the police report since it is usually the only public document that assesses occupant injuries. Police agencies usually use the "KABCO" injury scale, where the severity is coded as:

K = fatal injury
A = incapacitating injury
B = non-incapacitating injury
C = possible injury
O = no injury (property damage only)

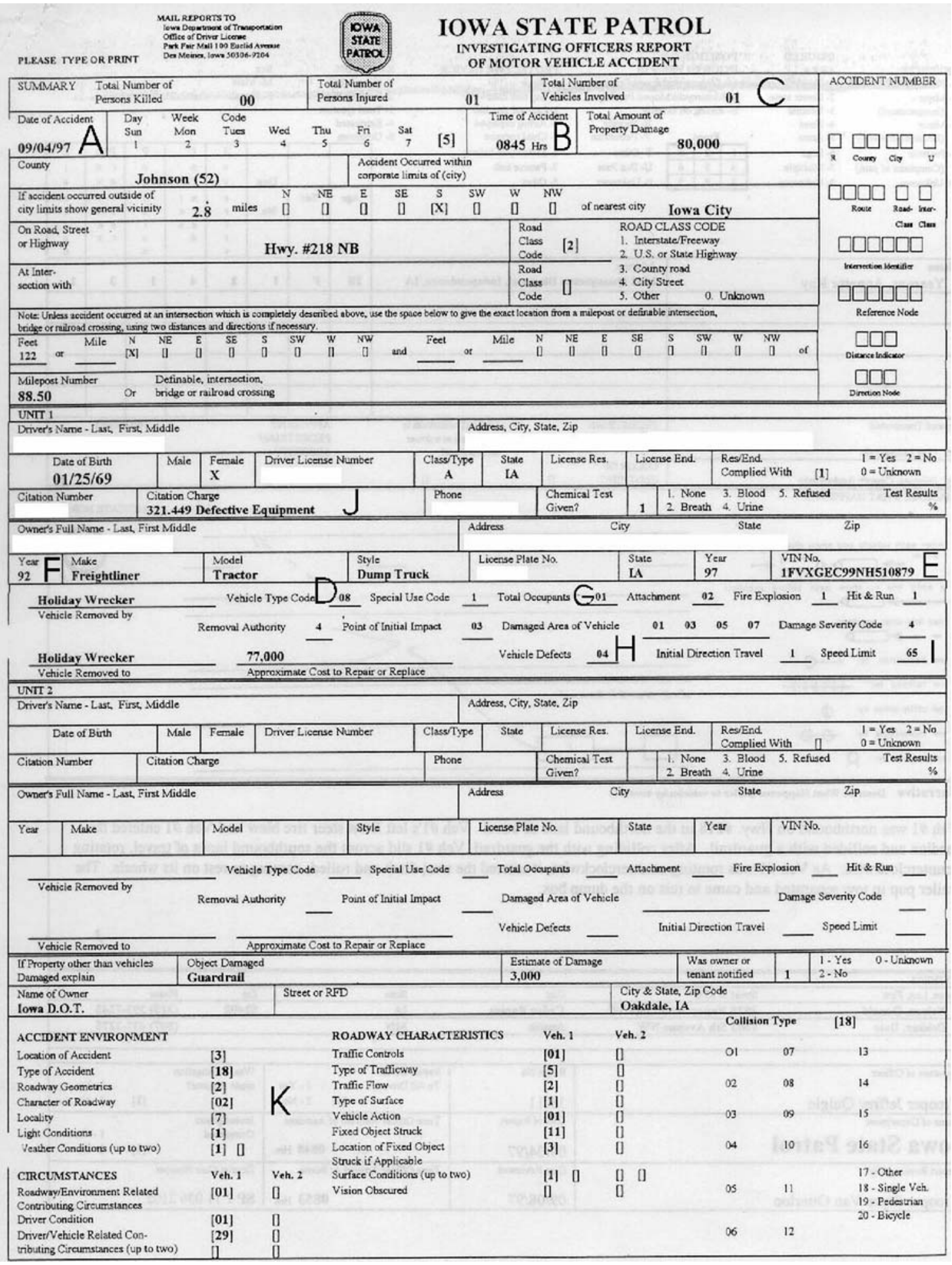
Describe Collision Event Sequence

From the accident report diagram, narrative, and other data entries, determine the collision event sequence and record the first four events. Also indicate the total number of impact events, whether the vehicle rolled over during the collision, and the result of the barrier collision.

Include Comments

Including appropriate information in the comments section is very important. While it is not possible to process the comment information using a statistical analysis program, the comments often provide valuable insight into the collision that can help answer questions and resolve ambiguous results during the analysis. During the statistical analysis an unusual case may appear that does not seem to fit any obvious pattern. If comments were carefully included in the forms, the analyst can often determine why the case was an outlier in the statistical analysis.

Another equally important data source that can be difficult to use in analysis but provides a great deal of understanding for the data collector is a collision diagram. In reviewing police reports the collision sketch is often the single most informative piece of information, and if possible a copy should be attached to the general form.



PLEASE TYPE OR PRINT

MAIL REPORTS TO
Iowa Department of Transportation
Office of Driver License
Park Fair Mall 100 Euclid Avenue
Des Moines, Iowa 50306-9204

IOWA STATE PATROL

IOWA STATE PATROL
INVESTIGATING OFFICERS REPORT
OF MOTOR VEHICLE ACCIDENT

SUMMARY Total Number of Persons Killed 00 | Total Number of Persons Injured 01 | Total Number of Vehicles Involved 01 C | ACCIDENT NUMBER

Date of Accident 09/04/97 A | Day of Week Code: Sun 1, Mon 2, Tues 3, Wed 4, Thu 5, Fri 6, Sat 7 [5] | Time of Accident 0845 Hrs B | Total Amount of Property Damage 80,000

☐ ☐☐ ☐☐ ☐
R County City U

County Johnson (52) | Accident Occurred within corporate limits of (city)

If accident occurred outside of city limits show general vicinity 2.8 miles N [] NE [] E [] SE [] S [X] SW [] W [] NW [] of nearest city Iowa City

☐☐☐☐ ☐ ☐
Route Road-Class Inter-Class

On Road, Street or Highway Hwy. #218 NB | Road Class Code [2]

ROAD CLASS CODE
1. Interstate/Freeway
2. U.S. or State Highway
3. County road
4. City Street
5. Other
0. Unknown

At Intersection with | Road Class Code []

☐☐☐☐☐☐
Intersection Identifier

☐☐☐☐☐☐
Reference Node

Note: Unless accident occurred at an intersection which is completely described above, use the space below to give the exact location from a milepost or definable intersection, bridge or railroad crossing, using two distances and directions if necessary.

Feet 122 or Mile ____ N [X] NE [] E [] SE [] S [] SW [] W [] NW [] and Feet ____ or Mile ____ N [] NE [] E [] SE [] S [] SW [] W [] NW [] of

☐☐☐
Distance Indicator

Milepost Number 88.50 Or Definable, intersection, bridge or railroad crossing

☐☐☐
Direction Node

UNIT 1

Driver's Name - Last, First, Middle [redacted] | Address, City, State, Zip [redacted]

Date of Birth 01/25/69 | Male | Female X | Driver License Number [redacted] | Class/Type A | State IA | License Res. | License End. | Res/End. Complied With [1] | 1 = Yes 2 = No 0 = Unknown

Citation Number [redacted] | Citation Charge 321.449 Defective Equipment J | Phone [redacted] | Chemical Test Given? 1 | 1. None 2. Breath 3. Blood 4. Urine 5. Refused | Test Results %

Owner's Full Name - Last, First Middle [redacted] | Address City State Zip [redacted]

Year 92 F | Make Freightliner | Model Tractor | Style Dump Truck | License Plate No. [redacted] | State IA | Year 97 | VIN No. 1FVXGEC99NH510879 E

Holiday Wrecker
Vehicle Removed by

Vehicle Type Code D 08 | Special Use Code 1 | Total Occupants G 01 | Attachment 02 | Fire Explosion 1 | Hit & Run 1

Removal Authority 4 | Point of Initial Impact 03 | Damaged Area of Vehicle 01 03 05 07 | Damage Severity Code 4

Vehicle Defects 04 H | Initial Direction Travel 1 | Speed Limit 65 I

Holiday Wrecker
Vehicle Removed to

77,000
Approximate Cost to Repair or Replace

UNIT 2

Driver's Name - Last, First, Middle | Address, City, State, Zip

Date of Birth | Male | Female | Driver License Number | Class/Type | State | License Res. | License End. | Res/End. Complied With [] | 1 = Yes 2 = No 0 = Unknown

Citation Number | Citation Charge | Phone | Chemical Test Given? | 1. None 2. Breath 3. Blood 4. Urine 5. Refused | Test Results %

Owner's Full Name - Last, First Middle | Address City State Zip

Year | Make | Model | Style | License Plate No. | State | Year | VIN No.

Vehicle Type Code ____ Special Use Code ____ Total Occupants ____ Attachment ____ Fire Explosion ____ Hit & Run ____

Vehicle Removed by

Removal Authority ____ Point of Initial Impact ____ Damaged Area of Vehicle ____ Damage Severity Code ____

Vehicle Defects ____ Initial Direction Travel ____ Speed Limit ____

Vehicle Removed to

Approximate Cost to Repair or Replace

If Property other than vehicles Damaged explain | Object Damaged Guardrail | Estimate of Damage 3,000 | Was owner or tenant notified 1 | 1 - Yes 2 - No 0 - Unknown

Name of Owner Iowa D.O.T. | Street or RFD | City & State, Zip Code Oakdale, IA

ACCIDENT ENVIRONMENT

Location of Accident	[3]
Type of Accident	[18]
Roadway Geometrics	[2]
Character of Roadway	[02]
Locality	[7]
Light Conditions	[1]
Weather Conditions (up to two)	[1] []

K

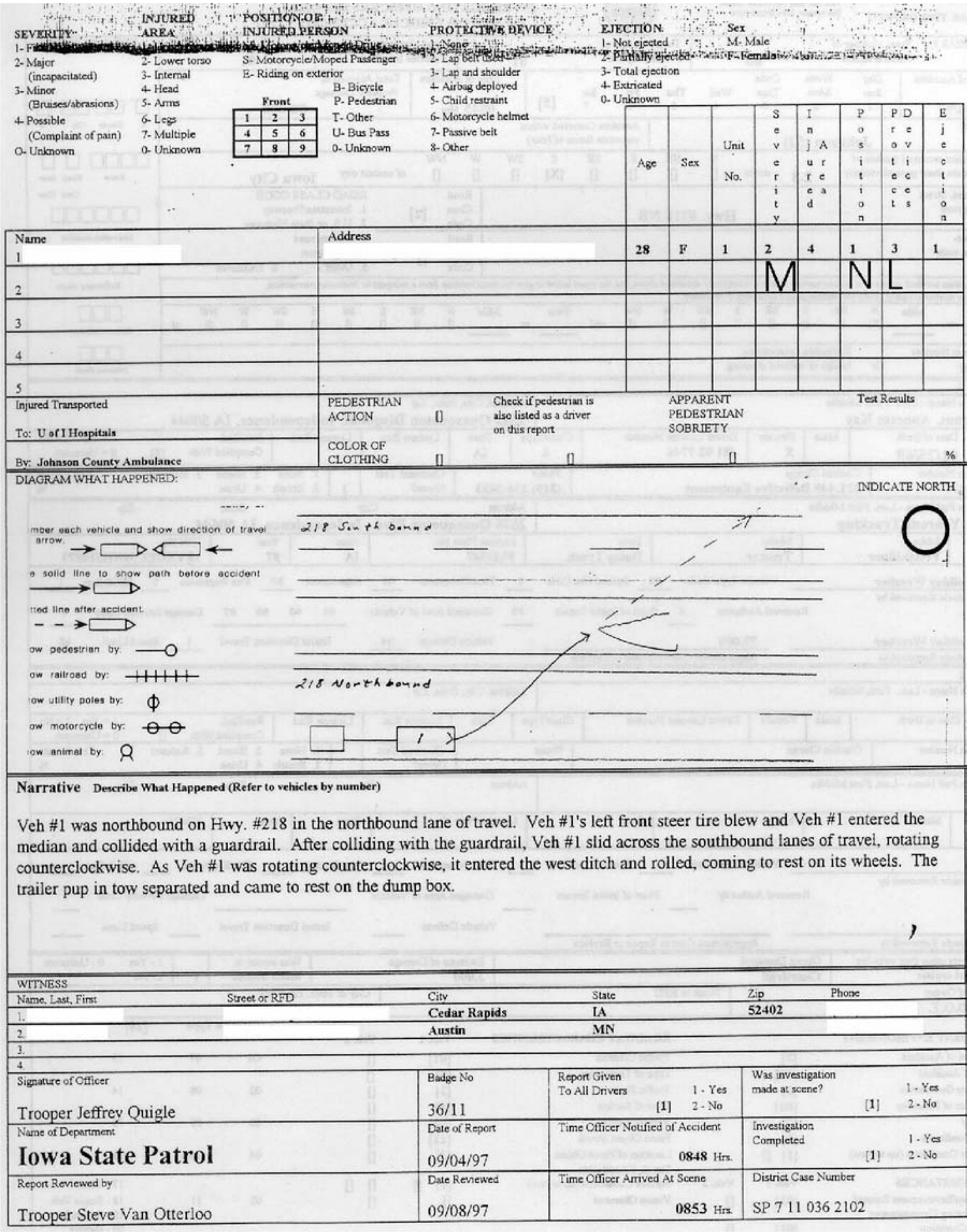
CIRCUMSTANCES	Veh. 1	Veh. 2
Roadway/Environment Related Contributing Circumstances	[01]	[]
Driver Condition	[01]	[]
Driver/Vehicle Related Contributing Circumstances (up to two)	[29] []	[] []

ROADWAY CHARACTERISTICS	Veh. 1	Veh. 2
Traffic Controls	[01]	[]
Type of Trafficway	[5]	[]
Traffic Flow	[2]	[]
Type of Surface	[1]	[]
Vehicle Action	[01]	[]
Fixed Object Struck	[11]	[]
Location of Fixed Object Struck if Applicable	[3]	[]
Surface Conditions (up to two)	[1] []	[] []
Vision Obscured	[]	[]

Collision Type [18]

01	07	13
02	08	14
03	09	15
04	10	16
		17 - Other
05	11	18 - Single Veh. 19 - Pedestrian 20 - Bicycle
06	12	

Figure 8a. Iowa State Patrol Accident Report



SEVERITY
1- F
2- Major (incapacitated)
3- Minor (Bruises/abrasions)
4- Possible (Complaint of pain)
O- Unknown

INJURED AREA
2- Lower torso
3- Internal
4- Head
5- Arms
6- Legs
7- Multiple
0- Unknown

POSITION OF INJURED PERSON
M- Motorcycle/Moped Driver
S- Motorcycle/Moped Passenger
E- Riding on exterior
B- Bicycle
P- Pedestrian
T- Other
U- Bus Pass
0- Unknown

Front

1	2	3
4	5	6
7	8	9

PROTECTIVE DEVICE
1- None
2- Lap belt used
3- Lap and shoulder
4- Airbag deployed
5- Child restraint
6- Motorcycle helmet
7- Passive belt
8- Other

EJECTION
1- Not ejected
2- Partially ejected
3- Total ejection
4- Extricated
0- Unknown

Sex
M- Male
F- Female

	Name	Address	Age	Sex	Unit No.	Severity	Injured Area	Position	Protective Devices	Ejection
1	[redacted]	[redacted]	28	F	1	2	4	1	3	1
2						M		N	L	
3										
4										
5										

Injured Transported
To: **U of I Hospitals**
By: **Johnson County Ambulance**

PEDESTRIAN ACTION []
Check if pedestrian is also listed as a driver on this report []
COLOR OF CLOTHING []
APPARENT PEDESTRIAN SOBRIETY []
Test Results %

DIAGRAM WHAT HAPPENED:
INDICATE NORTH

mber each vehicle and show direction of travel arrow.
e solid line to show path before accident
tted line after accident.
ow pedestrian by:
ow railroad by:
ow utility poles by:
ow motorcycle by:
ow animal by:

218 South bound
218 North bound
1

Narrative **Describe What Happened (Refer to vehicles by number)**

Veh #1 was northbound on Hwy. #218 in the northbound lane of travel. Veh #1's left front steer tire blew and Veh #1 entered the median and collided with a guardrail. After colliding with the guardrail, Veh #1 slid across the southbound lanes of travel, rotating counterclockwise. As Veh #1 was rotating counterclockwise, it entered the west ditch and rolled, coming to rest on its wheels. The trailer pup in tow separated and came to rest on the dump box.

WITNESS

	Name, Last, First	Street or RFD	City	State	Zip	Phone
1.	[redacted]	[redacted]	**Cedar Rapids**	**IA**	**52402**	
2.	[redacted]	[redacted]	**Austin**	**MN**		
3.						
4.						

Signature of Officer Trooper Jeffrey Quigle	Badge No 36/11	Report Given To All Drivers [1] 1 - Yes 2 - No	Was investigation made at scene? [1] 1 - Yes 2 - No
Name of Department **Iowa State Patrol**	Date of Report 09/04/97	Time Officer Notified of Accident **0848** Hrs.	Investigation Completed [1] 1 - Yes 2 - No
Report Reviewed by Trooper Steve Van Otterloo	Date Reviewed 09/08/97	Time Officer Arrived At Scene **0853** Hrs.	District Case Number SP 7 11 036 2102

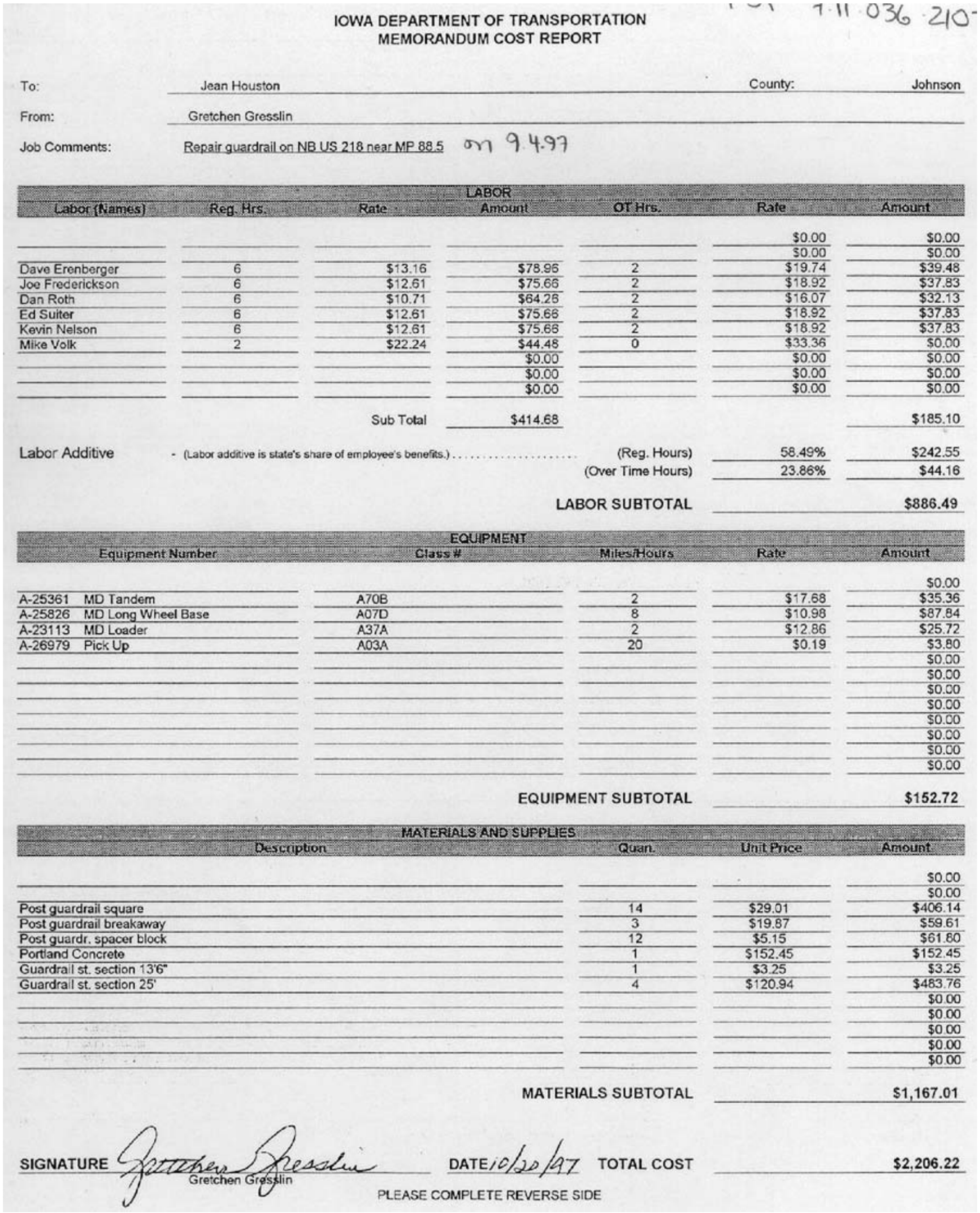
Figure 8b. Page Two of Iowa State Patrol Accident Report

Collecting Data from a Maintenance Cost Report

The third section of the general form includes information from a maintenance cost report. Figure 9 shows a completed Iowa DOT Maintenance Cost Report for repairs to the guardrail damaged in the collision recorded in Figures 7 and 8.

Record Costs

Record the cost of labor, material and equipment used to repair the hardware, and indicate the total cost. Some states will record the itemized cost of labor, parts and equipment on the maintenance cost recovery form whereas others will only report the total cost. Record only the information that is recorded in the DOT's report and do not attempt to back-calculate or estimate the component costs if all that is reported is the total cost.



7.11.036.210

IOWA DEPARTMENT OF TRANSPORTATION
MEMORANDUM COST REPORT

To: Jean Houston County: Johnson

From: Gretchen Gresslin

Job Comments: Repair guardrail on NB US 218 near MP 88.5 on 9.4.97

LABOR

Labor (Names)	Reg. Hrs.	Rate	Amount	OT Hrs.	Rate	Amount
					$0.00	$0.00
					$0.00	$0.00
Dave Erenberger	6	$13.16	$78.96	2	$19.74	$39.48
Joe Frederickson	6	$12.61	$75.66	2	$18.92	$37.83
Dan Roth	6	$10.71	$64.26	2	$16.07	$32.13
Ed Suiter	6	$12.61	$75.66	2	$18.92	$37.83
Kevin Nelson	6	$12.61	$75.66	2	$18.92	$37.83
Mike Volk	2	$22.24	$44.48	0	$33.36	$0.00
			$0.00		$0.00	$0.00
			$0.00		$0.00	$0.00
			$0.00		$0.00	$0.00
		Sub Total	$414.68			$185.10

Labor Additive	- (Labor additive is state's share of employee's benefits.) . . . . (Reg. Hours)	58.49%	$242.55
	(Over Time Hours)	23.86%	$44.16

LABOR SUBTOTAL **$886.49**

EQUIPMENT

Equipment Number	Class #	Miles/Hours	Rate	Amount
				$0.00
A-25361 MD Tandem	A70B	2	$17.68	$35.36
A-25826 MD Long Wheel Base	A07D	8	$10.98	$87.84
A-23113 MD Loader	A37A	2	$12.86	$25.72
A-26979 Pick Up	A03A	20	$0.19	$3.80
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00

EQUIPMENT SUBTOTAL **$152.72**

MATERIALS AND SUPPLIES

Description	Quan.	Unit Price	Amount
			$0.00
			$0.00
Post guardrail square	14	$29.01	$406.14
Post guardrail breakaway	3	$19.87	$59.61
Post guardr. spacer block	12	$5.15	$61.80
Portland Concrete	1	$152.45	$152.45
Guardrail st. section 13'6"	1	$3.25	$3.25
Guardrail st. section 25'	4	$120.94	$483.76
			$0.00
			$0.00
			$0.00
			$0.00
			$0.00

MATERIALS SUBTOTAL **$1,167.01**

SIGNATURE Gretchen Gresslin **DATE** 10/20/97 **TOTAL COST** **$2,206.22**

Gretchen Gresslin

PLEASE COMPLETE REVERSE SIDE

Figure 9. Iowa DOT Maintenance Cost Report

CHAPTER FOUR

DATA COLLECTION - SITE INVESTIGATION

One of the unique features of a detailed in-service performance evaluation is a physical investigation of the collision site shortly after the collision occurred, preferably before the hardware has been repaired. Visiting the site provides valuable insight to the data collector that would be unobtainable if the site were not visited. Observations are quantified by taking photographs, making sketches, and making measurements.

DATA COLLECTION EQUIPMENT

Safety Equipment

Data collectors should always wear safety vests (Figure 10) and place traffic cones to alert motorists to their presence on and near the roadway (Figure 11). Flashing yellow lights on the data collection vehicle are also a good idea. If data are collected by DOT maintenance workers, one group can set up the traffic control needed for repair of the barrier while another group collects the on-site data.

Figure 10. Safety Vest and Measuring Wheel

Measuring Wheel

A measuring wheel (see Figure 10) is a device with one or two rubber wheels and a rotary counter. They are available in SI or English units. Measuring wheels are used to measure long distances along the road such as the total length of a guardrail installation.

Figure 11. Traffic Cones

Tape Measure and Folding Ruler

Figure 12. Tape Measures and Folding Ruler

A standard tape measure or surveyor's cloth tape can be used to make many measurements, including post spacing, rail height and shoulder width. A folding ruler, however, is more resistant to gusts of wind from passing cars and trucks and is usually much easier to handle when measuring the rail height, post spacing and lane width. Figure 12 shows two types of tape measures and a folding ruler. All measuring devices, including tape measures and folding rules, should be marked in the same units required on the form. For example, if the form requires distance measurements in mm, then rulers and tapes that are marked in mm should be obtained. Many mistakes will be prevented by using measuring devices that use the same units as are required on the forms. Every effort should be made to avoid the possibility of transcription errors. Today, most common measuring devices are available in both English and SI units.

Post Number Flipchart

Figure 13. Flipchart

A wire-bound pad of index cards such as the one shown in Figure 13 is useful for documenting post numbers. A large number should be written on each card. The flip pad should be positioned in the camera view to document the post number whenever photographs are taken. This way, the location of the photograph is easy to determine when analyzing the data in the office.

Stringline

Figure 14. Carpenter's chalk line.

Any type of stringline (Figure 14) can be used for measuring deflections. Typical carpenter's snap lines (without the marking chalk) are particularly useful since the string winds into the body of the device for storage.

Plumb Bob

A standard surveyor's plumb bob (Figure 15) is useful for projecting distances to the ground. For example, the plumb bob can be used to project the point of the largest deflection to the ground. Once the point is identified on the ground it is easy to measure the distance between the original position of the guardrail and the deflected position of the guardrail.

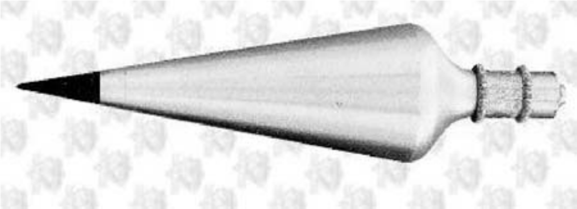


Figure 15. Plumb bob.

Camera

A standard or digital camera (Figure 16) is essential for documenting the collision site. Digital cameras have the advantage of providing easy storage of a large number of photographs without the expense of film or developing.

Figure 16. Digital camera.

Carpenter’s Square and Level

These devices (Figure 17) are used in measuring slopes. The level should be at least 24 inches long and a 48-inch mason’s level is even better. The long levels make terrain measurements easier. Likewise a 24-inch carpenter’s square is preferable to smaller squares. Digital carpenter's levels, while more expensive than standard levels, are very convenient for collecting slope data. Digital levels like the one shown in Figure 18 provide a digital reading of the slope directly. Using a digital level will help to avoid transcription

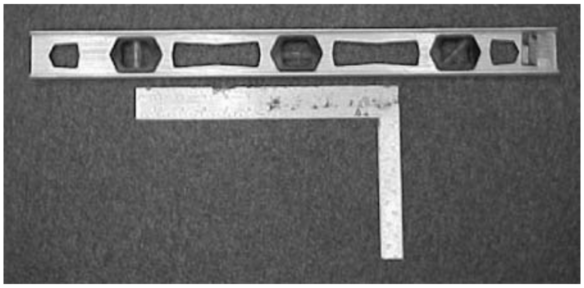


Figure 17. Square and level

Figure 18. Digital level

and calculation errors since the value displayed by the level readout is the same value that should be recorded on the data collection form.

FIELD PROCEDURES

Data collection at the collision site involves the use of a number of specific field procedures. In order to obtain data that are comparable between different studies in different areas, it is important to follow similar procedures for each in-service evaluation project.

Site Photography

While photographs cannot be stored in a database for statistical analysis, they are one of the most important sources of information about the collision event. As a general rule of thumb, a data collector can never take too many photographs. While data collection must be efficient, the cost of extra film and developing is minor in comparison to the potential loss of information once the site is repaired. One advantage to digital cameras is that there is no limit to the number of photographs that can be taken. Since there are no development costs, taking additional photographs is a simple matter of storing more electronic files. Many digital cameras will store the data directly on floppy disk or other media that can be filed with the paper records.

Figure 19. Upstream View of Scene

Figure 20. Downstream View of Scene

Investigators should always take at least the following photographs:

1. Several views of the general scene -- photographs of the roadway up and down stream of the impact will provide information about the general roadway environment and the location of the traffic barrier. (See Figures 19 and 20.)

2. Damaged components -- every damaged component of the traffic barrier should be labeled and photographed to document how the component performed and its final position. (See Figure 21.)

3. Damaged vehicle -- when possible the vehicle should be located and photographed to document the damage sustained by the vehicle in the collision. (See Figure 22.)

Figure 21. Damaged Post

Figure 22. Damaged Car

An alternative to photographs is videotaping the scene. The process and intent are exactly the same but video is used rather than still photography. One advantage of video is that the overall nature of the scene is sometimes more apparent in a videotape than in still photographs. Video tapes also do not require developing so they can be used immediately by the data collectors and are easily shared with other investigators. When videotape is used, the data collectors should be careful not to rush from view to view.

Installation Characteristics

Overall Dimensions

Figure 23. Length of Barrier - Starting Point

The length of a roadside barrier installation along the roadway (L) is usually measured with a measuring wheel. The length of a guardrail or median barrier should include the terminals or anchors. The length of a terminal or transition should include only the terminal or transition section itself. Begin the measurement at a point perpendicular to the end of the guardrail system (Figure 23) and measure the length parallel to the roadway (Figure 24) to the end of the system.

The length should always be measured parallel to the road even if the guardrail is flared away from the road.

Figure 24. Measuring the Length of Barrier

Post Numbering

A consistent post-numbering method must be used. The recommended method is to label the first post of the upstream terminal as post 1 and continue the numbering downstream (in the direction of travel) until the last post. The numbered flipchart discussed in "Data Collection Equipment" is useful for labeling posts in the photographs. Even if the guardrail terminal was not involved in the collision, the post numbering should still start at the upstream end of the terminal for consistency and to avoid ambiguity.

Figure 25. Measuring Post Spacing

Post Spacing

The typical post spacing of a guardrail is the center-to-center distance between posts near the impact point. This can be determined using a folding measuring rule or tape measure. The easiest method is to measure from outside edge to outside edge as shown in Figures 25 and 26. Alternatively, the distance from the centerline of the post-rail bolts can be measured.

Figure 26. Measuring Post Spacing (close-up)

Rail Height

The rail height (H) is “the vertical distance from the top of the cable or beam (rail) to the environmental surface immediately below the barrier (paved or unpaved),” as shown in Figures 27 and 28. *(1)*

Lateral Offset

The lateral offset is “the perpendicular distance from the edge line, or pavement edge if no edge line exists, to the roadside structure/object.” *(1)* Figure 29 shows an example of the lateral offset to the first post of a guardrail terminal. The distance is usually measured from the outside edge of the edge line. Similarly, the edge line is usually considered to be part of the lane so lane widths are measured to the outside of the edge line.

Figure 27. Measuring Rail Height

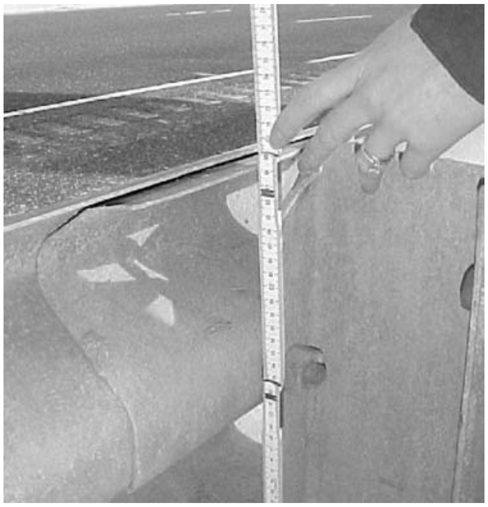


Figure 28. Rail Height (close-up)

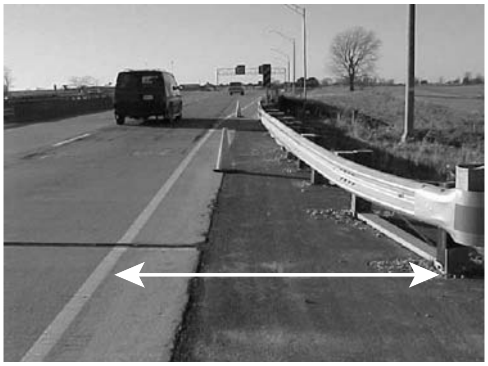


Figure 29. Lateral Offset

Nearest Hazard

The distance to the first hazard (X) is the distance along the barrier from the upstream end of the system (i.e., post 1) to a perpendicular line to the first hazard (fixed object or beginning of a steep slope), as shown in Figure 30. It is also useful to measure the lateral offset to the nearest hazard (O) at this point (Figure 31). The distance to the first hazard is measured parallel to the roadway, typically with the measuring wheel.

Figure 30. Distance to the First Hazard (X)

Figure 31. Offset to Nearest Hazard.

Side Slopes

A “typical cross-section” should be described at or near the impact point. For a guardrail terminal, this cross-section should be at the last post of the terminal (i.e., where it connects to the guardrail) regardless of the impact point, in order to document the typical cross-section. Terminals are often installed on specially graded “blisters” so cross-section measurements near the nose may not reflect the typical cross-section.

A typical cross-section is shown in Figure 32.

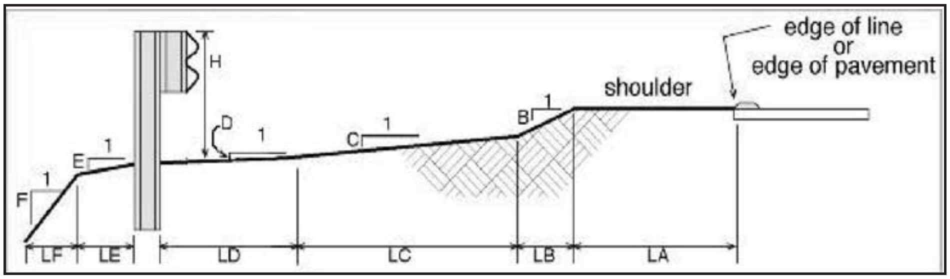


Figure 32. Typical Cross-section.

"LA" is the width of the paved shoulder, and "LB" through "LF" are the horizontal lengths of slopes "B" through "F." "B" refers to a gravel shoulder, and "C" and "D" refer to two different grassy slopes approaching the barrier. If there is no gravel shoulder, "LB" should be recorded as zero or "N/A." "E" and "F" refer to slopes behind the barrier.

Slopes "B" through "F" are determined by placing a two-foot level horizontal on the slope and measuring the vertical distance from the end of the level to the ground as shown in Figures 33 and 34. The slope shown in Figure 34 would be recorded as +4.5/24 on the data collection form (i.e., 4.5 inches vertical to 24 inches horizontal distance). Alternatively, as shown in Figures 35 and 36, if a digital level is used the slope can be measured directly from the digital readout and recorded on the form.

Figure 33. Measuring a Slope Behind a Barrier

Figure 34. Measuring a Slope

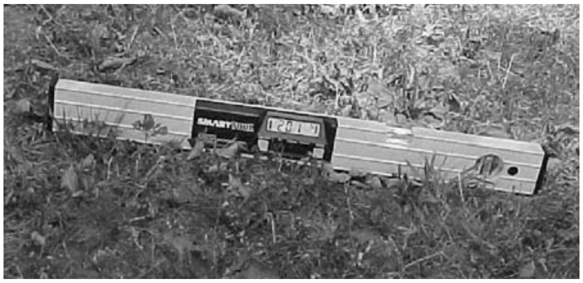


Figure 35. Measuring a Slope with a Digital Level

Figure 36. Digital Level Readout

Hardware Description

At the typical cross-section, note the shoulder type, which can be paved, unpaved (i.e., dirt or grass), partially paved (i.e., part paved and part gravel), gravel, or none. Figures 37a through 37c show examples of these shoulder types.

Figure 37a. Paved Shoulder

Figure 37b. Unpaved Shoulder

Figure 37c. Partially Paved Shoulder

Also note the post type, the rail type, and the blockout type if applicable. Figure 38 identifies the post, rail, and blockout in one W-beam guardrail system.

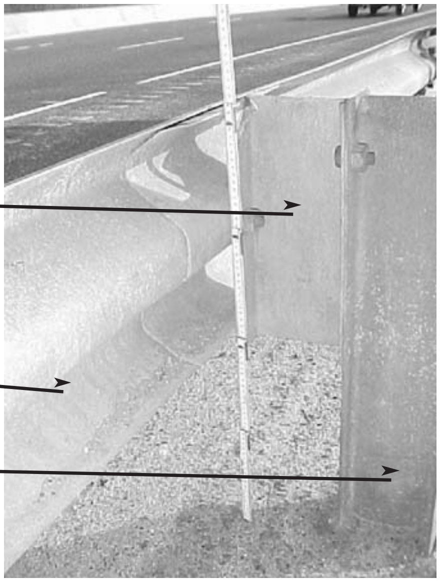


Figure 38. Steel Post, Blockout, and W-Beam Rail

Figures 38 through 42 show some examples of different types of posts, blockouts, and rails. Posts may be steel shapes, as in Figures 38, 39, 41, and 42, or wood shapes, as in Figure 40. Blockouts may also be made of steel (Figure 38) or wood (Figures 39 and 40), as well as other materials. Rails may be W-beam (Figures 38 and 39), thrie beam (Figure 40), cable (Figure 41), or boxbeam (Figure 42).

Figure 39. W-Beam, Steel Post and Wood Blockout

Figure 40. Thrie Beam with Wood Posts

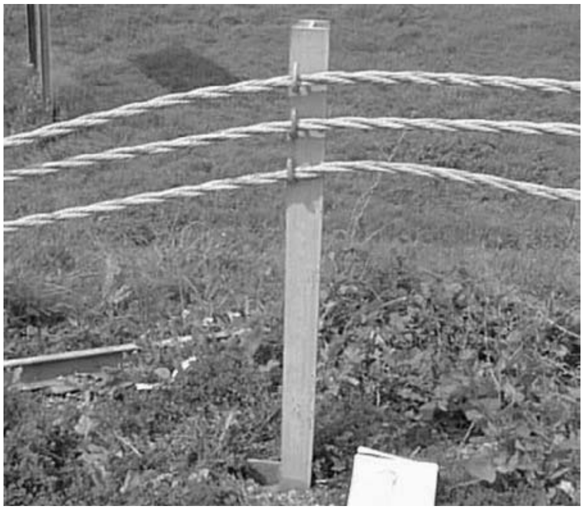


Figure 41. Steel Post and Cable

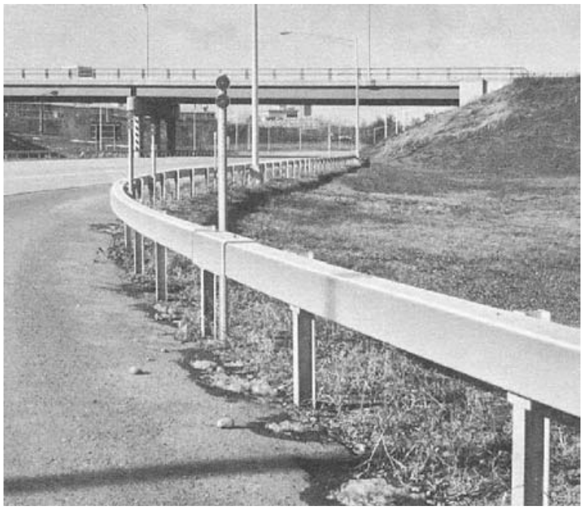


Figure 42. Boxbeam guardrail system

Lane and Shoulder Widths

The lane width is the distance between the outside of the lane markings as shown in Figure 43. Measure the width of a lane with the measuring wheel or folding ruler. While this is a useful piece of data, if traffic or weather conditions do not permit the data collectors to safely measure the lane width, the lane width can be estimated. Also measure the width of the paved shoulder (LA) using the folding ruler. The shoulder width is the distance from the outside of the edgeline to the edge of the paved shoulder as shown in Figure 43.

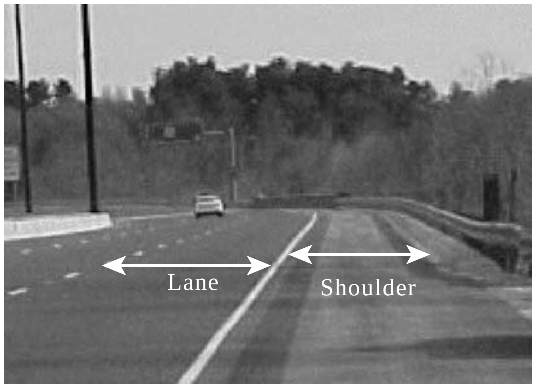


Figure 43. Lane and Shoulder Widths

Horizontal and Vertical Curvature

The horizontal curvature at a site can be assessed in several ways. One method is to measure the length of a straight line between two points on the curve (the chord length, *C*) and the largest perpendicular distance from that line to the curve (the middle ordinate, *M*), shown in Figure 44. From these two measurements, the degree of curvature can be calculated using the following equation:

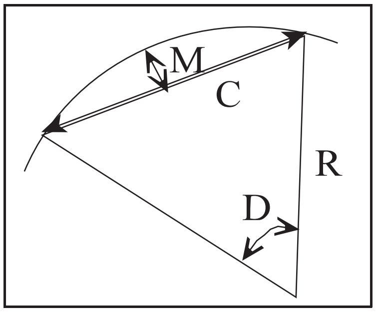


Figure 44. Horizontal Curvature

$$M=\left(\frac{1-\cos D/2}{2\sin D/2}\right)C$$

where M = the middle ordinate in inches,
C = the chord length in feet, and
D = the degree of curvature in radians

This is derived from the relationships among *M*, *C*, *D*, and *R*, the radius of the curve:

$$M=R\left(1-\cos D/2\right)$$

$$R=\frac{C}{2\sin D/2}$$

If the chord length is 38.2 feet, or 38 feet and 2.5 inches, then the middle ordinate (*M*) in inches is equal to the degree of curvature (*D*)in radians. Thus, if a chord 38.2 feet long can be measured anywhere on the curve, the calculation of the horizontal curvature is greatly simplified.

The vertical curvature, or grade, can most easily be estimated by using a level and folding rule or digital level as discussed in the section on side slopes. Figure 45 shows how a digital level can be used.

Figure 45. Estimating Grade with a Digital Level

Special Features

Other measurements may be useful for specific hardware types. For example, when studying guardrail terminals, measure the vertical distance from the ground to the center of the breakaway hole in the post. Also note if the anchor cable is loose (see Figure 46) and if there is a groundline strut between posts 1 and 2 (see Figure 47). For a BCT or MELT, also measure the post spacing between posts six and seven and note the type of rail-to-post connectors used, such as bolts or washers.

Figure 46. Anchor Cable

Figure 47. Groundline Strut

Hardware Damage

Groundline Post Deflection

The deflection of a post at the groundline is the perpendicular distance from the original post location (i.e., at ground level) to the damaged post. The original post location can often be identified by a hole or indentation in the ground if the site visit is made soon after the collision. Measure the distance from the front of the hole to the front of the damaged post with a folding ruler as shown in Figure 48.

Figure 48. Measuring Groundline Post Deflection

If the original position of the post is not apparent, tie a stringline to a post just beyond the impact area at the groundline with the string on the impact face of the post. This is illustrated in Figure 49 with a dashed line. Pull the string across the damaged area and secure it to a post just beyond the damaged area. The groundline deflection will be the distance from the string to the face of the deflected post as shown in Figure 50.

Rail-Height Post Deflection

The deflection at rail height is the perpendicular distance from the original rail location to the damaged rail. Deflections are measured by attaching a string to undamaged posts at each end of the damaged section, as shown by the dashed line in Figure 51. The string marks the presumed undamaged location of the posts; the distance between the string and a damaged post is the deflection of that post at rail height.

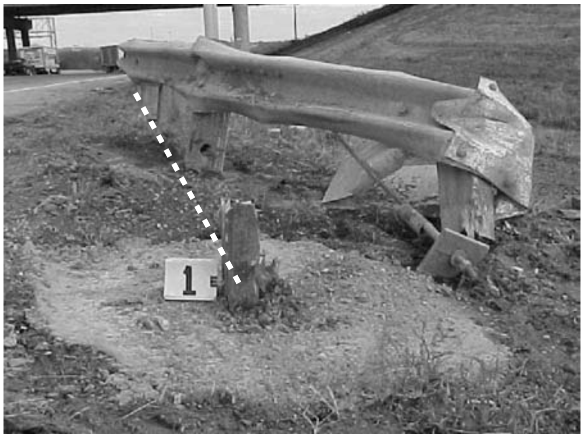


Figure 49. Measuring Groundline Post Deflection

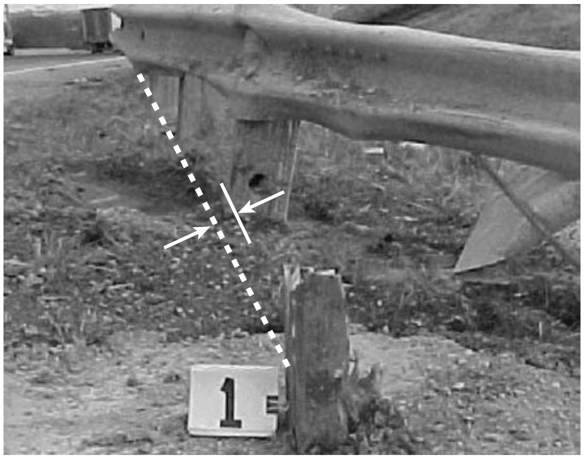


Figure 50. Measuring Groundline Post Deflection

Figure 51. Measuring Rail-Height Post Deflection

Damaged Components Inventory

An inventory of damaged hardware components includes counts of broken or bent posts (Figures 52 and 53), snagged posts (Figure 54), failed splices (Figure 55), failed guardrail bolts, and posts at which the rail was torn or broken (Figure 57).

Wooden posts break, whereas steel posts generally bend in an impact, as shown in Figures 52 and 53.

Post snagging suggests that there was some evidence of wheel-post contact, such as black tire marks on the post, a dig or a dent where the rim hit the post, or a small piece torn out where the wheel hit the post. Figure 54 shows an example of evidence of post snagging. Only indicate post snagging if there is physical evidence of contact between the post and the vehicle wheel.

Figure 55 shows an example of a splice failure, and Figure 56 shows a torn rail.

Figure 52. Broken Wood Posts

Figure 53. Bent Steel Weak Guardrail Post

Figure 54. Snagged Post

Figure 55. Splice Failure

Figure 56. Torn Rail

Damaged Length

The total damaged length of guardrail is measured parallel to the roadway with a measuring wheel or folding ruler, as shown in Figure 57. The damaged length is usually indicated by damaged components, but care should be taken to inspect beyond the region where there is bent metal to be sure that there are not paint scraps or rubber marks. Shallow angle impacts often are apparent as minor scrapes in advance of the bent metal. Vehicles also sometimes lose contact with the guardrail for a short time and then recontact the guardrail. The length of damage should include the length of all damage that resulted from the collision.

Figure 57. Damaged Length of Guardrail

Special Features

For terminals, measure the movement of the foundations of posts one and two at the groundline, the total damaged length of guardrail, and the movement of the terminal nose (distance upstream and lateral distance from edgeline). Figure 58 shows an example of movement of a nose four meters upstream and seven meters laterally. The dashed line represents the approximate original position of the terminal.

Figure 58. Nose Movement

For bridge-to-guardrail transitions, note if there is any evidence of wheel snagging on the end of the bridge railing, such as black tire marks or small dents.

DATA COLLECTION FORMS

One form for each hardware type should be used to record data during a site visit. This form should have an installation section to capture information about the characteristics of the hardware prior to the collision and a damage section to capture information about the hardware damage resulting from the collision. Separate forms have been prepared for a variety of hardware types including terminals, guardrails, and guardrail-bridge transitions. The forms developed to date are shown in Appendix A. If an impact damaged three different systems (e.g., a terminal, guardrail and transition) a separate form should be filled out for each damaged installation.

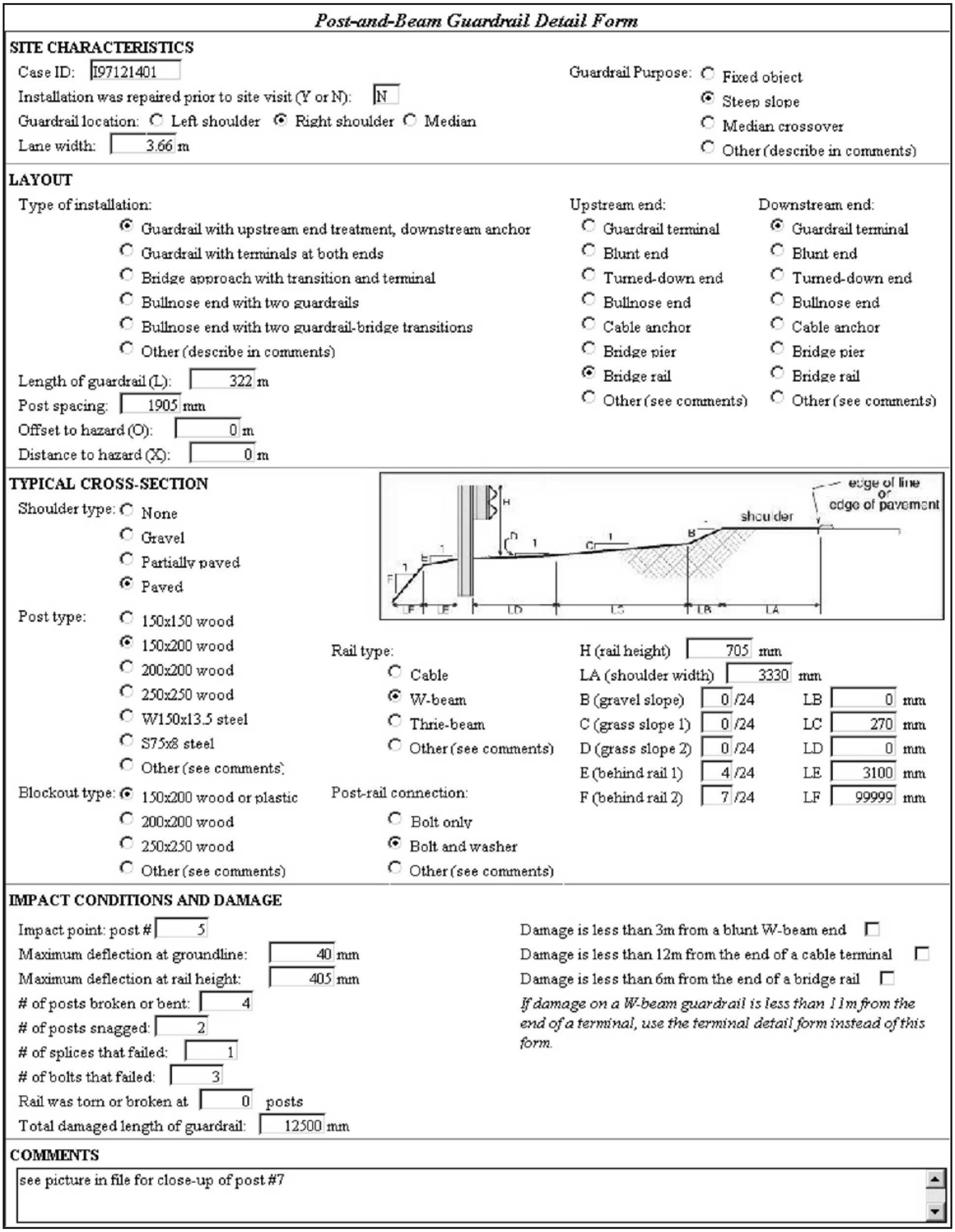
Guardrail Data

An example form for guardrails is shown in Figure 59.

Site Characteristics

Indicate if the damaged hardware was repaired prior to the site visit. If the installation was repaired before the site visit, site information like lane and shoulder widths, rail types, etc. can still be collected. The information about the damaged hardware will obviously not be available and need not be filled out.

The guardrail location relative to the roadway can be on the left or right shoulder or in a median. Choose the purpose from the choices given (i.e., fixed object, steep slope, or median crossover) or choose “other” and explain the purpose in the comments section at the bottom of the form. Determine the width of the lanes at or near the point of impact as described previously in “Field Procedures.”



Post-and-Beam Guardrail Detail Form

SITE CHARACTERISTICS

Case ID: I97121401

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

Guardrail location: ○ Left shoulder ● Right shoulder ○ Median

Lane width: 3.66 m

Guardrail Purpose:
- ○ Fixed object
- ● Steep slope
- ○ Median crossover
- ○ Other (describe in comments)

LAYOUT

Type of installation:
- ● Guardrail with upstream end treatment, downstream anchor
- ○ Guardrail with terminals at both ends
- ○ Bridge approach with transition and terminal
- ○ Bullnose end with two guardrails
- ○ Bullnose end with two guardrail-bridge transitions
- ○ Other (describe in comments)

Upstream end:
- ○ Guardrail terminal
- ○ Blunt end
- ○ Turned-down end
- ○ Bullnose end
- ○ Cable anchor
- ○ Bridge pier
- ● Bridge rail
- ○ Other (see comments)

Downstream end:
- ● Guardrail terminal
- ○ Blunt end
- ○ Turned-down end
- ○ Bullnose end
- ○ Cable anchor
- ○ Bridge pier
- ○ Bridge rail
- ○ Other (see comments)

Length of guardrail (L): 322 m

Post spacing: 1905 mm

Offset to hazard (O): 0 m

Distance to hazard (X): 0 m

TYPICAL CROSS-SECTION

Shoulder type:
- ○ None
- ○ Gravel
- ○ Partially paved
- ● Paved

Post type:
- ○ 150x150 wood
- ● 150x200 wood
- ○ 200x200 wood
- ○ 250x250 wood
- ○ W150x13.5 steel
- ○ S75x8 steel
- ○ Other (see comments)

Rail type:
- ○ Cable
- ● W-beam
- ○ Thrie-beam
- ○ Other (see comments)

H (rail height) 705 mm

LA (shoulder width) 3330 mm

B (gravel slope)	0 /24	LB	0	mm
C (grass slope 1)	0 /24	LC	270	mm
D (grass slope 2)	0 /24	LD	0	mm
E (behind rail 1)	4 /24	LE	3100	mm
F (behind rail 2)	7 /24	LF	99999	mm

Blockout type:
- ● 150x200 wood or plastic
- ○ 200x200 wood
- ○ 250x250 wood
- ○ Other (see comments)

Post-rail connection:
- ○ Bolt only
- ● Bolt and washer
- ○ Other (see comments)

IMPACT CONDITIONS AND DAMAGE

Impact point: post # 5

Maximum deflection at groundline: 40 mm

Maximum deflection at rail height: 405 mm

# of posts broken or bent: 4

# of posts snagged: 2

# of splices that failed: 1

# of bolts that failed: 3

Rail was torn or broken at 0 posts

Total damaged length of guardrail: 12500 mm

Damage is less than 3m from a blunt W-beam end ☐

Damage is less than 12m from the end of a cable terminal ☐

Damage is less than 6m from the end of a bridge rail ☐

If damage on a W-beam guardrail is less than 11m from the end of a terminal, use the terminal detail form instead of this form.

COMMENTS

see picture in file for close-up of post #7

Figure 59. Guardrail Detail Form

Layout

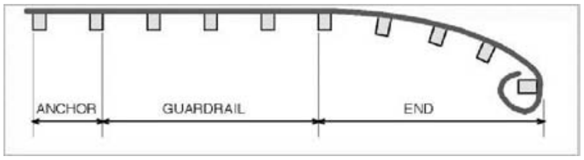


Figure 60. Guardrail Installation Scenarios

In the “layout” section, five general types of guardrail installation are described. Figure 60 also shows these installation scenarios. Choose the scenario that most closely matches the collision site or choose “other” if the installation is significantly different from all the choices. Indicate the type of hardware located at the upstream and downstream ends of the guardrail. If “other” is chosen for any characteristics, provide an explanation in the “comments” section. Record the length of the guardrail installation, post spacing, and the offset and distance to the nearest hazard, which are described in the “Field Procedures” section.

Impact Conditions and Damage

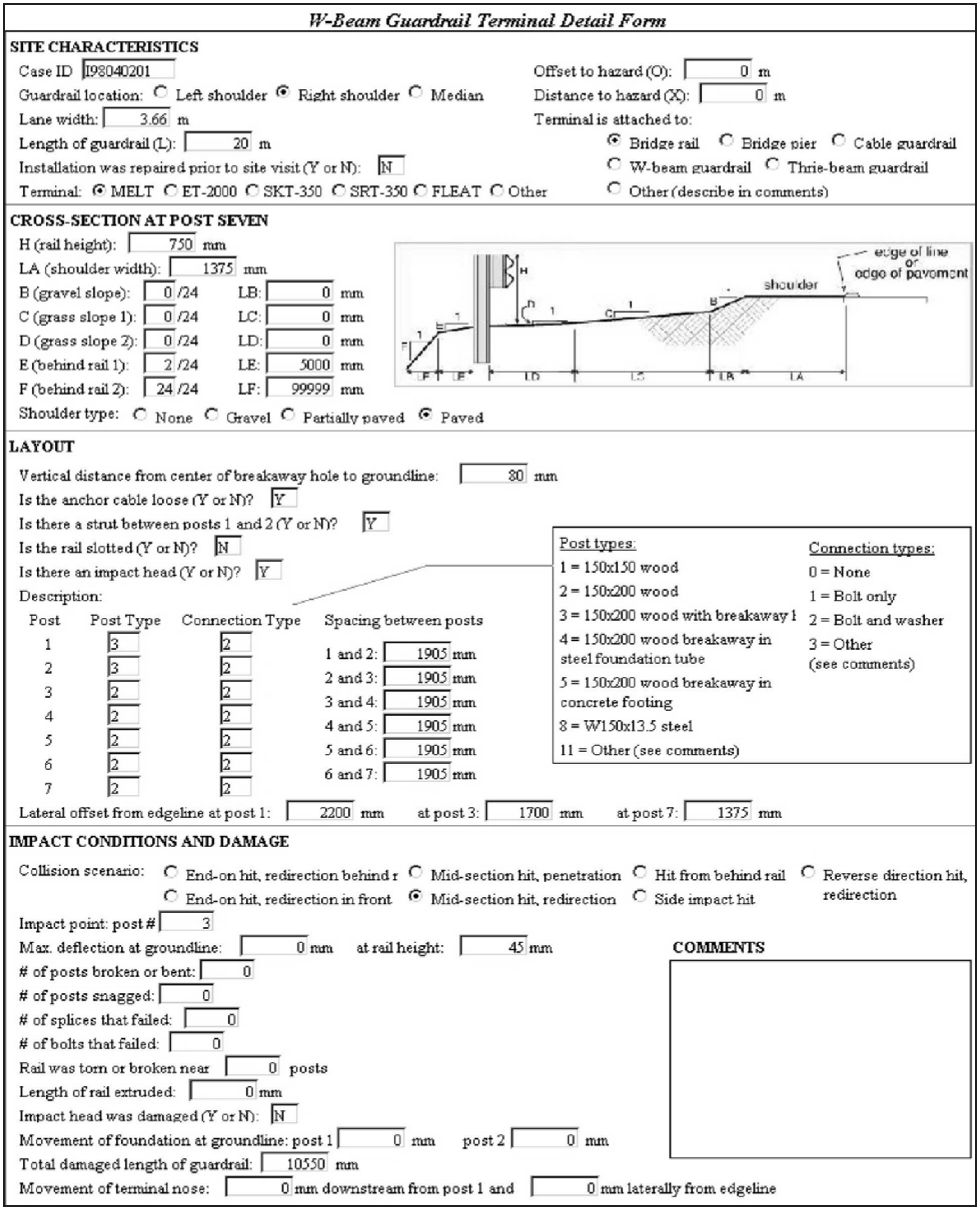
Indicate the post nearest to the impact point and record the maximum deflections at groundline and rail height, the damaged hardware inventory, and the total damaged length of guardrail as discussed in the “Field Procedures” section. Finally, indicate if the damage is less than three meters from a blunt W-beam end, 12 meters from a cable terminal end, or six meters from a bridge rail. This would indicate that another hardware form, such as a terminal or transition form, should be completed.

W-Beam Guardrail Terminal Data

A detailed form for W-beam guardrail terminals is shown in Figure 61.

Site Characteristics

Indicate the case ID and the guardrail location (i.e., left or right shoulder or in the median). Measure the lane width, the length of the terminal, and the offset and distance to the nearest hazard as described in the “Field Procedures” section. Indicate whether the installation was repaired prior to the site visit. Also, identify the type of hardware that the terminal is attached to (i.e., bridge rail or pier, cable or W-beam guardrail); if “other” is the appropriate choice, provide an explanation in the comments section of the form.



W-Beam Guardrail Terminal Detail Form

SITE CHARACTERISTICS

Case ID I98040201

Offset to hazard (O): 0 m

Guardrail location: ○ Left shoulder ● Right shoulder ○ Median

Distance to hazard (X): 0 m

Lane width: 3.66 m

Terminal is attached to:

Length of guardrail (L): 20 m

● Bridge rail ○ Bridge pier ○ Cable guardrail

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

○ W-beam guardrail ○ Thrie-beam guardrail

Terminal: ● MELT ○ ET-2000 ○ SKT-350 ○ SRT-350 ○ FLEAT ○ Other

○ Other (describe in comments)

CROSS-SECTION AT POST SEVEN

H (rail height): 750 mm

LA (shoulder width): 1375 mm

B (gravel slope): 0 /24 LB: 0 mm

C (grass slope 1): 0 /24 LC: 0 mm

D (grass slope 2): 0 /24 LD: 0 mm

E (behind rail 1): 2 /24 LE: 5000 mm

F (behind rail 2): 24 /24 LF: 99999 mm

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

LAYOUT

Vertical distance from center of breakaway hole to groundline: 80 mm

Is the anchor cable loose (Y or N)? Y

Is there a strut between posts 1 and 2 (Y or N)? Y

Is the rail slotted (Y or N)? N

Is there an impact head (Y or N)? Y

Description:

Post	Post Type	Connection Type
1	3	2
2	3	2
3	2	2
4	2	2
5	2	2
6	2	2
7	2	2

Spacing between posts

1 and 2: 1905 mm

2 and 3: 1905 mm

3 and 4: 1905 mm

4 and 5: 1905 mm

5 and 6: 1905 mm

6 and 7: 1905 mm

Post types:

1 = 150x150 wood

2 = 150x200 wood

3 = 150x200 wood with breakaway l

4 = 150x200 wood breakaway in steel foundation tube

5 = 150x200 wood breakaway in concrete footing

8 = W150x13.5 steel

11 = Other (see comments)

Connection types:

0 = None

1 = Bolt only

2 = Bolt and washer

3 = Other (see comments)

Lateral offset from edgeline at post 1: 2200 mm at post 3: 1700 mm at post 7: 1375 mm

IMPACT CONDITIONS AND DAMAGE

Collision scenario: ○ End-on hit, redirection behind r ○ Mid-section hit, penetration ○ Hit from behind rail ○ Reverse direction hit, redirection ○ End-on hit, redirection in front ● Mid-section hit, redirection ○ Side impact hit

Impact point: post # 3

Max. deflection at groundline: 0 mm at rail height: 45 mm

# of posts broken or bent: 0

# of posts snagged: 0

# of splices that failed: 0

# of bolts that failed: 0

Rail was torn or broken near 0 posts

Length of rail extruded: 0 mm

Impact head was damaged (Y or N): N

Movement of foundation at groundline: post 1 0 mm post 2 0 mm

Total damaged length of guardrail: 10550 mm

Movement of terminal nose: 0 mm downstream from post 1 and 0 mm laterally from edgeline

COMMENTS

Figure 61. Guardrail Terminal Detail Form

Cross-Section at the Last Post

Measure and record the characteristics of a cross-section at the last post of the terminal as described in the “Field Procedures” section.

Layout

Measure vertical distance from the center of the breakaway hole in the post to the ground and note whether the anchor cable is loose. To help in correctly identifying the terminal type, indicate whether there is a groundline strut between posts 1 and 2, whether the rail is slotted, and whether there is an impact head. Indicate the post type and rail-to-post connection type at each post (i.e., posts one through seven) and measure the spacing between the posts. Also measure and record the lateral offset from the edgeline at posts 1, 3, and 7. Details on these procedures are found in the “Field Procedures” section. These data help confirm the type of guardrail terminal that was involved.

Impact Conditions and Damage

Choose the most appropriate collision scenario from the possibilities on the form, which are illustrated in Figure 62. Indicate the post at which the impact occurred. Measure and record the maximum deflections of the terminal at groundline and at rail height, the damaged hardware inventory, the movement of the foundations of posts one and two at groundline, the total damaged length of guardrail, and the movement of the terminal nose as described in the “Field Procedures” section.

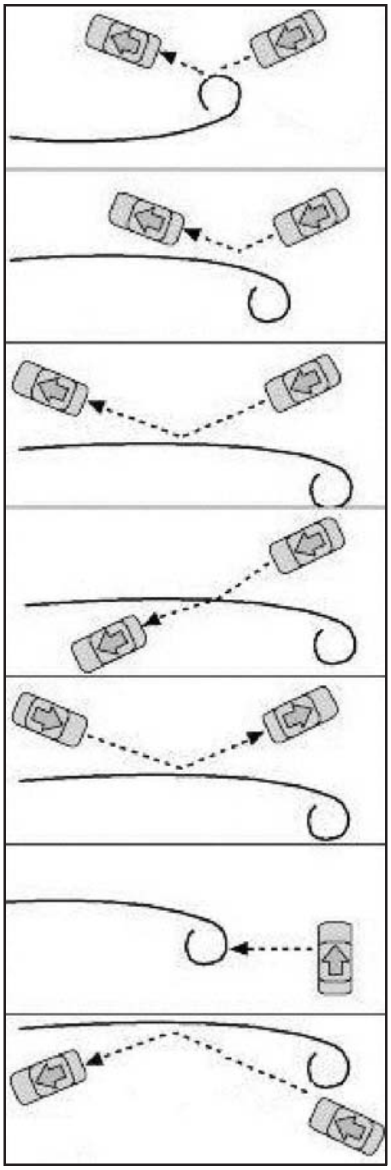
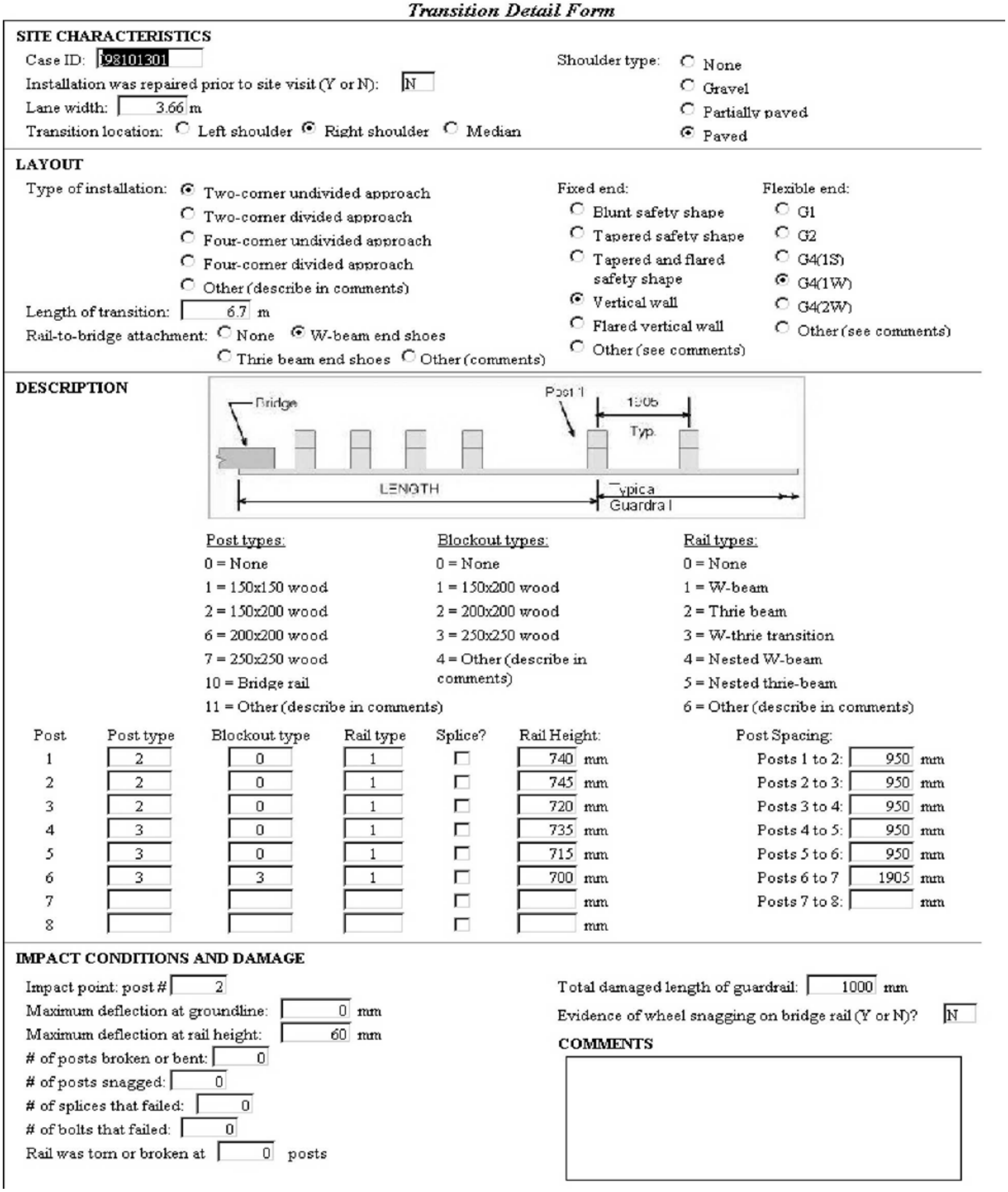


Figure 62. Terminal Impact Scenarios (End-on behind rail, End-on in front of rail, Mid-section redirection, Mid-section penetration, Reverse hit, Side impact, and Hit from behind rail)

Guardrail-Bridge Transition Data

A detailed form for guardrail-bridge transitions is shown in Figure 63.



Transition Detail Form

SITE CHARACTERISTICS

Case ID: 98101301

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

Lane width: 3.66 m

Transition location: ○ Left shoulder ● Right shoulder ○ Median

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

LAYOUT

Type of installation:
- ● Two-corner undivided approach
- ○ Two-corner divided approach
- ○ Four-corner undivided approach
- ○ Four-corner divided approach
- ○ Other (describe in comments)

Length of transition: 6.7 m

Rail-to-bridge attachment: ○ None ● W-beam end shoes ○ Thrie beam end shoes ○ Other (comments)

Fixed end:
- ○ Blunt safety shape
- ○ Tapered safety shape
- ○ Tapered and flared safety shape
- ● Vertical wall
- ○ Flared vertical wall
- ○ Other (see comments)

Flexible end:
- ○ G1
- ○ G2
- ○ G4(1S)
- ● G4(1W)
- ○ G4(2W)
- ○ Other (see comments)

DESCRIPTION

Post types:
0 = None
1 = 150x150 wood
2 = 150x200 wood
6 = 200x200 wood
7 = 250x250 wood
10 = Bridge rail
11 = Other (describe in comments)

Blockout types:
0 = None
1 = 150x200 wood
2 = 200x200 wood
3 = 250x250 wood
4 = Other (describe in comments)

Rail types:
0 = None
1 = W-beam
2 = Thrie beam
3 = W-thrie transition
4 = Nested W-beam
5 = Nested thrie-beam
6 = Other (describe in comments)

Post	Post type	Blockout type	Rail type	Splice?	Rail Height:
1	2	0	1	☐	740 mm
2	2	0	1	☐	745 mm
3	2	0	1	☐	720 mm
4	3	0	1	☐	735 mm
5	3	0	1	☐	715 mm
6	3	3	1	☐	700 mm
7				☐	mm
8				☐	mm

Post Spacing:
Posts 1 to 2: 950 mm
Posts 2 to 3: 950 mm
Posts 3 to 4: 950 mm
Posts 4 to 5: 950 mm
Posts 5 to 6: 950 mm
Posts 6 to 7 1905 mm
Posts 7 to 8: mm

IMPACT CONDITIONS AND DAMAGE

Impact point: post # 2
Maximum deflection at groundline: 0 mm
Maximum deflection at rail height: 60 mm
# of posts broken or bent: 0
# of posts snagged: 0
# of splices that failed: 0
# of bolts that failed: 0
Rail was torn or broken at 0 posts

Total damaged length of guardrail: 1000 mm
Evidence of wheel snagging on bridge rail (Y or N)? N

COMMENTS

Figure 63. Transition Detail Form.

Site Characteristics

Indicate the case ID, the shoulder type, and whether the damage to the installation was repaired prior to the site visit. Also record the lane width near the impact point.

Layout

Under “layout,” four types of installations are given. These installation types are also illustrated in Figure 64. Choose the scenario that most closely describes the collision site or choose “other” if the installation is significantly different from all the choices. If “other” is chosen, describe the site in the “comments” section.

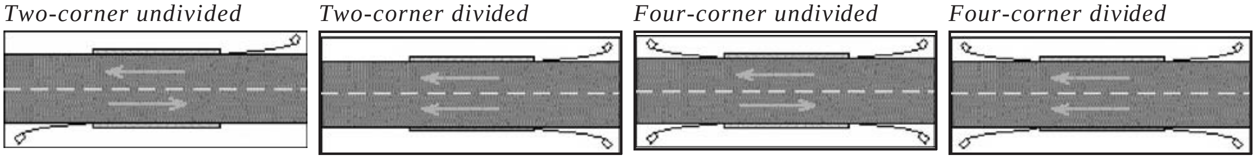


Figure 64. Transition Installation Types

Indicate the type of fixed end and flexible end of the transition from the choices given. The flexible end is usually one of the guardrail types discussed previously. The fixed end can be a safety shape, vertical wall, or other type. A safety shape or vertical wall can be flared away from the road, and a safety shape can also be tapered down to the road. Figure 65 shows a safety shape concrete barrier, and Figure 66 shows a vertical flared transition end.

Figure 65. Concrete Safety Shape Barrier

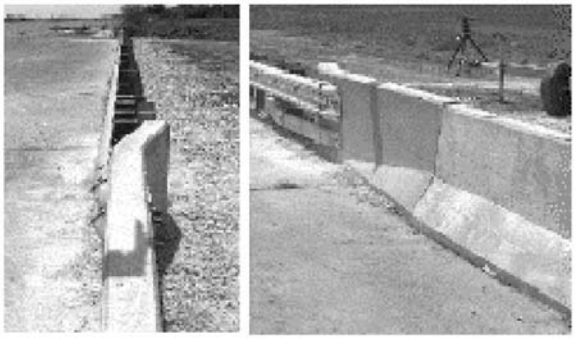


Figure 66. Vertical Flared Transition

To describe the transition, record the following information for up to eight posts, starting at the last post of the typical guardrail (the first post of the transition): the post type, block type, whether there is a splice at the post, the rail height, and the post spacing. Also measure the total length of the transition and indicate what type of rail-to-bridge attachment is used.

Impact Conditions and Damage

Indicate the post at which the impact occurred and record the maximum deflections at groundline and rail height. Also indicate the total damaged length of transition and the damaged hardware inventory. Finally, note if there is any evidence of wheel snagging on the end of the bridge railing.

Concrete Barrier Data

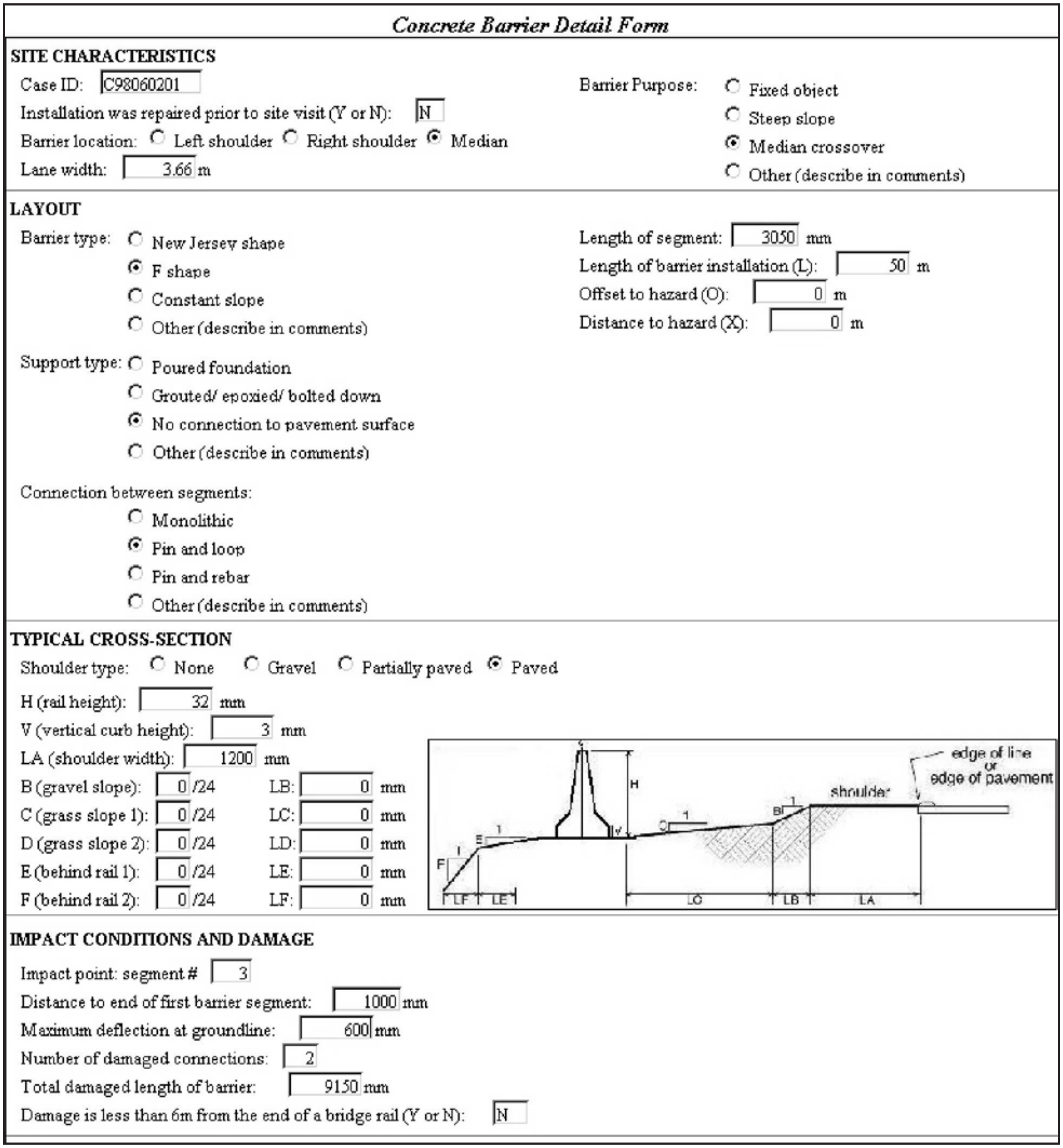
A detail form for concrete barriers is shown in Figure 67. Similar information is collected as for guardrail installations.

Site Characteristics

Indicate the barrier location relative to the roadway (i.e., left or right shoulder or in a median) and whether the damaged hardware was repaired prior to the site visit. Choose the purpose from the choices given (i.e., fixed object, steep slope, or median crossover) or choose “other” and explain the purpose in the comments section at the bottom of the form. Determine the width of the lanes at or near the point of impact as described previously in “Field Procedures.”

Layout

The “layout” section describes the concrete barrier. Indicate the shape of the barrier (i.e., New Jersey shape, F shape, constant slope, or “other”), the support type, and the connection between barrier segments from the choices given. If “other” is chosen for any characteristics, provide an explanation in the “comments” section. Also record the length of the barrier segment. The length of the barrier installation, post spacing, and the offset and distance to the nearest hazard are described in the “Field Procedures” section.



Concrete Barrier Detail Form

SITE CHARACTERISTICS

Case ID: C98060201

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

Barrier location: ○ Left shoulder ○ Right shoulder ● Median

Lane width: 3.66 m

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

LAYOUT

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

Length of segment: 3050 mm

Length of barrier installation (L): 50 m

Offset to hazard (O): 0 m

Distance to hazard (X): 0 m

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

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

TYPICAL CROSS-SECTION

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

H (rail height): 32 mm

V (vertical curb height): 3 mm

LA (shoulder width): 1200 mm

B (gravel slope): 0 /24 LB: 0 mm

C (grass slope 1): 0 /24 LC: 0 mm

D (grass slope 2): 0 /24 LD: 0 mm

E (behind rail 1): 0 /24 LE: 0 mm

F (behind rail 2): 0 /24 LF: 0 mm

IMPACT CONDITIONS AND DAMAGE

Impact point: segment # 3

Distance to end of first barrier segment: 1000 mm

Maximum deflection at groundline: 600 mm

Number of damaged connections: 2

Total damaged length of barrier: 9150 mm

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

Figure 67. Concrete Barrier Form

Typical Cross-Section

The measurements needed to record the typical cross-section are also described in the “Field Procedures” section. The only difference between a post-and-beam guardrail cross-section and a concrete barrier cross-section is that two heights are measured for the concrete barrier. “H” is the height to the top of the barrier, and “V” is the height of the vertical curb at the base of the barrier.

Impact Conditions and Damage

Indicate which segment was impacted first and how far away the impact point was from the end of the segment. Record the maximum deflection at groundline, the number of segment connections damaged, and the total damaged length of barrier as discussed in the “Field Procedures” section. Finally, indicate if the damage is less than six meters from a bridge rail.

CHAPTER FIVE

UNREPORTED COLLISIONS

Presumably, many impacts with roadside safety hardware are so minor that the vehicle is driven away and the collision is never reported to either the police or the highway maintenance agency. If police-reported collisions are considered to document roadside hardware failures, unreported collisions represent the undocumented successes of roadside hardware since they result in neither injury to occupants nor serious damage to the vehicles. Estimating the number of unreported collisions that occur on typical roadside hardware systems has been very difficult since there is no official source of such information. In many states, there is even a threshold for the monetary amount of property damage required for an accident report to be filed.

The control site methodology is an attempt to observe unreported as well as reported collisions. Control sites are specific locations that data collectors inspect at regular intervals to determine if the barrier has been struck. This technique provides an estimate but there are limitations. First, some collisions may leave no damage at all and therefore will not be observable. Second, it is difficult to determine if a series of dents, scrub marks and scratches is the result of one or several impact events. Inspecting the system frequently will help to reduce this problem. Third, some minor damage is caused by maintenance activities like grass mowing and snow plowing.

It is not necessary to perform control section surveys in order to perform an in-service evaluation. The methodology is included here for those agencies that are interested in making more direct measurements of the unreported collision problem.

FIELD PROCEDURES

Surveying Control Sections for Damage

Data collectors should visit the control site periodically (e.g. every week or two), walk along the barrier, and carefully scan the barrier for evidence of damage. While some collisions may be so minor that they leave no trace, many more will leave some physical evidence such as rub marks from tires, small dents and scratches, slightly deformed posts and other minor damage. The type of damage that can be observed is different for each type of roadside hardware system. Tire scrub marks are easily observed on concrete barriers, bent and broken posts are common on cable guardrails, and bent nose sections are common on guardrail terminals like the BCT and MELT. Figures 68 through 70 show some examples of damage that may be observed in minor unreported collisions.

Figure 68. Bent post (cable guardrail)

When damage is observed, the date, location of the damage and type of damage should be recorded and the damage should be marked to indicate that it has been recorded. For example, if concrete barriers are being monitored, tire scrub marks can be painted white. Each time the data collection team inspects the concrete barrier, new scrub marks will be obvious since the older scrub marks are painted over. For steel-beam guardrails, scrub marks, scratches and dents can be painted with a silver or grey paint.

Figure 69. Marks on W-beam guardrail.

An “unreported collision inspection log” form is included in the ISPE workbook. Figure 71 shows part of a completed form based on a study section in Iowa.

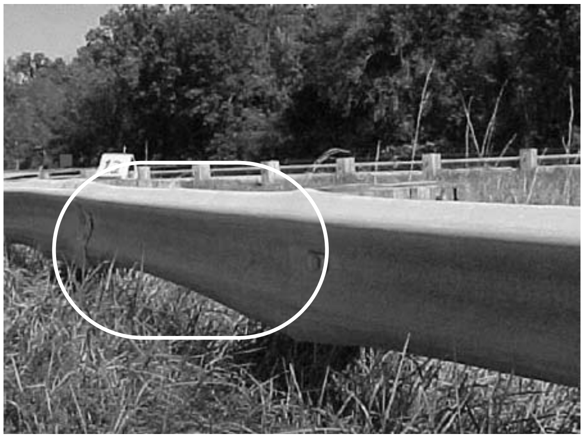
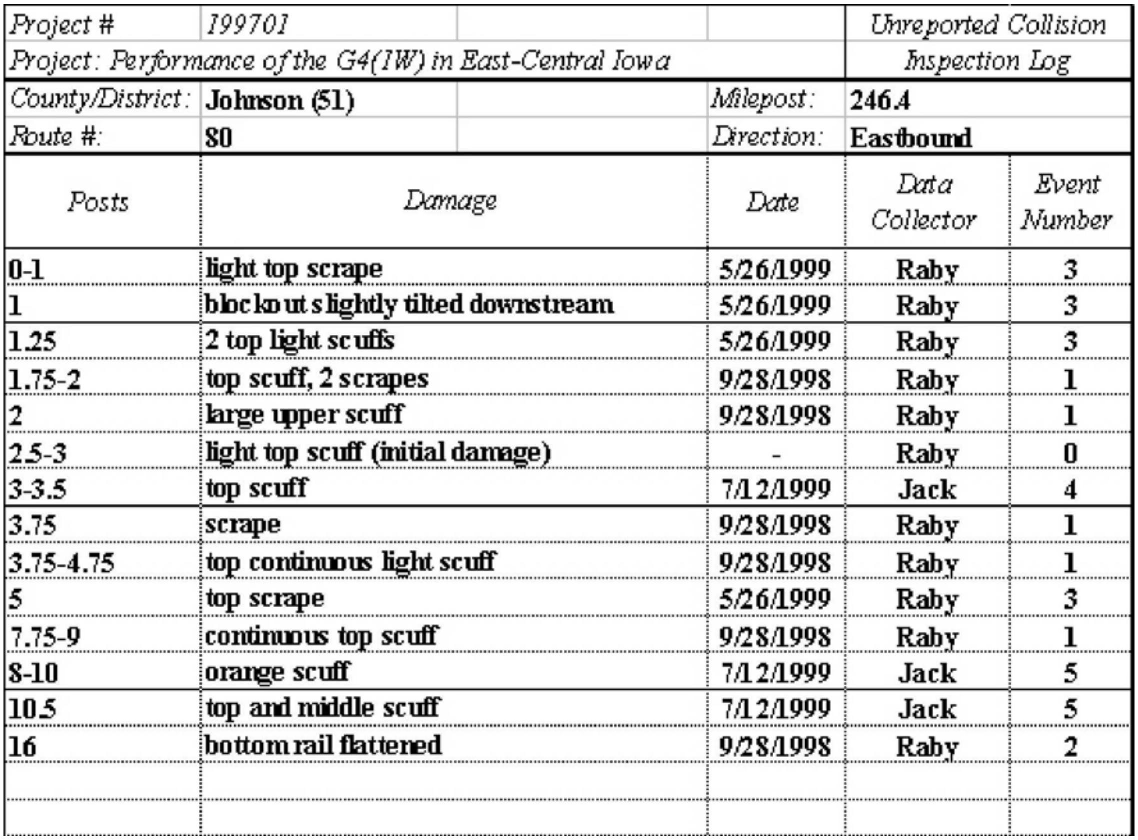


Figure 70. Deformation of W-beam guardrail.



Project #	199701		Unreported Collision Inspection Log
Project: Performance of the G4(1W) in East-Central Iowa			
County/District:	Johnson (51)	Milepost:	246.4
Route #:	80	Direction:	Eastbound

Posts	Damage	Date	Data Collector	Event Number
0-1	light top scrape	5/26/1999	Raby	3
1	blockout slightly tilted downstream	5/26/1999	Raby	3
1.25	2 top light scuffs	5/26/1999	Raby	3
1.75-2	top scuff, 2 scrapes	9/28/1998	Raby	1
2	large upper scuff	9/28/1998	Raby	1
2.5-3	light top scuff (initial damage)	-	Raby	0
3-3.5	top scuff	7/12/1999	Jack	4
3.75	scrape	9/28/1998	Raby	1
3.75-4.75	top continuous light scuff	9/28/1998	Raby	1
5	top scrape	5/26/1999	Raby	3
7.75-9	continuous top scuff	9/28/1998	Raby	1
8-10	orange scuff	7/12/1999	Jack	5
10.5	top and middle scuff	7/12/1999	Jack	5
16	bottom rail flattened	9/28/1998	Raby	2

Figure 71. Partially Completed Inspection Log.

Estimating Number of Events

The number of instances of denting, scrubbing, scratching and post deflection can be used to estimate the number of impacts with the roadside hardware. If any of these events were reported to the police the ratio between reported and unreported collisions can be calculated. Grouping a set of gouges, scraps and paint marks into events is perhaps the most difficult and subjective feature of this methodology. The data collector must try to associate the various marks into events. Sometimes this is straightforward, as when the same color paint mark is left at several different locations along the guardrail. Frequent surveys of the site will alleviate this problem since less damage will appear between surveys.

CHAPTER SIX

DATA STORAGE AND QUALITY CHECKS

Data collected should be stored in two ways. First, copies of police and maintenance reports, data collection forms, photographs, and any other data relevant to the case should be kept in a hardcopy file. Information such as collision location, driver name and statistics are not usually needed for analysis but may be helpful in tracking data collection problems and verifying data. Second, data recorded on data collection forms should be entered into an electronic database for analysis and data sharing. The database should contain no information that threatens the privacy of persons involved in any of the studied collisions. It should, however, contain all data that may be used in analyses, perhaps even photographs, so that the database is useful to others without access to the hardcopy files. A database stores these data in tables. Spreadsheet applications like Microsoft Excel and Quattro Pro and database applications like Microsoft Access can be used to create databases.

A sample database has been prepared in Microsoft Access 2000 and is available on the Internet at http://www.wpi.edu/Academics/Depts/CEE/Roadsafe/ISPE/procedures.html. This database contains the general and hardware-specific data collection forms discussed in previous chapters. Data entered into the forms in the database are stored in a number of tables. Many different queries can be run to aid in data analyses, and summary reports can be produced; several examples are set up in the sample database. The structure of the database is shown in Figure 72.

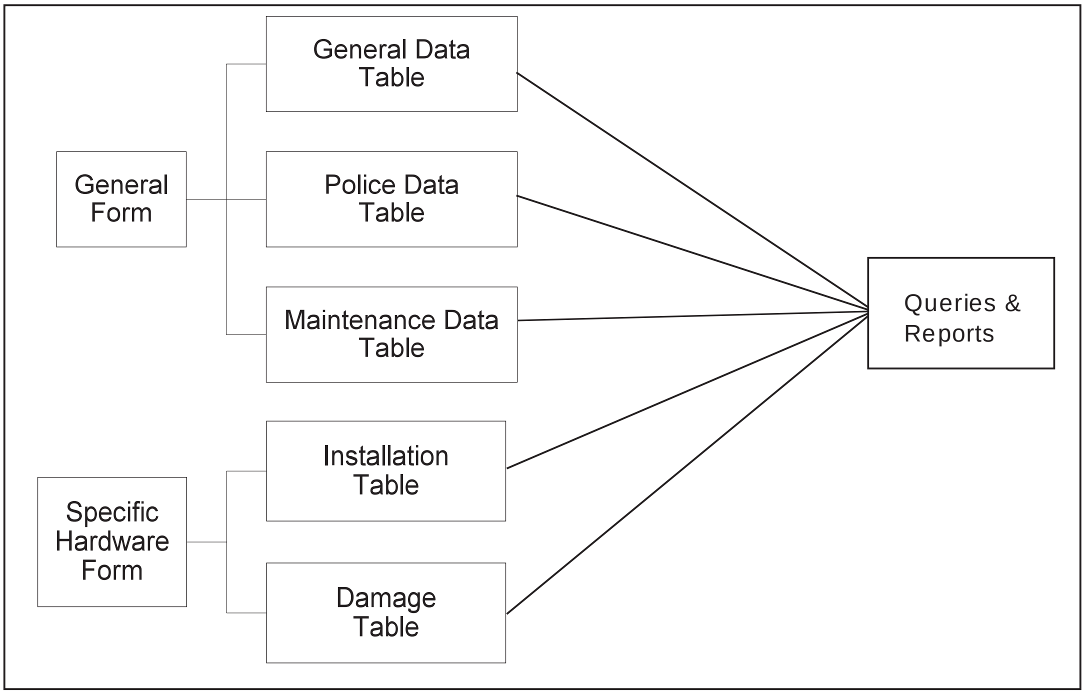


Figure 72. Database structure

Quality checks should be built into the analysis procedures. Quality checks use variables to check the consistency of the data. These checks usually must be designed for the specific hardware being used. There are two basic types of quality checks: range checks and consistency checks.

Range checking involves verifying that each data element is within a prescribed range appropriate for that particular data element. For example, dates of collisions must fall within the dates of the study. Another example involves physical measurements like rail height and post spacing. The post spacing should be less than 2 m for most common types of barriers and rail heights should in general be less than 1 m. These ranges do not indicate the correctness of the installation but rather the reasonableness of the data. Whenever a data element is included in the data, a range check should be added that automatically establishes the validity of each data element. For example, in a Microsoft Access database, each data element can have a validation rule assigned to it to perform a range check.

Consistency checks involve comparing redundant information within the data and ensuring that the information is consistent. For example, if a particular device is coded as a BCT but the data also indicate that there is a groundline strut, then the analyst should be notified that there is a possible error in the data since BCT terminals do not use a groundline strut. Similarly if the post offsets at post 1, 3 and 7 are dramatically different than the design values, the original data should be checked. Consistency checks usually must be designed for each ISPE since the types of hardware being studied will be different.

INSTALLATION QUALITY SCORE

One type of quality checking that can be done is an assessment of the quality of hardware installations. In order for a roadside safety device to function as intended, the physical properties of the system should conform as closely as possible to the details used in the crash tests. If the physical details depart significantly from the design details, the system may not perform as intended. This will affect the severity of collisions and the collision rates calculated in the data analysis.

As an example, an installation quality score was developed in order to quantify the overall correctness of a particular BCT or MELT terminal installation. The score is a single number between zero and ten, with zero representing an installation where all the characteristics were within reasonable construction tolerances. A score of ten represents a system where all the characteristics were outside of reasonable tolerances. Since the characteristics of the BCT and the MELT differ from each other, the scoring method is slightly different for each of the systems. The scoring procedure progresses as follows:

1. The rail height at the last post of the BCT or MELT is measured. The nominal design value is 685 mm. If the measured height is more than 25 mm above or below the nominal value, a penalty of one point is assessed.

2. The distance from the ground surface to the center of the breakaway hole at post one is measured. The nominal design value is 90 mm; if the measured value is greater than 115 mm or less than 25 mm, a penalty of one point is assessed.

3. Posts one and two should be breakaway posts set either in concrete or a steel foundation tube. If the post type or foundation is incorrect, a one-point penalty is assessed.

4. The spacing between the posts is an important design variable, since the rail will buckle around the posts in an end-on impact. If there are incorrectly spaced posts, a one-point penalty is assessed. The tolerance for measuring the post spacing is equal to the length of the guardrail bolt slot (e.g., ± 65 mm).

5. The offset to the first post is the perpendicular distance from the face of the first post to a line tangent to the face of the main guardrail. The nominal design value is 1220 mm. This is one of the most frequently deficient characteristics of guardrail terminals because it is often difficult to install the terminal with adequate offset on a slope. If the offset is more than ±300 mm from the desired 1220-mm value, a penalty of one point is assessed.

6. Sometimes the first post offset is much too small. In addition to the penalty listed in the previous step, if the first post is less than 620 mm, an additional one-point penalty is assessed.

7. The flare of the system describes the shape of the curved rail. The BCT and MELT have different flares, and the shape of the flare is considered an important design element. The location of each post could be measured to assess the correctness of the flare, but only the offset to the third post is used in this scoring procedure for simplicity. If the offset to the third post is more than 150 mm from its nominal design location (e.g., 550 mm for both BCT systems and 355 for the MELT), a one-point penalty is assessed.

8. The anchor cable provides a load path from the guardrail into the foundation. If the cable is too loose, downstream loading may fracture the first breakaway post rather than load the foundation. If the cable is noticeably loose, a one-point penalty is assessed.

The foregoing eight items are necessary for scoring both the BCT and MELT. For MELT systems, two additional items should be scored:

9. If the groundline strut between posts one and two is missing, a one-point penalty is assessed.

10. If there are any bolts attaching posts two through six to the guardrail, a one-point penalty is assessed. The MELT should not be bolted at these locations, and a bolt would cause incorrect buckling behavior in an end-on impact.

Once all the penalties have been assessed, they are summed. The total is multiplied by ten and then divided by the number of items (e.g., eight for the BCT systems or ten for the MELT). The resulting value is the installation quality score. Table 4 shows a sample score sheet for a wood-post BCT in Iowa, and Figure 73 shows the BCT system.

Table 4. Example installation score sheet for a wood-post BCT in Iowa.

Item	Description	Value	YES	NO
1.	Rail height at post seven is between 660 and 710 mm.	705 mm	1	
2.	Distance from ground to breakaway hole between 25 and 115 mm.	45 mm	1	
3.	Post one and two are breakaway posts set in concrete or a steel tube.			1
4.	Spacing between all posts is 1905 mm.		1	
5.	Offset to post one is between 620 and 1820 mm.	1023 mm	1	
6.	Offset to post one is between 920 and 1520 mm.	1023 mm	1	
7.	Offset to post three is between 400 and 700 mm.	546 mm	1	
8.	The anchor cable is not loose.		1	
	Sum the number of “NO” entries. Multiply by 10 and divide by the number of questions to obtain score		1x10/8 =1.25	

Figure 73. Example Iowa Wood-post BCT

Installation quality scores were calculated for 93 BCT and MELT installations in Iowa and North Carolina using the procedure described above. The distribution of installation quality scores is shown in Table 5. The scores have been grouped into five categories as follows: excellent (score≤1), good (1 <score≤3), fair (3 <score≤5), poor (5 <score≤7) and bad (score> 7). The category divisions are arbitrary, but they serve to divide the installations into reasonable groups. In some cases it was not possible to calculate an installation quality score because all the information needed was not available. This generally occurred when a BCT or MELT installation was so severely damaged in a collision that the pre-impact condition of the system could no longer be assessed. Cases where there was not sufficient information to calculate the quality score were discarded from the data summarized in Table 5.

As shown in Table 5, of the BCT installations that could be scored in Iowa, 96 percent were at least fair (score≤5) and 60 percent were categorized as “good” or “excellent” (score≤3). Similarly, over 90 percent of the MELT installations in both states were categorized as “fair” or better and almost 60 percent were categorized as “good” or “excellent.” However, almost 30 percent of the BCT installations in North Carolina were “poor” or “bad.” The data indicate that it is not unreasonable to expect field installations to conform to the construction tolerances used in the scoring procedure, since good and excellent installations were found in the field, but that a number of poor installations are in place.

Table 5. Distribution of installation quality scores for BCT and MELT installations in Iowa and North Carolina.

Device	Excellent		Good		Fair		Poor		Bad		Total
	No.	%	No.	%	No.	%	No.	%	No.	%	No.
Iowa Cases											
BCT	4	16	11	44	9	36	1	4	0	0	25
MELT	1	9	6	55	3	27	1	9	0	0	11
North Carolina Cases											
BCT	1	2	15	35	15	35	5	12	7	16	43
MELT	1	7	7	50	5	36	1	7	0	0	14
Total	7	8	39	42	32	34	8	9	7	8	93

This type of scoring procedure could be used to plan terminal upgrades or as an acceptance criterion for construction. For example, a state might survey its guardrail terminals and calculate the installation scores. The score is a measure of the priority that should be given to repairing or upgrading the terminal: installations characterized as “bad” should be brought into conformance as soon as practical, systems categorized as “poor ” should be upgraded next, and so on. Improving the “poor” installations in the data collection area would be inexpensive and would likely decrease the likelihood of observing an injury collision.

CHAPTER SEVEN

ANALYSIS

The number of available cases will determine the level of sophistication of analysis that can be applied to the data collected in an in-service evaluation. As discussed in Chapter 2, any analysis should take into account statistical significance. If an in-service evaluation is concerned with a piece of hardware that will likely be struck infrequently (e.g., a new guardrail terminal) then anecdotal information may be all that will be developed. Sometimes there are enough cases that clinical analysis on a case-by-case basis yields some new insights into the barrier performance. For evaluations with larger numbers of available cases, several rates and measures can be calculated.

COLLISION RATES AND PROBABILITIES

For reported crashes, gross rates such as number of crashes per year by type of device and roadway are easily obtained. Rates per million passing vehicles should also be calculated using traffic volume data. Calculation of crash rates for longer objects such as roadside barriers requires knowledge about the amount and location of the barrier in place to develop reasonable precision. These types of rates can be used as performance measures. If other roadside hardware has been studied and similar rates calculated, these types of gross summary statistics can provide a very useful comparison between devices.

The purpose of roadside hardware is to prevent or at least minimize the chance of vehicle occupant injuries or deaths in collisions. Property damage crashes, therefore, can be considered successful crashes since no one was injured or killed. Also, the threshold for reporting property damage collisions is often different in different localities and may even be different based on the weather at the time of the collision. For these reasons, injury collision rates are the most useful.

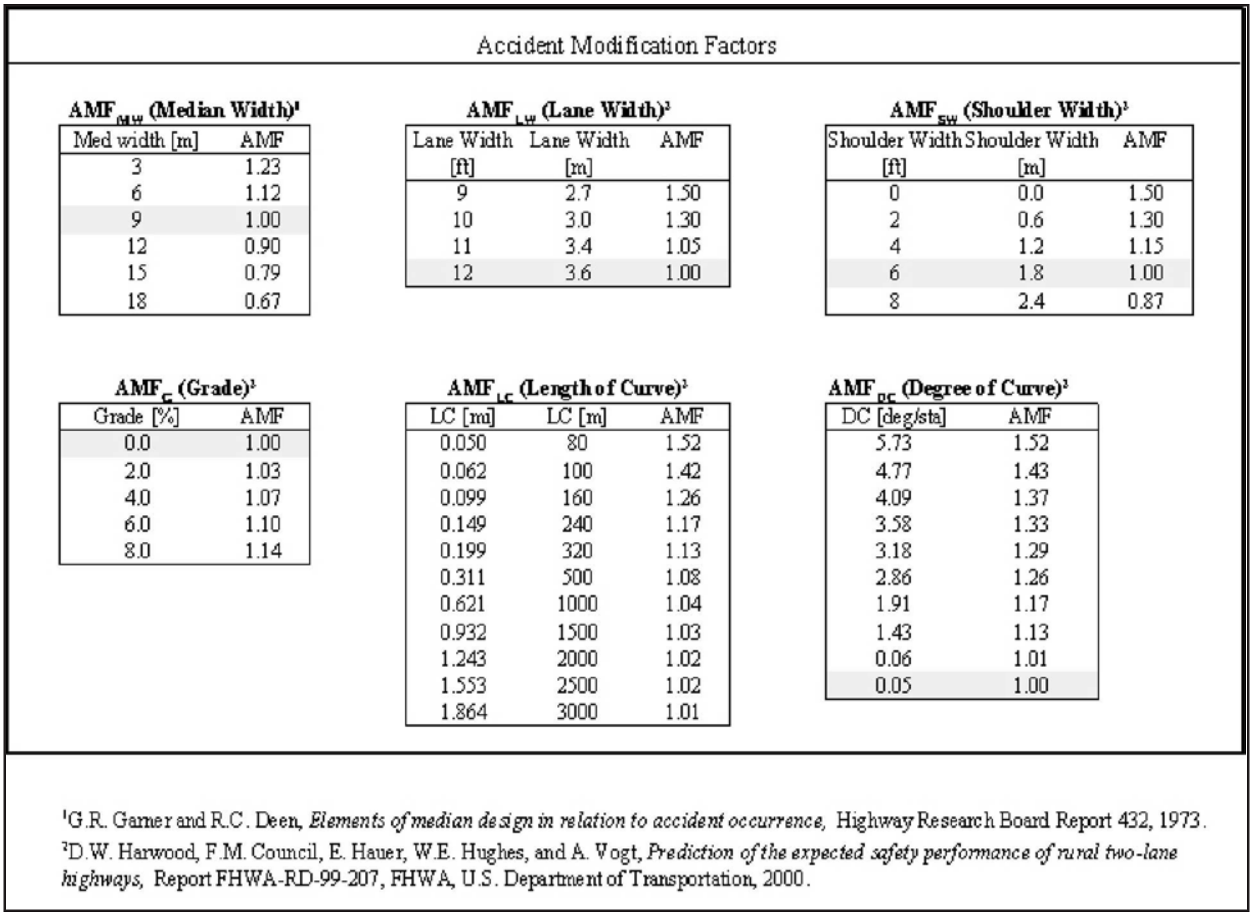
Effect of Highway Geometry on Collision Rates

Table 6. Properties of the standard reference cross-section.

Characteristic	**Standard**
Lane width	3.6m
Shoulder width	1.8m
Roadside hazard rating	3
Driveway density	3 per km
Horizontal curvature	None
Vertical curvature	None

In order to compare the performance of two devices, the geometric characteristics of the sites must be taken into account. Lane and shoulder widths, median widths, horizontal and vertical curvature, etc. all contribute to the frequency of collisions at a particular site. In 2000, Harwood *et al* compiled all the available studies on the effect of highway characteristics on collision rates and attempted to develop comprehensive models.*(4)* The models were reviewed by an expert panel, which further amplified the method using their expert judgment and combined experience. Harwood *et al* developed a base model that predicts the total number of collisions on a roadway segment for a two-lane rural road with a standard cross-section. The standard cross-section is defined in Table 6.

The base model developed by Harwood *et al* represents nominal site conditions; it does not account for the effects of specific geometric and traffic elements on the collision rate for a specific roadway segment. The base collision frequency determined by the base model is therefore adjusted using Accident Modification Factors (AMFs). AMFs are multiplicative factors that adjust the base collision frequency to reflect the effects of the geometric or traffic elements at a site. An AMF of 1.0 represents the nominal or base value for each geometric element. For example, if 3.6-m wide lanes are used in a particular segment, the AMF for lane width is equal to 1.0 since the specific site condition and the condition assumed in the base model are the same. Any element that increases the collision frequency has an AMF greater than 1.0; an AMF of less than 1.0 represents an element that reduces the collision frequency to lower than the nominal value. Values for the AMFs are shown in Figure 74. The minimum and maximum values for each AMF are shown, as well as several values inside the range. Other values between the minimum and maximum can be calculated by linear interpolation.



Accident Modification Factors

AMF_{MW} (Median Width)[1]

Med width [m]	AMF
3	1.23
6	1.12
9	1.00
12	0.90
15	0.79
18	0.67

AMF_{LW} (Lane Width)[2]

Lane Width [ft]	Lane Width [m]	AMF
9	2.7	1.50
10	3.0	1.30
11	3.4	1.05
12	3.6	1.00

AMF_{SW} (Shoulder Width)[2]

Shoulder Width [ft]	Shoulder Width [m]	AMF
0	0.0	1.50
2	0.6	1.30
4	1.2	1.15
6	1.8	1.00
8	2.4	0.87

AMF_{G} (Grade)[2]

Grade [%]	AMF
0.0	1.00
2.0	1.03
4.0	1.07
6.0	1.10
8.0	1.14

AMF_{LC} (Length of Curve)[2]

LC [mi]	LC [m]	AMF
0.050	80	1.52
0.062	100	1.42
0.099	160	1.26
0.149	240	1.17
0.199	320	1.13
0.311	500	1.08
0.621	1000	1.04
0.932	1500	1.03
1.243	2000	1.02
1.553	2500	1.02
1.864	3000	1.01

AMF_{DC} (Degree of Curve)[2]

DC [deg/sta]	AMF
5.73	1.52
4.77	1.43
4.09	1.37
3.58	1.33
3.18	1.29
2.86	1.26
1.91	1.17
1.43	1.13
0.06	1.01
0.05	1.00

[1] G.R. Garner and R.C. Deen, *Elements of median design in relation to accident occurrence,* Highway Research Board Report 432, 1973.

[2] D.W. Harwood, F.M. Council, E. Hauer, W.E. Hughes, and A. Vogt, *Prediction of the expected safety performance of rural two-lane highways,* Report FHWA-RD-99-207, FHWA, U.S. Department of Transportation, 2000.

Figure 74. Accident Modification Factors

From the historical number of collisions, geometric characteristics, and traffic volume of a roadway segment, a base injury collision rate can be back calculated for a roadside device that is independent of geometry and roadside characteristics. Base injury collision rates for different types of hardware can be directly compared since the geometry, roadside characteristics and traffic exposure have been standardized. A base injury collision rate is the number of injury-causing collisions per million vehicle-kilometers traveled past the device on a standard cross-section of roadway. It is expressed by the following equation:

$$\hat{R}_h = \frac{\sum_{j=1}^{n} C_j}{\sum_{j=1}^{n} AADT(365)\, L_h \times \prod_{i=1}^{m} AMF_i}$$

where $\hat{R}_h$ = base injury collision rate for hardware h on a road section made up of n segments, C_h = number of injury collisions on segment j,

$AADT$ = annual average daily traffic volume (vehicles/day) on segment j,

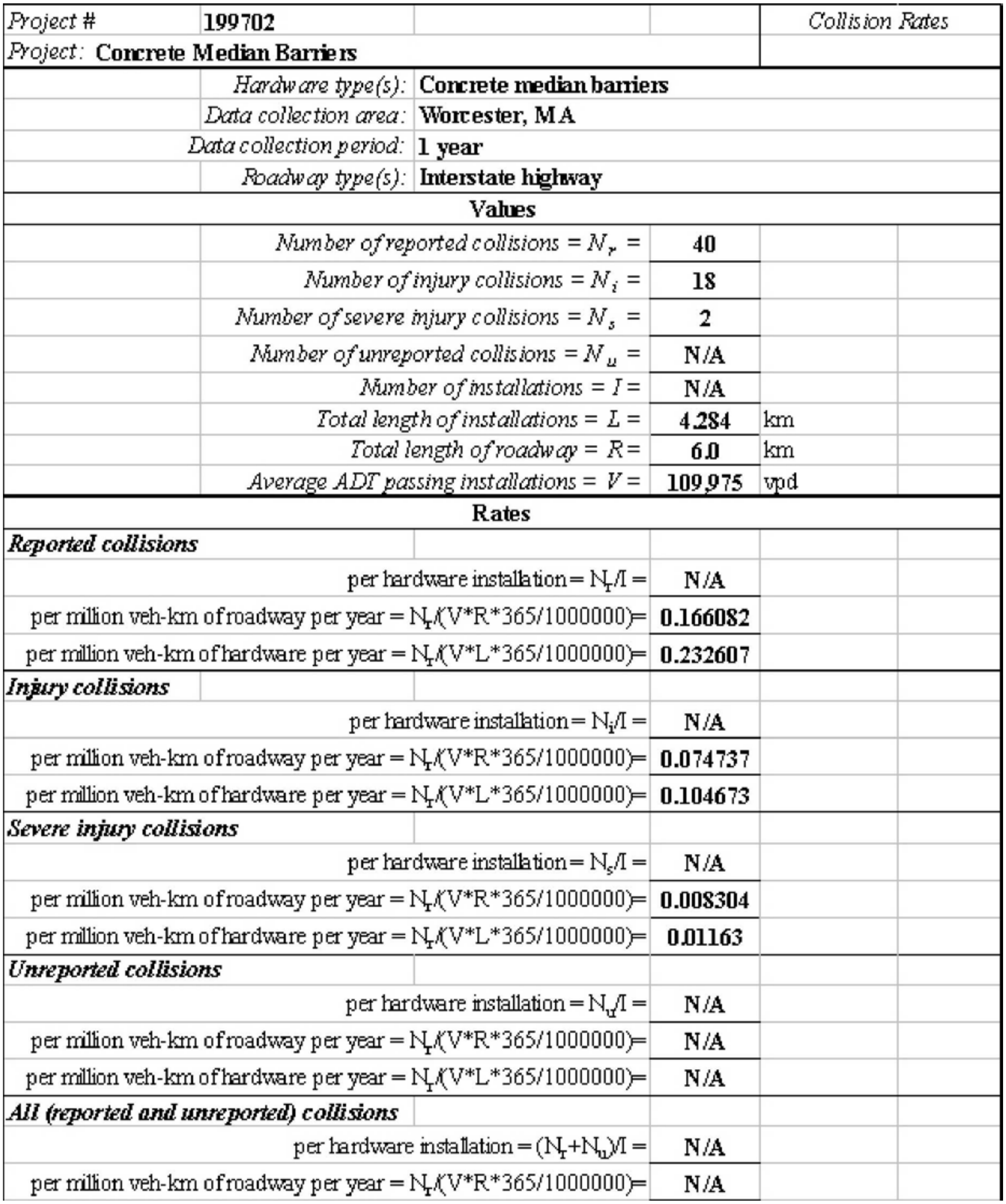
L_h = length of hardware h on segment j, and

AMF_i = m accident modification factors for segment j

This base injury collision rate is used to compare two or more features or devices.

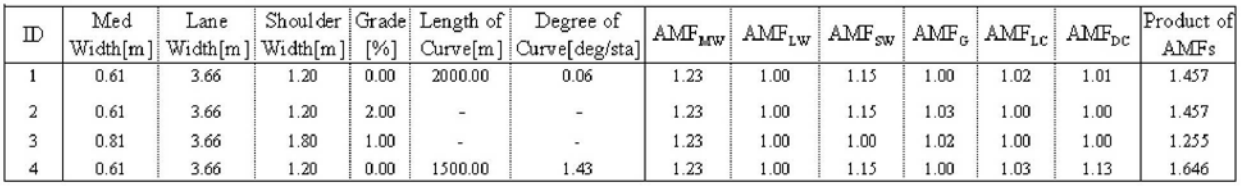
The ISPE workbook contains a form called “collision rates” that can be used to find various rates associated with the collisions. Figure 75 shows an example of a completed form. In this example, in one year on four sections of a highway there were forty collisions involving concrete median barriers (CMBs), eighteen of which resulted in injuries. The barrier inventory indicates there were 4.284 km of guardrails installed on 6.0 km of highway. The average AADT was 109,975 vehicles per day. With these data, several rates can be calculated for the CMBs. For example, the overall injury collision rate is 0.1047 injury collisions/million vehicle-km traveled past a CMB.

Figures 76a through 76c illustrate the process of calculating base collision rates. The first step, shown in Figure 76a, is to assign AMFs to each road section that contained the hardware. Next, traffic volume and hardware inventory data are used to calculate how many million vehicle-km were traveled past a CMB on each road section in one year. This value is multiplied by the product of all the AMFs for the road section, resulting in the column labeled “(MVKT/yr)*AMFs” in Figure 76b. The number of collisions (injury collisions in this case) per year divided by “(MVKT/yr)*AMFs” yields the base (injury) collision rate for each section. The total number of collisions on the four sections divided by the sum of the “(MVKT/yr)*AMFs” values yields the overall base (injury) collision rate for the 6.0 km of highway. Figure 76c shows one graph that could be produced from these data.



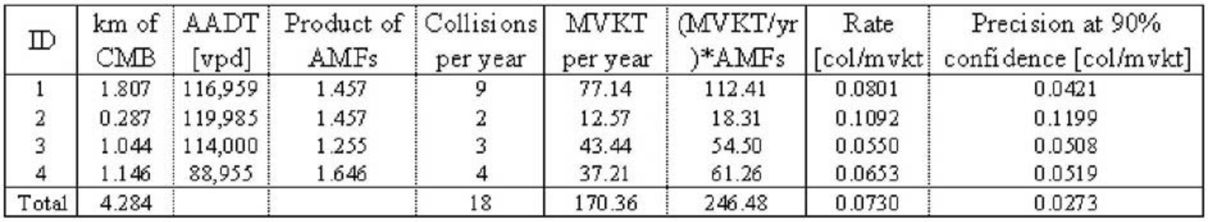
Project #	**199702**		*Collision Rates*
Project: **Concrete Median Barriers**			
Hardware type(s):	**Concrete median barriers**		
Data collection area:	**Worcester, MA**		
Data collection period:	**1 year**		
Roadway type(s):	**Interstate highway**		
Values			
Number of reported collisions = N_r *=*	**40**		
Number of injury collisions = N_i *=*	**18**		
Number of severe injury collisions = N_s *=*	**2**		
Number of unreported collisions = N_u *=*	**N/A**		
Number of installations = I *=*	**N/A**		
Total length of installations = L *=*	**4.284**	km	
Total length of roadway = R *=*	**6.0**	km	
Average ADT passing installations = V *=*	**109,975**	vpd	
Rates			
Reported collisions			
per hardware installation = N_r/I =	**N/A**		
per million veh-km of roadway per year = $N_r/(V*R*365/1000000)$=	**0.166082**		
per million veh-km of hardware per year = $N_r/(V*L*365/1000000)$=	**0.232607**		
Injury collisions			
per hardware installation = N_i/I =	**N/A**		
per million veh-km of roadway per year = $N_r/(V*R*365/1000000)$=	**0.074737**		
per million veh-km of hardware per year = $N_r/(V*L*365/1000000)$=	**0.104673**		
Severe injury collisions			
per hardware installation = N_s/I =	**N/A**		
per million veh-km of roadway per year = $N_r/(V*R*365/1000000)$=	**0.008304**		
per million veh-km of hardware per year = $N_r/(V*L*365/1000000)$=	**0.01163**		
Unreported collisions			
per hardware installation = N_u/I =	**N/A**		
per million veh-km of roadway per year = $N_r/(V*R*365/1000000)$=	**N/A**		
per million veh-km of hardware per year = $N_r/(V*L*365/1000000)$=	**N/A**		
All (reported and unreported) collisions			
per hardware installation = $(N_r+N_u)/I$ =	**N/A**		
per million veh-km of roadway per year = $N_r/(V*R*365/1000000)$=	**N/A**		

Figure 75. Collision Rates Form.



ID	Med Width[m]	Lane Width[m]	Shoulder Width[m]	Grade [%]	Length of Curve[m]	Degree of Curve[deg/sta]	AMF_{MW}	AMF_{LW}	AMF_{SW}	AMF_G	AMF_{LC}	AMF_{DC}	Product of AMFs
1	0.61	3.66	1.20	0.00	2000.00	0.06	1.23	1.00	1.15	1.00	1.02	1.01	1.457
2	0.61	3.66	1.20	2.00	-	-	1.23	1.00	1.15	1.03	1.00	1.00	1.457
3	0.81	3.66	1.80	1.00	-	-	1.23	1.00	1.00	1.02	1.00	1.00	1.255
4	0.61	3.66	1.20	0.00	1500.00	1.43	1.23	1.00	1.15	1.00	1.03	1.13	1.646

Figure 76a. Example of Assigning AMFs to Road Sections.



ID	km of CMB	AADT [vpd]	Product of AMFs	Collisions per year	MVKT per year	(MVKT/yr)*AMFs	Rate [col/mvkt	Precision at 90% confidence [col/mvkt]
1	1.807	116,959	1.457	9	77.14	112.41	0.0801	0.0421
2	0.287	119,985	1.457	2	12.57	18.31	0.1092	0.1199
3	1.044	114,000	1.255	3	43.44	54.50	0.0550	0.0508
4	1.146	88,955	1.646	4	37.21	61.26	0.0653	0.0519
Total	4.284			18	170.36	246.48	0.0730	0.0273

Figure 76b. Example of Calculating Base Collision Rates.

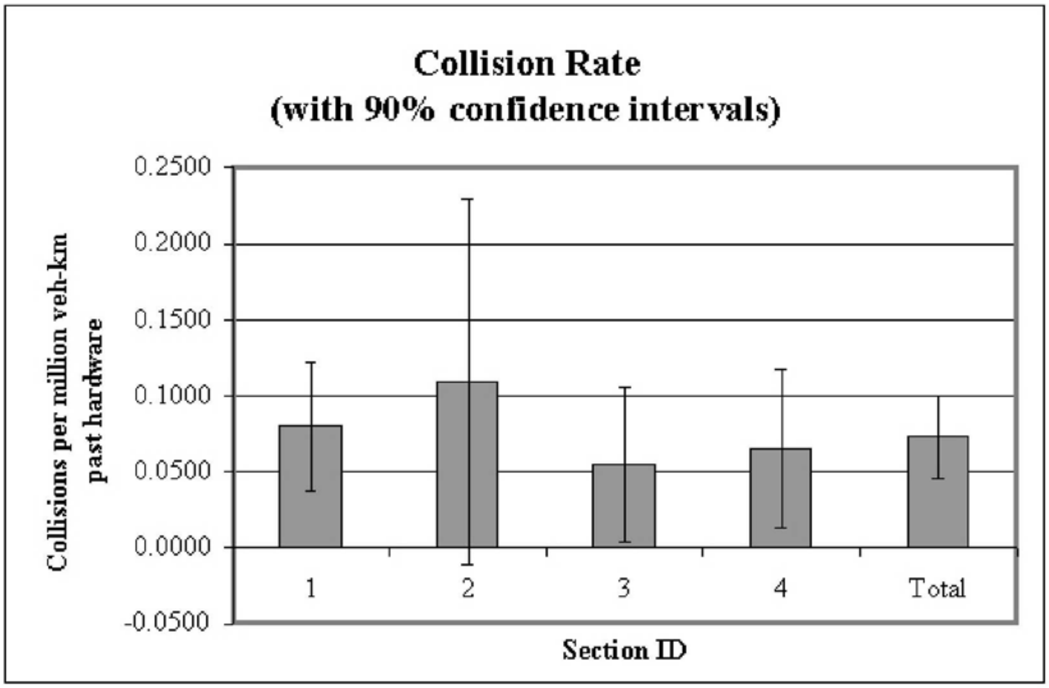


Figure 76c. Example Graph of Base Collision Rates with Confidence Intervals.

COMPARING DIFFERENT SYSTEMS AND STATISTICAL SIGNIFICANCE

Crash data collected in an in-service evaluation are often used to estimate the performance of roadside hardware with respect to collision outcome measures and to make statistical comparisons between these estimates. Two such outcome measures are occupant injury severity and whether or not the vehicle rolls over after striking the guardrail face or end.

As discussed in Chapter Two, it is important to assess the statistical significance of differences when comparing such measures. Often this is done by calculating confidence intervals. For example, a study in Iowa estimated that collisions with a G1 guardrail resulting in injuries occurred at a rate of 0.0665 collisions per million vehicle-km traveled past a guardrail, and collisions with a G4(1W) guardrail resulting in injuries occurred at a rate of 0.1617 collisions per million vehicle-km past a guardrail. During the study, 37.6 million vehicle-km were traveled past G1 guardrails and 49.5 million vehicle-km were traveled past G4(1W) guardrails. Using this information, the precision of the rate estimate can be calculated at a given confidence level as follows:

$$w = Z\sqrt{\frac{p(1-p)}{N}}$$

where w = precision,

Z = 1.645 for 90% confidence,

p = rate (collisions per veh-km),

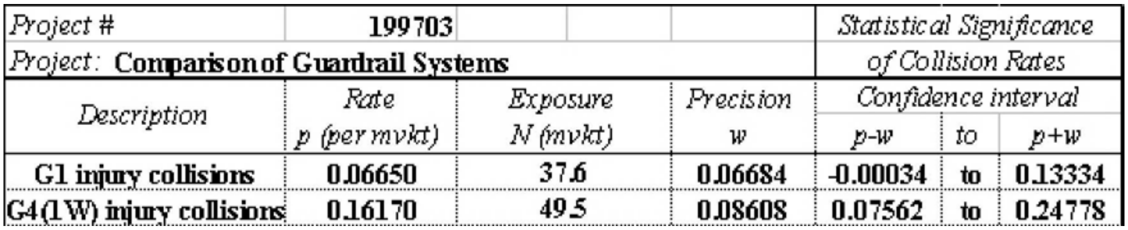
N = veh-km traveled.

So for the G1 guardrail, $w = 1.645\sqrt{\frac{(0.0665)(1-0.0665)}{37.6}} = 0.06684$

and for the G4(1W) guardrail, $w = 1.645\sqrt{\frac{(0.1617)(1-0.1617)}{49.5}} = 0.08608$

The 90 percent confidence interval is from p-w to $p+w$. In this example, between 0 and 0.1333 injury collisions occurred per million vehicle-km traveled past a G1 guardrail; between 0.0756 and 0.2478 injury collisions occurred per million vehicle-km traveled past a G4(1W) guardrail. Since the confidence intervals for the G1 and G4(1W) overlap, the difference between the two injury collision rates is not statistically significant. In other words, the difference may be due to random error and sample size rather than to actual performance differences. From a statistical point of view, both systems have essentially the same injury collision rate.

A “statistical significance” form is included in the ISPE workbook to help in calculating the confidence intervals of rates. Figure 77 shows part of a completed form using the example data. If desired, confidence intervals can also be calculated for proportions, such as for the proportion of police-reported collisions that result in serious or fatal (A+K) injuries.



Project #	**199703**			*Statistical Significance*		
Project: **Comparison of Guardrail Systems**				*of Collision Rates*		
Description	*Rate*	*Exposure*	*Precision*	*Confidence interval*		
	p (per mvkt)	*N (mvkt)*	*w*	*p-w*	*to*	*p+w*
G1 injury collisions	**0.06650**	**37.6**	**0.06684**	**-0.00034**	**to**	**0.13334**
G4(1W) injury collisions	**0.16170**	**49.5**	**0.08608**	**0.07562**	**to**	**0.24778**

Figure 77. Statistical Significance Form.

Of course, there are many factors which may influence driver injury other than the specific object struck. These factors might include vehicle type, collision events, and many other factors. Data collected on such factors through police reports and investigations at the scene can be used to develop models of injury collision rates and other measures of performance. These models (e.g., logistic regression models) should provide much more powerful analyses of the performance of guardrails and end treatments or other roadside hardware by taking into account many of these other factors.

CHAPTER EIGHT

SUMMARY

The procedures described in the preceding chapters can be used as a general framework for developing and performing an in-service performance evaluation of a roadside barrier or feature. The procedures are based on techniques that have been used in other in-service performance evaluations as well as other collision data studies. The procedures are intended to be used by design and maintenance engineers and do not require that the collisions be reconstructed. The procedures could be implemented into the routine operations of many roadway maintenance organizations and used as an on-going management tool.

REFERENCES

1. King K. Mak and Anthony Magaro, “National Accident Sampling System (NASS) Longitudinal Barrier Special Study Coding/Editing and Field Procedures Manual,” NHTSA, October 1982.

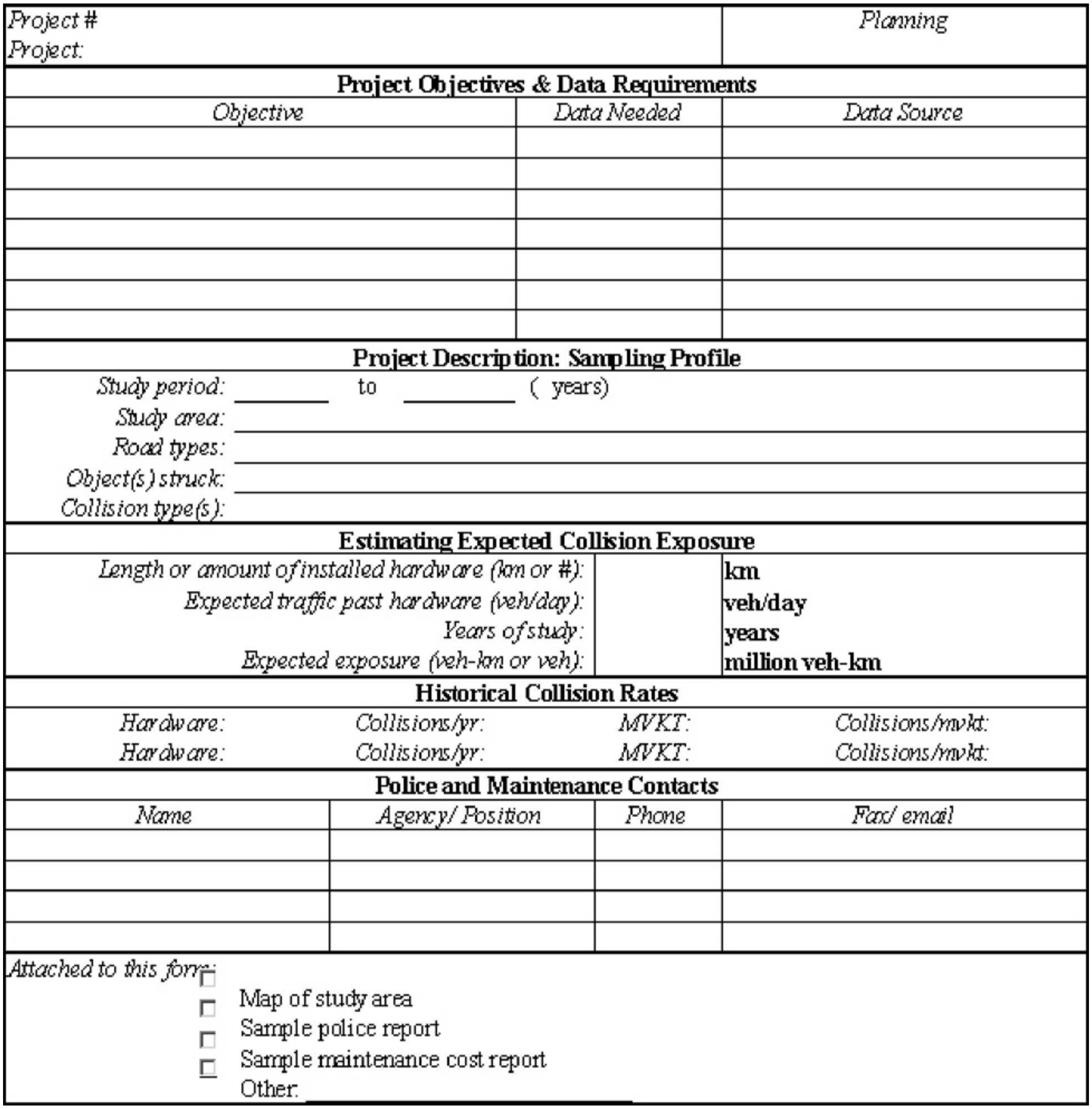
2. King K. Mak and Robert L. Mason, Ph.D., “Accident Analysis - Breakaway and Nonbreakaway Poles Including Sign and Light Standards Along Highways,” NHTSA and FHWA, August 1980.

3. K. K. Mak and L. R. Calcote, “Accident Analysis of Highway Narrow Bridge Sites,” FHWA and NHTSA, February 1983.

4. D. W. Harwood, F.M. Council, E. Hauer, W.E. Hughes, and A. Vogt, *Prediction of the Expected Safety Performance of Rural Two-lane Highways*, Report FHWA-RD-99-207, FHWA, U.S. Department of Transportation, 2000.

APPENDIX A

IN-SERVICE PERFORMANCE EVALUATION WORKBOOK



Project # *Project:*	*Planning*

Project Objectives & Data Requirements

Objective	*Data Needed*	*Data Source*

Project Description: Sampling Profile

Study period: ________ to __________ (years)

Study area: ____________________

Road types: ____________________

Object(s) struck: ____________________

Collision type(s):

Estimating Expected Collision Exposure

Length or amount of installed hardware (km or #):		**km**
Expected traffic past hardware (veh/day):		**veh/day**
Years of study:		**years**
Expected exposure (veh-km or veh):		**million veh-km**

Historical Collision Rates

Hardware:	*Collisions/yr:*	*MVKT:*	*Collisions/mvkt:*
Hardware:	*Collisions/yr:*	*MVKT:*	*Collisions/mvkt:*

Police and Maintenance Contacts

Name	*Agency/ Position*	*Phone*	*Fax/ email*

Attached to this form:

- ☐ Map of study area
- ☐ Sample police report
- ☐ Sample maintenance cost report
- ☐ Other: ____________________

Project #
Project:

Hardware Survey
Date:

County/District:
Route #:

Date of survey:
Other description:

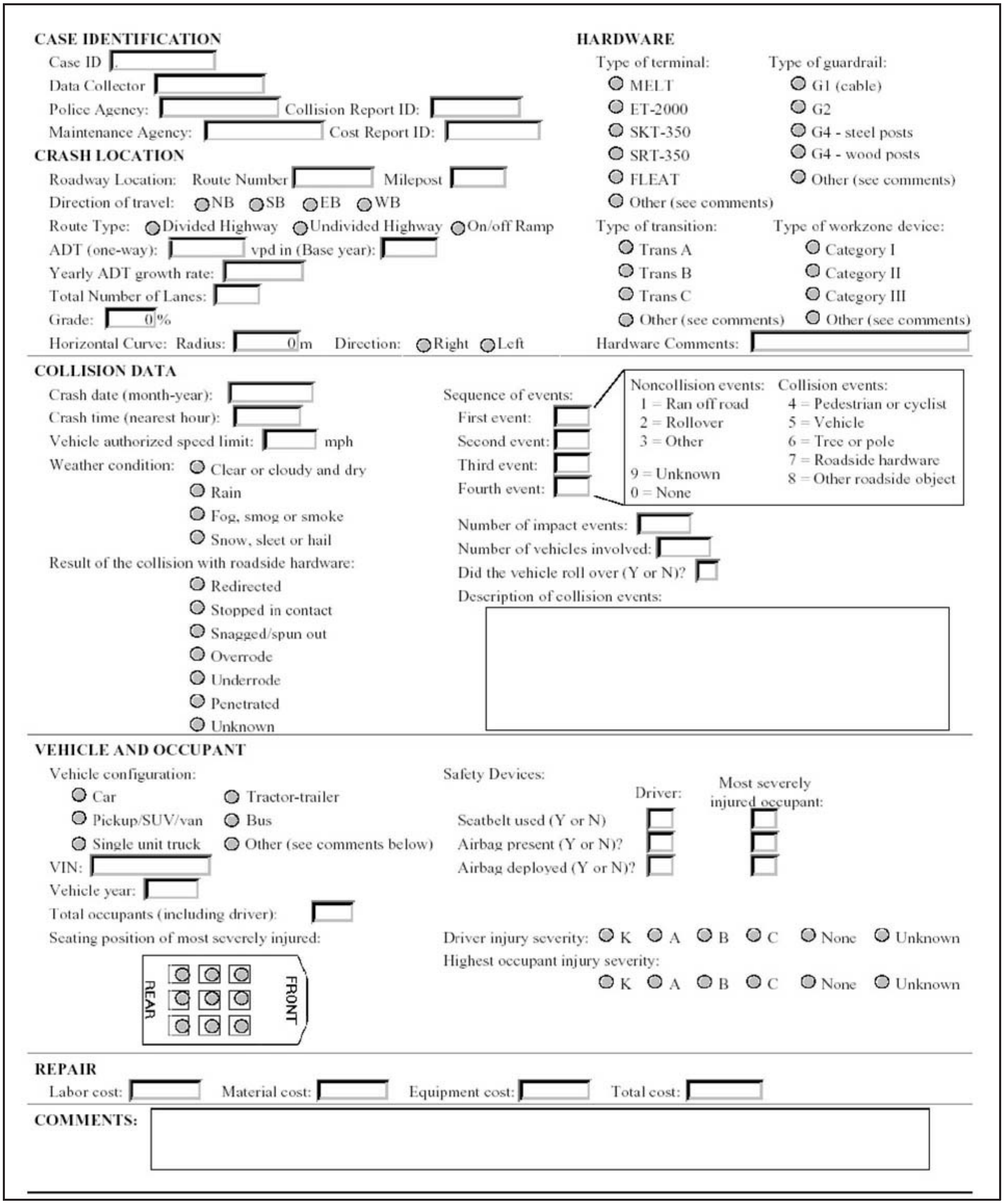
Beginning Mileage	*Ending Mileage*	*Length*	*Side of Road*	*Hardware Description*
Total length of section (ending mileage - beginning mileage):				

Project #
Project:

Hardware Inventory
Date:

County/ District	Route #	Hardware Type	Side of Road	Length	1-way ADT (vpd)	Date of survey

Project # *Project:*				*Collision Notification* *Call/Visit Log*
Date	*Contact / Agency*	*Collision Description*	*Case ID*	*Notes*



CASE IDENTIFICATION

Case ID ☐

Data Collector ☐

Police Agency: ☐ Collision Report ID: ☐

Maintenance Agency: ☐ Cost Report ID: ☐

CRASH LOCATION

Roadway Location: Route Number ☐ Milepost ☐

Direction of travel: ○NB ○SB ○EB ○WB

Route Type: ○Divided Highway ○Undivided Highway ○On/off Ramp

ADT (one-way): ☐ vpd in (Base year): ☐

Yearly ADT growth rate: ☐

Total Number of Lanes: ☐

Grade: 0 %

Horizontal Curve: Radius: 0 m Direction: ○Right ○Left

HARDWARE

Type of terminal:	Type of guardrail:
○ MELT	○ G1 (cable)
○ ET-2000	○ G2
○ SKT-350	○ G4 - steel posts
○ SRT-350	○ G4 - wood posts
○ FLEAT	○ Other (see comments)
○ Other (see comments)	

Type of transition:	Type of workzone device:
○ Trans A	○ Category I
○ Trans B	○ Category II
○ Trans C	○ Category III
○ Other (see comments)	○ Other (see comments)

Hardware Comments: ☐

COLLISION DATA

Crash date (month-year): ☐

Crash time (nearest hour): ☐

Vehicle authorized speed limit: ☐ mph

Weather condition:
- ○ Clear or cloudy and dry
- ○ Rain
- ○ Fog, smog or smoke
- ○ Snow, sleet or hail

Result of the collision with roadside hardware:
- ○ Redirected
- ○ Stopped in contact
- ○ Snagged/spun out
- ○ Overrode
- ○ Underrode
- ○ Penetrated
- ○ Unknown

Sequence of events:

First event: ☐

Second event: ☐

Third event: ☐

Fourth event: ☐

Noncollision events:	Collision events:
1 = Ran off road	4 = Pedestrian or cyclist
2 = Rollover	5 = Vehicle
3 = Other	6 = Tree or pole
	7 = Roadside hardware
9 = Unknown	8 = Other roadside object
0 = None	

Number of impact events: ☐

Number of vehicles involved: ☐

Did the vehicle roll over (Y or N)? ☐

Description of collision events: ☐

VEHICLE AND OCCUPANT

Vehicle configuration:
- ○ Car ○ Tractor-trailer
- ○ Pickup/SUV/van ○ Bus
- ○ Single unit truck ○ Other (see comments below)

VIN: ☐

Vehicle year: ☐

Total occupants (including driver): ☐

Seating position of most severely injured:

REAR				FRONT
	○	○	○	
	○	○	○	
	○	○	○	

Safety Devices:

	Driver:	Most severely injured occupant:
Seatbelt used (Y or N)	☐	☐
Airbag present (Y or N)?	☐	☐
Airbag deployed (Y or N)?	☐	☐

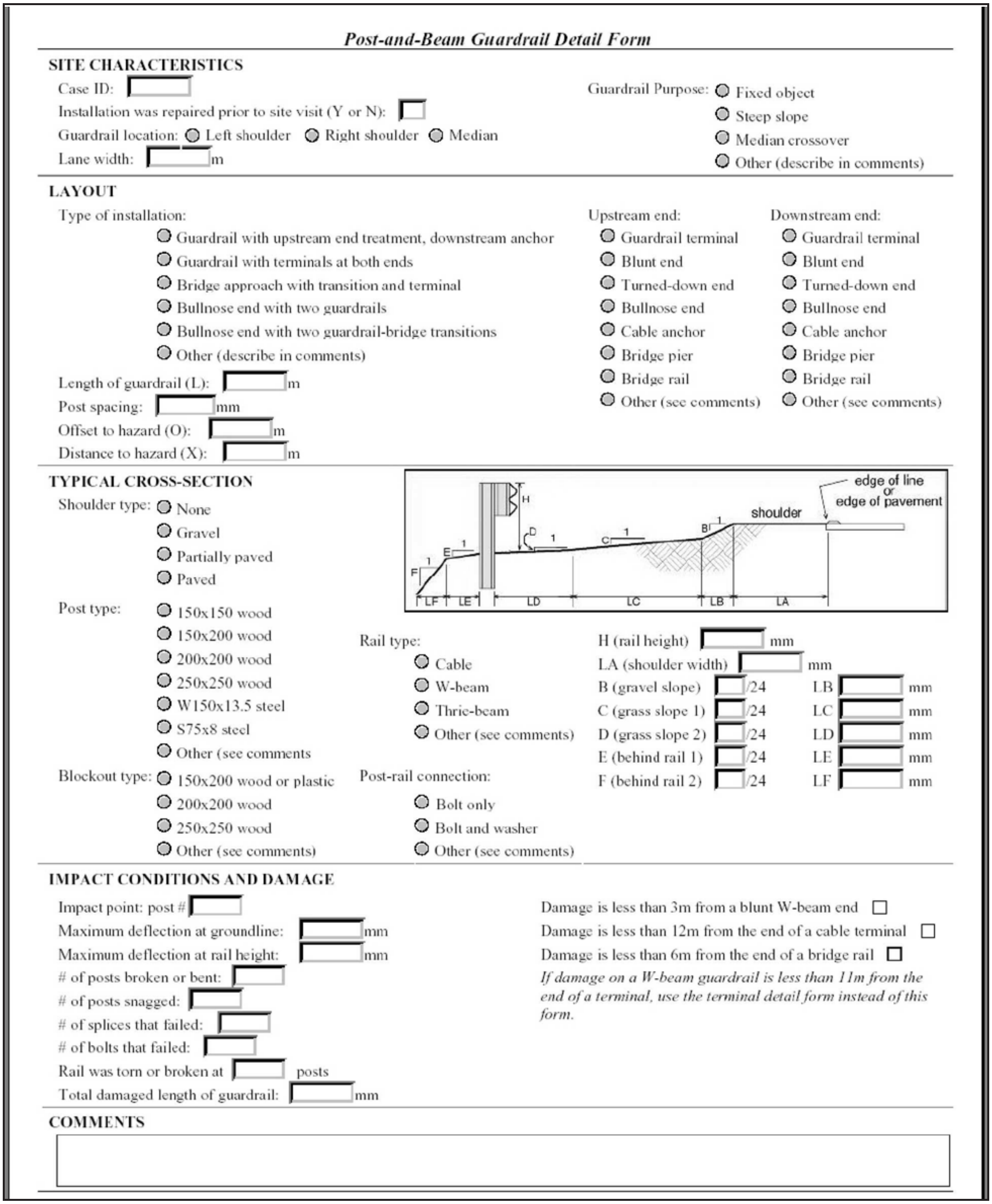
Driver injury severity: ○K ○A ○B ○C ○None ○Unknown

Highest occupant injury severity: ○K ○A ○B ○C ○None ○Unknown

REPAIR

Labor cost: ☐ Material cost: ☐ Equipment cost: ☐ Total cost: ☐

COMMENTS: ☐



Post-and-Beam Guardrail Detail Form

SITE CHARACTERISTICS

Case ID:

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

Guardrail location: ○ Left shoulder ○ Right shoulder ○ Median

Lane width: m

Guardrail Purpose:
- ○ Fixed object
- ○ Steep slope
- ○ Median crossover
- ○ Other (describe in comments)

LAYOUT

Type of installation:
- ○ Guardrail with upstream end treatment, downstream anchor
- ○ Guardrail with terminals at both ends
- ○ Bridge approach with transition and terminal
- ○ Bullnose end with two guardrails
- ○ Bullnose end with two guardrail-bridge transitions
- ○ Other (describe in comments)

Upstream end:	Downstream end:
○ Guardrail terminal	○ Guardrail terminal
○ Blunt end	○ Blunt end
○ Turned-down end	○ Turned-down end
○ Bullnose end	○ Bullnose end
○ Cable anchor	○ Cable anchor
○ Bridge pier	○ Bridge pier
○ Bridge rail	○ Bridge rail
○ Other (see comments)	○ Other (see comments)

Length of guardrail (L): m

Post spacing: mm

Offset to hazard (O): m

Distance to hazard (X): m

TYPICAL CROSS-SECTION

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

Post type:
- ○ 150x150 wood
- ○ 150x200 wood
- ○ 200x200 wood
- ○ 250x250 wood
- ○ W150x13.5 steel
- ○ S75x8 steel
- ○ Other (see comments

Blockout type:
- ○ 150x200 wood or plastic
- ○ 200x200 wood
- ○ 250x250 wood
- ○ Other (see comments)

Rail type:
- ○ Cable
- ○ W-beam
- ○ Thrie-beam
- ○ Other (see comments)

Post-rail connection:
- ○ Bolt only
- ○ Bolt and washer
- ○ Other (see comments)

H (rail height) mm

LA (shoulder width) mm

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

IMPACT CONDITIONS AND DAMAGE

Impact point: post #

Maximum deflection at groundline: mm

Maximum deflection at rail height: mm

# of posts broken or bent:

# of posts snagged:

# of splices that failed:

# of bolts that failed:

Rail was torn or broken at posts

Total damaged length of guardrail: mm

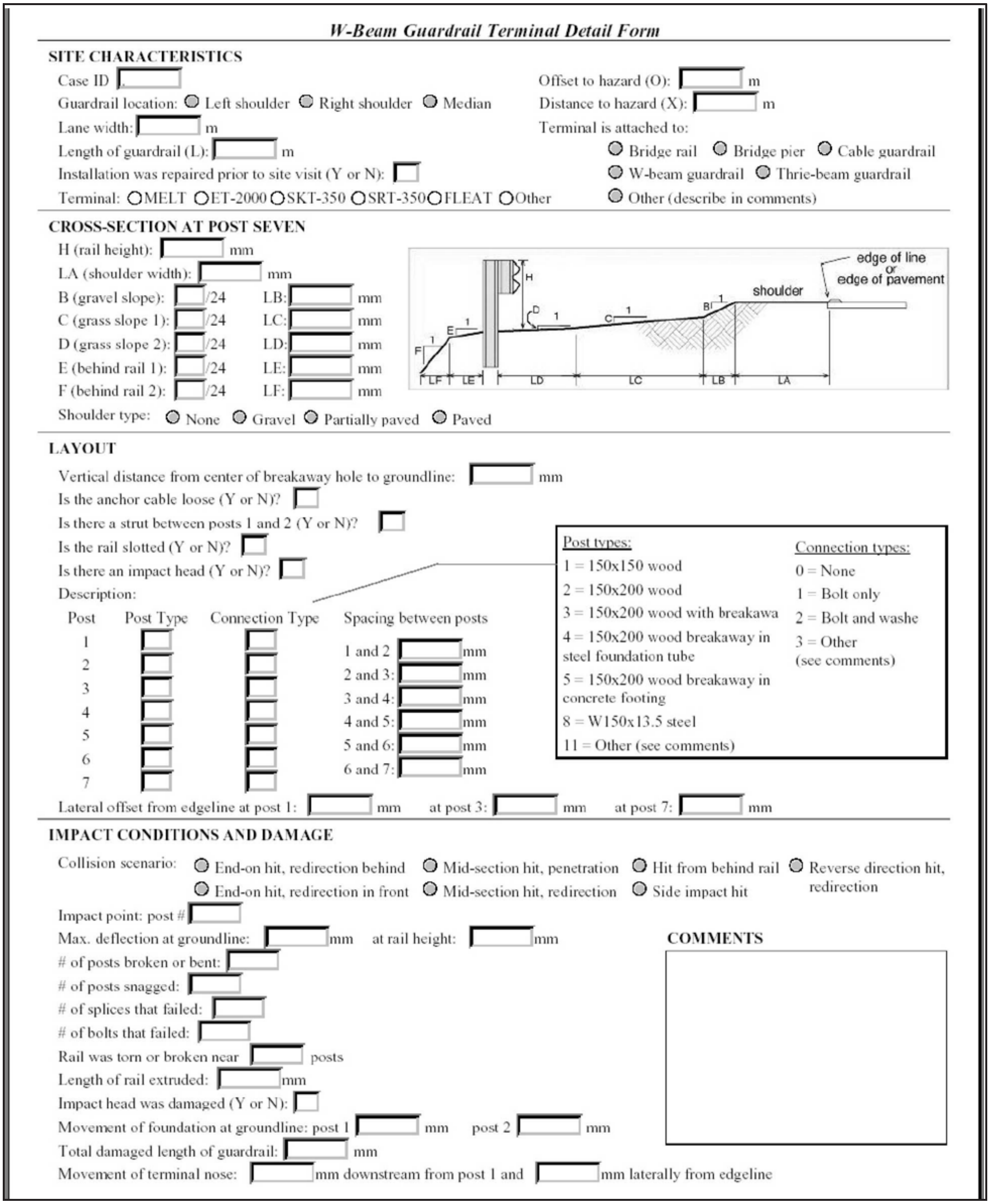
Damage is less than 3m from a blunt W-beam end ☐

Damage is less than 12m from the end of a cable terminal ☐

Damage is less than 6m from the end of a bridge rail ☐

If damage on a W-beam guardrail is less than 11m from the end of a terminal, use the terminal detail form instead of this form.

COMMENTS



W-Beam Guardrail Terminal Detail Form

SITE CHARACTERISTICS

Case ID ☐

Guardrail location: ○ Left shoulder ○ Right shoulder ○ Median

Lane width: ☐ m

Length of guardrail (L): ☐ m

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

Terminal: ○MELT ○ET-2000 ○SKT-350 ○SRT-350 ○FLEAT ○Other

Offset to hazard (O): ☐ m

Distance to hazard (X): ☐ m

Terminal is attached to:

○ Bridge rail ○ Bridge pier ○ Cable guardrail

○ W-beam guardrail ○ Thrie-beam guardrail

○ Other (describe in comments)

CROSS-SECTION AT POST SEVEN

H (rail height): ☐ mm

LA (shoulder width): ☐ mm

B (gravel slope): ☐/24 LB: ☐ mm

C (grass slope 1): ☐/24 LC: ☐ mm

D (grass slope 2): ☐/24 LD: ☐ mm

E (behind rail 1): ☐/24 LE: ☐ mm

F (behind rail 2): ☐/24 LF: ☐ mm

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

LAYOUT

Vertical distance from center of breakaway hole to groundline: ☐ mm

Is the anchor cable loose (Y or N)? ☐

Is there a strut between posts 1 and 2 (Y or N)? ☐

Is the rail slotted (Y or N)? ☐

Is there an impact head (Y or N)? ☐

Description:

Post	Post Type	Connection Type	Spacing between posts
1	☐	☐	1 and 2 ☐ mm
2	☐	☐	2 and 3: ☐ mm
3	☐	☐	3 and 4: ☐ mm
4	☐	☐	4 and 5: ☐ mm
5	☐	☐	5 and 6: ☐ mm
6	☐	☐	6 and 7: ☐ mm
7	☐	☐	

Post types:

1 = 150x150 wood

2 = 150x200 wood

3 = 150x200 wood with breakawa

4 = 150x200 wood breakaway in steel foundation tube

5 = 150x200 wood breakaway in concrete footing

8 = W150x13.5 steel

11 = Other (see comments)

Connection types:

0 = None

1 = Bolt only

2 = Bolt and washe

3 = Other (see comments)

Lateral offset from edgeline at post 1: ☐ mm at post 3: ☐ mm at post 7: ☐ mm

IMPACT CONDITIONS AND DAMAGE

Collision scenario: ○ End-on hit, redirection behind ○ Mid-section hit, penetration ○ Hit from behind rail ○ Reverse direction hit, redirection

○ End-on hit, redirection in front ○ Mid-section hit, redirection ○ Side impact hit

Impact point: post # ☐

Max. deflection at groundline: ☐ mm at rail height: ☐ mm

# of posts broken or bent: ☐

# of posts snagged: ☐

# of splices that failed: ☐

# of bolts that failed: ☐

Rail was torn or broken near ☐ posts

Length of rail extruded: ☐ mm

Impact head was damaged (Y or N): ☐

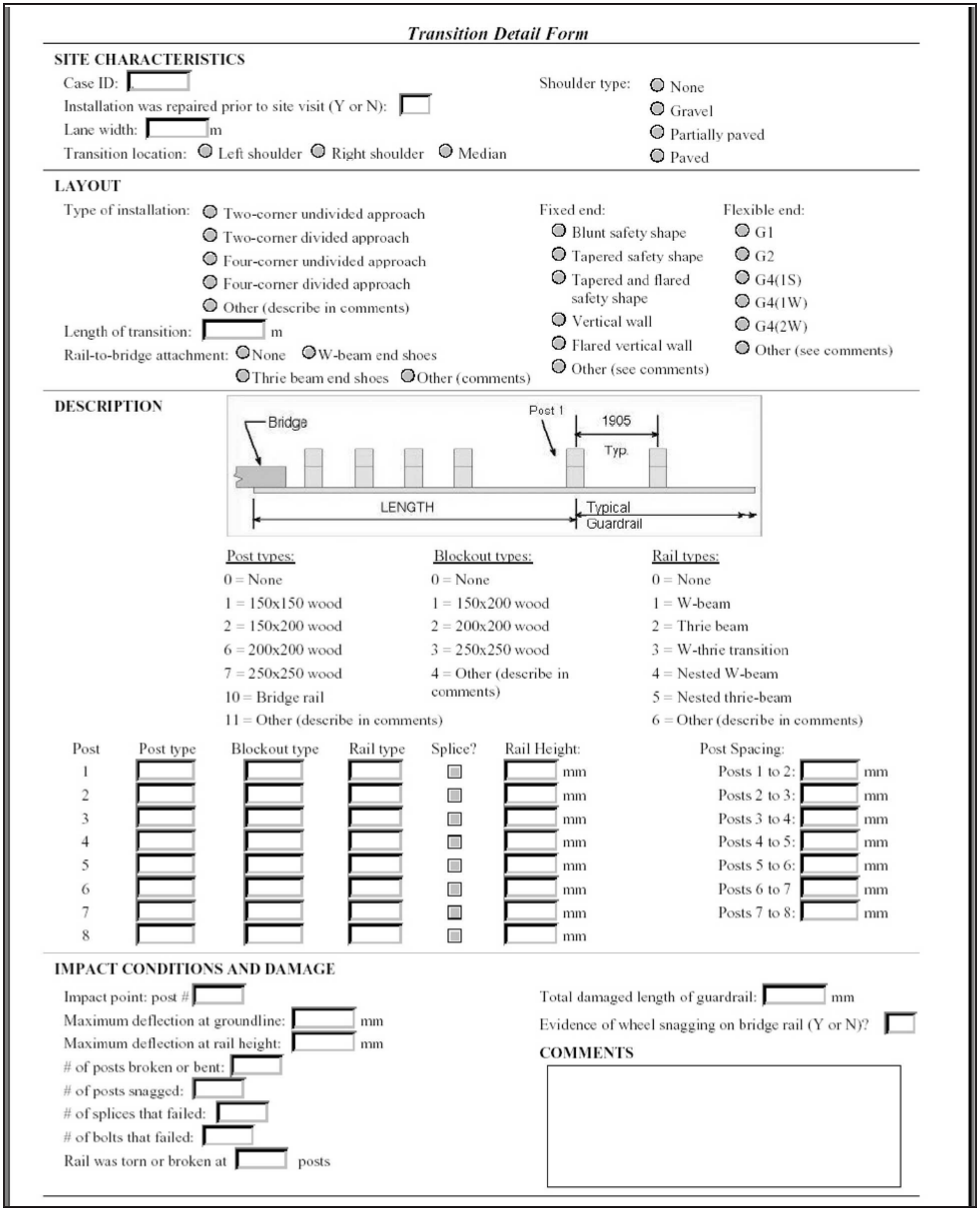
Movement of foundation at groundline: post 1 ☐ mm post 2 ☐ mm

Total damaged length of guardrail: ☐ mm

Movement of terminal nose: ☐ mm downstream from post 1 and ☐ mm laterally from edgeline

COMMENTS

☐



Transition Detail Form

SITE CHARACTERISTICS

Case ID:

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

Lane width: m

Transition location: ○ Left shoulder ○ Right shoulder ○ Median

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

LAYOUT

Type of installation:
- ○ Two-corner undivided approach
- ○ Two-corner divided approach
- ○ Four-corner undivided approach
- ○ Four-corner divided approach
- ○ Other (describe in comments)

Length of transition: m

Rail-to-bridge attachment: ○ None ○ W-beam end shoes ○ Thrie beam end shoes ○ Other (comments)

Fixed end:
- ○ Blunt safety shape
- ○ Tapered safety shape
- ○ Tapered and flared safety shape
- ○ Vertical wall
- ○ Flared vertical wall
- ○ Other (see comments)

Flexible end:
- ○ G1
- ○ G2
- ○ G4(1S)
- ○ G4(1W)
- ○ G4(2W)
- ○ Other (see comments)

DESCRIPTION

Post types:
- 0 = None
- 1 = 150x150 wood
- 2 = 150x200 wood
- 6 = 200x200 wood
- 7 = 250x250 wood
- 10 = Bridge rail
- 11 = Other (describe in comments)

Blockout types:
- 0 = None
- 1 = 150x200 wood
- 2 = 200x200 wood
- 3 = 250x250 wood
- 4 = Other (describe in comments)

Rail types:
- 0 = None
- 1 = W-beam
- 2 = Thrie beam
- 3 = W-thrie transition
- 4 = Nested W-beam
- 5 = Nested thrie-beam
- 6 = Other (describe in comments)

Post	Post type	Blockout type	Rail type	Splice?	Rail Height:
1				☐	mm
2				☐	mm
3				☐	mm
4				☐	mm
5				☐	mm
6				☐	mm
7				☐	mm
8				☐	mm

Post Spacing:

Posts 1 to 2: mm

Posts 2 to 3: mm

Posts 3 to 4: mm

Posts 4 to 5: mm

Posts 5 to 6: mm

Posts 6 to 7 mm

Posts 7 to 8: mm

IMPACT CONDITIONS AND DAMAGE

Impact point: post #

Maximum deflection at groundline: mm

Maximum deflection at rail height: mm

# of posts broken or bent:

# of posts snagged:

# of splices that failed:

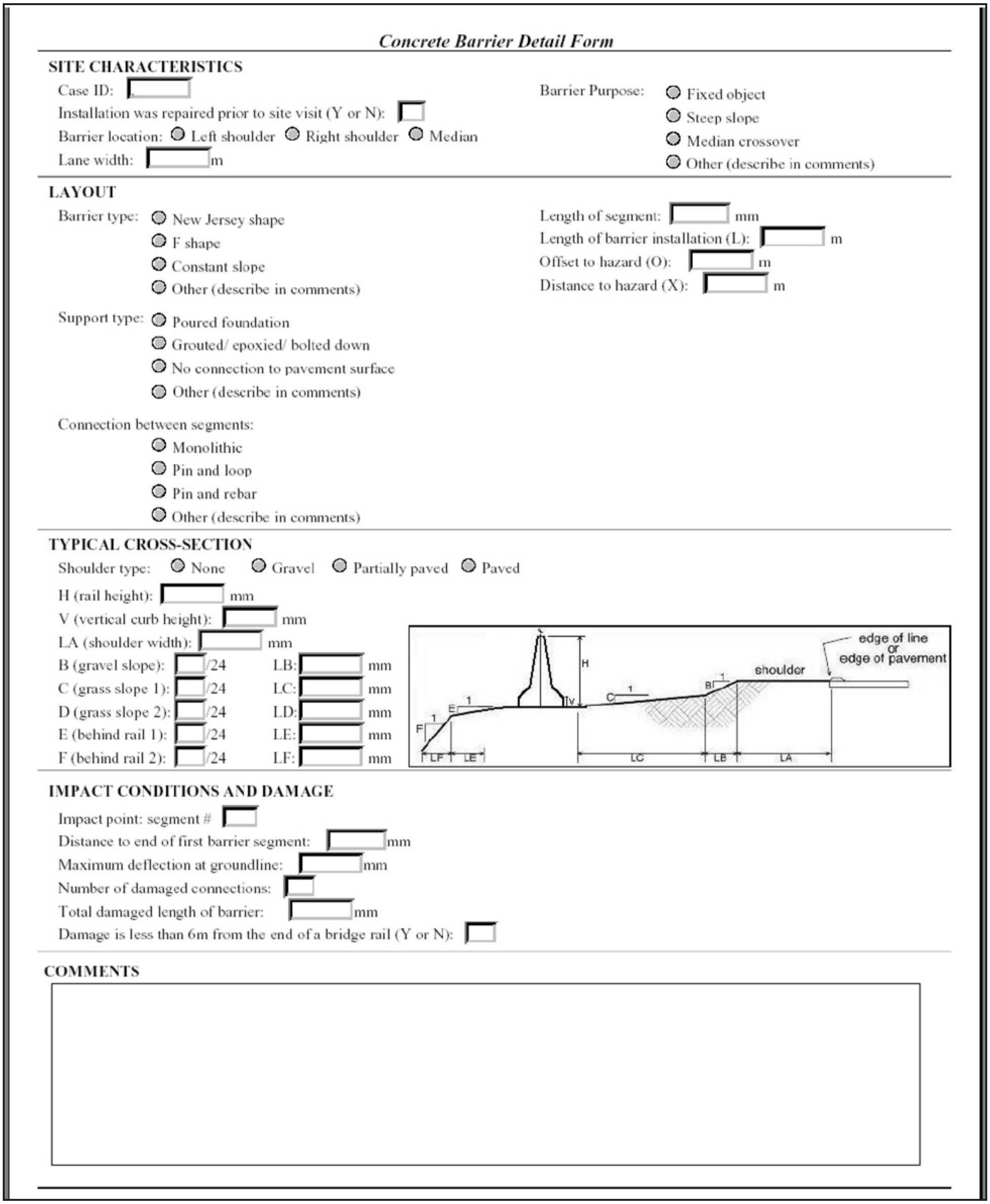
# of bolts that failed:

Rail was torn or broken at posts

Total damaged length of guardrail: mm

Evidence of wheel snagging on bridge rail (Y or N)?

COMMENTS



Concrete Barrier Detail Form

SITE CHARACTERISTICS

Case ID: ☐

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

Barrier location: ○ Left shoulder ○ Right shoulder ○ Median

Lane width: ☐ m

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

LAYOUT

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

Length of segment: ☐ mm

Length of barrier installation (L): ☐ m

Offset to hazard (O): ☐ m

Distance to hazard (X): ☐ m

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

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

TYPICAL CROSS-SECTION

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

H (rail height): ☐ mm

V (vertical curb height): ☐ mm

LA (shoulder width): ☐ mm

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

IMPACT CONDITIONS AND DAMAGE

Impact point: segment # ☐

Distance to end of first barrier segment: ☐ mm

Maximum deflection at groundline: ☐ mm

Number of damaged connections: ☐

Total damaged length of barrier: ☐ mm

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

COMMENTS

☐

Project #

Project:

Unreported Collision Inspection Log

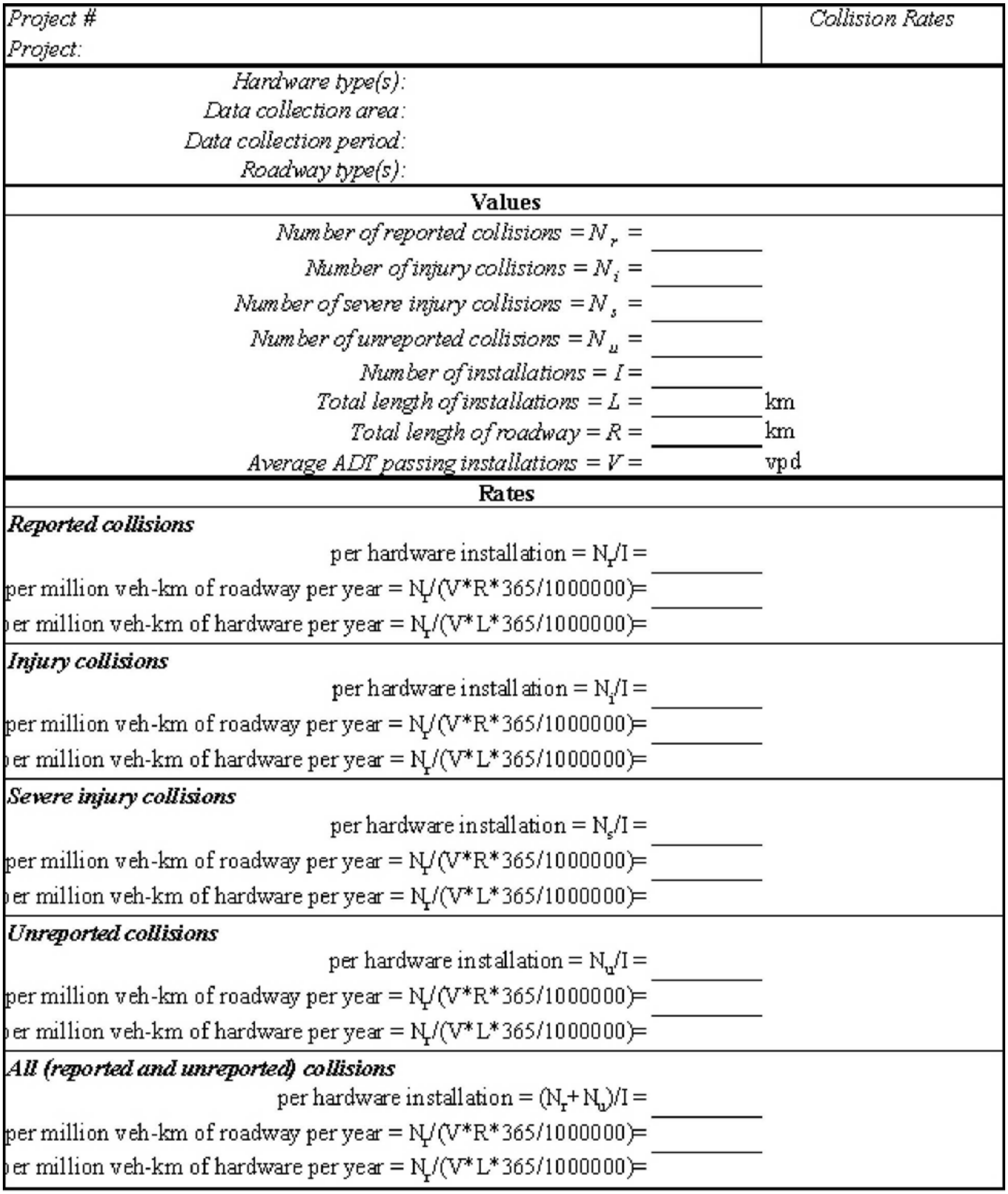
County/District:

Milepost:

Route #:

Direction:

Posts	Damage	Date	Data Collector	Event Number



Project #
Project:

Collision Rates

Hardware type(s):
Data collection area:
Data collection period:
Roadway type(s):

Values

Number of reported collisions = N_r = ________
Number of injury collisions = N_i = ________
Number of severe injury collisions = N_s = ________
Number of unreported collisions = N_u = ________
Number of installations = I = ________
Total length of installations = L = ________ km
Total length of roadway = R = ________ km
Average ADT passing installations = V = ________ vpd

Rates

Reported collisions

per hardware installation = N_r/I = ________
per million veh-km of roadway per year = $N_r/(V*R*365/1000000)$= ________
er million veh-km of hardware per year = $N_r/(V*L*365/1000000)$= ________

Injury collisions

per hardware installation = N_i/I = ________
per million veh-km of roadway per year = $N_r/(V*R*365/1000000)$= ________
er million veh-km of hardware per year = $N_r/(V*L*365/1000000)$= ________

Severe injury collisions

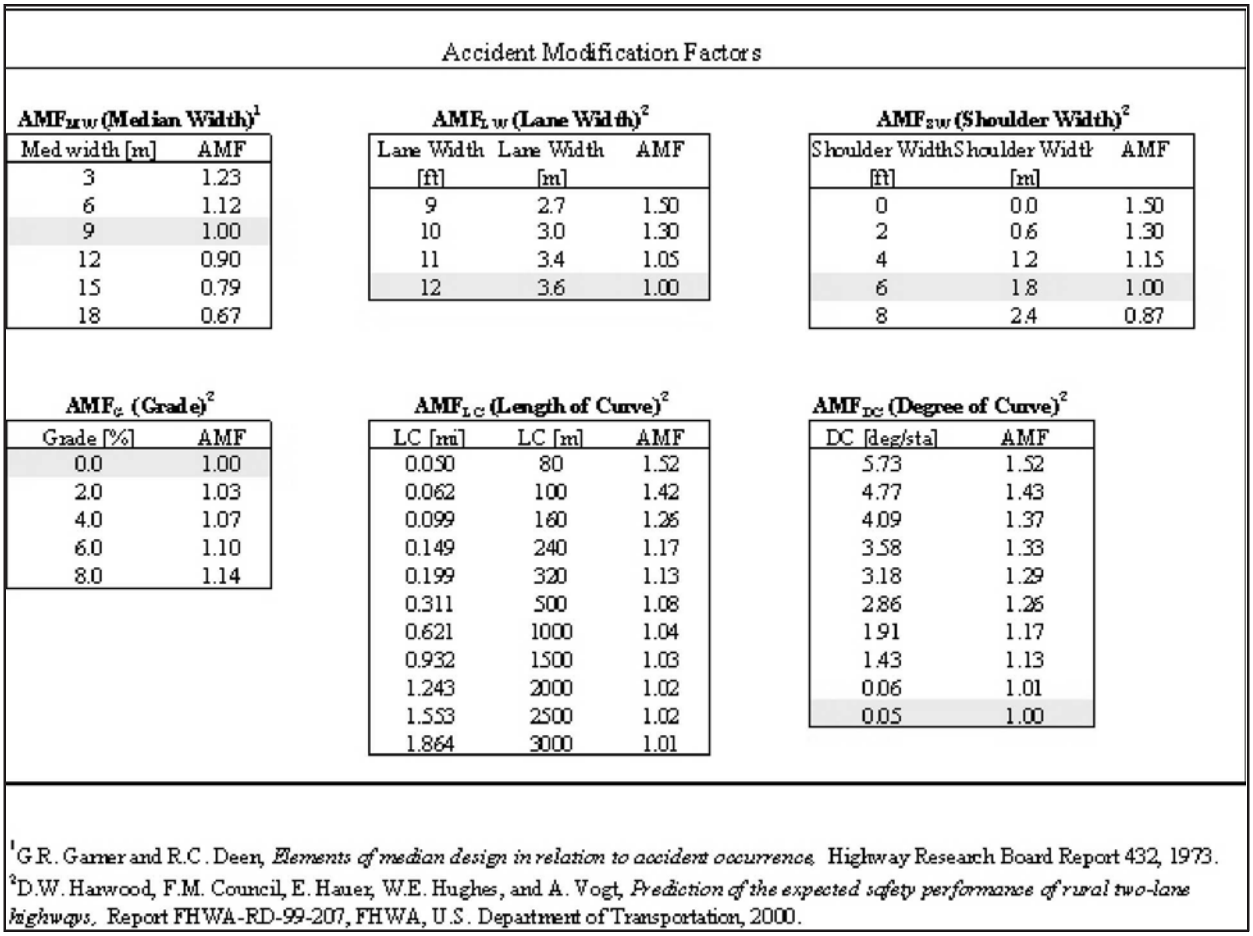
per hardware installation = N_s/I = ________
per million veh-km of roadway per year = $N_r/(V*R*365/1000000)$= ________
er million veh-km of hardware per year = $N_r/(V*L*365/1000000)$= ________

Unreported collisions

per hardware installation = N_u/I = ________
per million veh-km of roadway per year = $N_r/(V*R*365/1000000)$= ________
er million veh-km of hardware per year = $N_r/(V*L*365/1000000)$= ________

All (reported and unreported) collisions

per hardware installation = $(N_r+N_u)/I$ = ________
per million veh-km of roadway per year = $N_r/(V*R*365/1000000)$= ________
er million veh-km of hardware per year = $N_r/(V*L*365/1000000)$= ________



Accident Modification Factors

AMF_{MW} (Median Width)[1]

Med width [m]	AMF
3	1.23
6	1.12
9	1.00
12	0.90
15	0.79
18	0.67

AMF_{LW} (Lane Width)[2]

Lane Width [ft]	Lane Width [m]	AMF
9	2.7	1.50
10	3.0	1.30
11	3.4	1.05
12	3.6	1.00

AMF_{SW} (Shoulder Width)[2]

Shoulder Width [ft]	Shoulder Widtl [m]	AMF
0	0.0	1.50
2	0.6	1.30
4	1.2	1.15
6	1.8	1.00
8	2.4	0.87

AMF_{G} (Grade)[2]

Grade [%]	AMF
0.0	1.00
2.0	1.03
4.0	1.07
6.0	1.10
8.0	1.14

AMF_{LC} (Length of Curve)[2]

LC [mi]	LC [m]	AMF
0.050	80	1.52
0.062	100	1.42
0.099	160	1.26
0.149	240	1.17
0.199	320	1.13
0.311	500	1.08
0.621	1000	1.04
0.932	1500	1.03
1.243	2000	1.02
1.553	2500	1.02
1.864	3000	1.01

AMF_{DC} (Degree of Curve)[2]

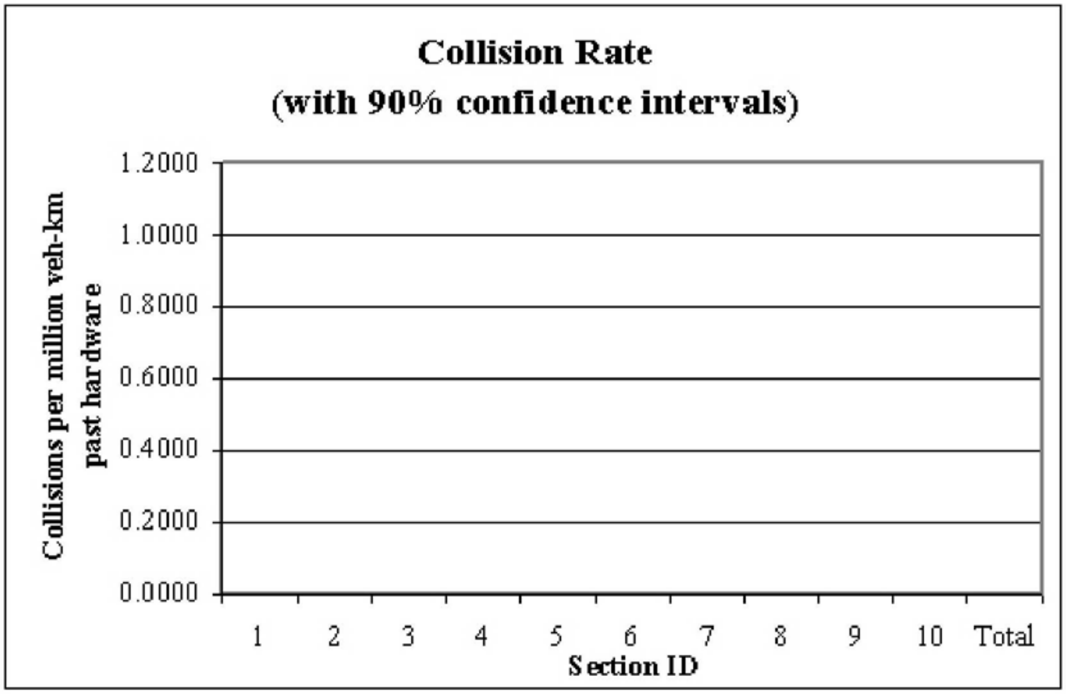
DC [deg/sta]	AMF
5.73	1.52
4.77	1.43
4.09	1.37
3.58	1.33
3.18	1.29
2.86	1.26
1.91	1.17
1.43	1.13
0.06	1.01
0.05	1.00

[1] G.R. Garner and R.C. Deen, *Elements of median design in relation to accident occurrence,* Highway Research Board Report 432, 1973.

[2] D.W. Harwood, F.M. Council, E. Hauer, W.E. Hughes, and A. Vogt, *Prediction of the expected safety performance of rural two-lane highways,* Report FHWA-RD-99-207, FHWA, U.S. Department of Transportation, 2000.

ID	*Med Width[m]*	*Lane Width[m]*	*Shoulder Width[m]*	*Grade [%]*	*Length of Curve[m]*	*Degree of Curve[deg/sta]*	AMF_{MW}	AMF_{LW}	AMF_{SW}	AMF_{G}	AMF_{LC}	AMF_{DC}	*Product of AMFs*

ID	km of CMB	AADT [vpd]	Product of AMFs	Collisions per year	MVKT per year	(MVKT/yr)*AMFs	Rate [col/mvkt	Precision at 90% confidence [col/mvkt]
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
Total								



Project #
Project:

Statistical Significance of Collision Rates

Description	*Rate*	*Exposure*	*Precision*	*Confidence interval*		
	p (per mvkt)	*N (mvkt)*	*w*	*p-w*	*to*	*p+w*
					to	
					to	
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Notes:
(1) 90% confidence intervals; Z=1.645
(2) w = Z*[p*(1-p)/N]^0.5
(3) If two confidence intervals do not overlap, the difference between the two rates is statistically significant at the given confidence level.

APPENDIX B

MODEL MINIMUM UNIFORM CRASH CRITERIA

(Extracted from NAGHSR's Final Model Minimum Uniform Crash Criteria, August 1998)

Crash Data Elements

C1. **Crash Case Identifier**

Definition: The unique identifier within a given year that identifies a given crash.

Code: State specific identifier

C2. **Crash Date and Time**

Definition: The date (year, month, and day) and time (hour and minute) at which a crash occurred.

Code: YYYYMMDDHHMM

C3. **Crash County**

Definition: The county in which a crash occurred.

Code: Record the name of the county in which a crash occurred. If codes are used instead of narrative, use the Federal Information Processing Standards #6-4 (FIPS) Code for county (Pub 55DC-4/87). If state-specific codes are used, they should be convertible to the FIPS format.

C4. **Crash City/Place**

Definition: The city/place in which a crash occurred.

Code: Record the name identifying the city/place in which a crash occurred. If codes are used instead of narrative, use the Federal Information Processing Standards #8-6 (FIPS) Code for city or place (Pub 55DC-4/87). If state specific code used, it should be convertible to the FIPS format.

C5. **Crash Roadway Location**

Definition: Exact location on the roadway indicating where the crash occurred.

Code: The optimum definition of crash roadway location is a route name and

GPS (Global Positioning System/GIS(Geographic Information System) if a highway agency has a linear referencing system that allows them to relate GPS coordinates to specific locations in road inventory, traffic, driver, and other files. The location information in a crash file must have the capability to be linked to location information in these other important files required in studying site-specific safety issues. A GPS/GIS provides latitude/longitude coordinates. States without GPS/GIS should indicate location using their current system including route name/number and milepoint/link-node.

C9. **Source of Information**

Definition: Identity of the source providing the information on the crash report.

Code: Subfield 1: Source of Information

- Police agency
- Motorist
- Other

Subfield 2: Police Reporting Agency Identifier

Subfield 3: Type of Police Agency

- State police/highway patrol
- City police
- Sheriff department
- BIA/Tribal
- Other

C11. **Weather Condition**s

Definition: The prevailing atmospheric conditions that existed at the time of the crash.

Code: Subfield 1: Weather Condition #1

- Clear
- Cloudy
- Fog, smog, smoke
- Rain
- Sleet, hail (freezing rain or drizzle)
- Snow
- Severe crosswinds
- Blowing sand, soil, dirt, snow
- Other
- Not reported
- Unknown

Subfield 2: Weather Condition #2

- See Subfield 1

C13. **Road Surface Condition**

Definition: The roadway surface condition at the time and place of a crash.

Code:
- Dry
- Wet
- Snow
- Ice
- Sand, mud, dirt, oil, gravel
- Water (standing, moving)
- Slush
- Other
- Not reported
- Unknown

C14 **Contributing Circumstances, Environment**

Definition: Apparent environmental conditions which contributed to the crash.

Code:
- None
- Weather conditions
- Physical obstruction
- Glare
- Animal in roadway
- Other
- Not reported
- Unknown

C15 **Contributing Circumstances, Road**

Definition: Apparent condition of the road which contributed to the crash.

Code:
- None
- Road surface condition (wet, icy, snow, slush, etc.)
- Debris
- Rut, holes, bumps
- Work zone (construction/maintenance/utility)
- Worn, travel-polished surface
- Obstruction in roadway
- Traffic control device inoperative, missing or obscured
- Shoulders (none, low, soft, high)
- Non-highway work
- Other
- Not reported
- Unknown

C18. **Work Zone Related** (**Construction/Maintenance/Utility**)

Definition: A crash that occurs in or near a construction, maintenance, or utility work zone, whether workers were actually present at the time of the crash or not. “Work zone related” crashes may also include those involving vehicles slowed or stopped because of the work zone, even if the first harmful event was before the first warning sign.

Code: Subfield 1: Was the crash in or near a construction, maintenance or utility work zone?

- No
- Unknown
- Yes (complete subfields 2-4)

Subfield 2: Location of the crash:

- Before the first work zone warning sign
- Advance warning area (after the first warning sign but before the work area)
- Transition area (where lanes are shifted or tapered for lane closure)
- Activity Area (adjacent to actual work area, whether workers and equipment were present or not)
- Termination area (after the activity area but before traffic resumes normal conditions)

Subfield 3: Type of work zone

- Lane closure
- Lane shift/crossover
- Work on shoulder or median
- Intermittent or moving work
- Other

Subfield 4: Workers present

- Yes
- No
- Unknown

CD1. **Crash Severity**

Definition: The severity of a crash based on the most severe injury to any person involved in the crash.

Source: Derived from **Injury Status (P4)** for each person involved in the crash.

Code:
- Property-damage-only (none injured)
- Nonfatal injury
- Fatal injury
- Not reported
- Unknown

CD2. **Number of Vehicles**

Definition: The count of motor vehicles (e.g., automobiles, single-unit trucks, truck combinations that are in motion or on a roadway) involved in the crash.

Source: Derived by counting the number of vehicles involved in a crash as indicated in **Vehicle Unit Number (V1)**.

Code: Total Number of Vehicles

V10. **Vehicle Configuration**

Definition: Indicates the general configuration of vehicle.

Code: Passenger car
Light truck(van, mini-van, panel, pickup, sport utility) with only four tires
Single-unit truck (2-axle, 6-tire)
Single-unit truck (3-or-more axles)
Truck/trailer
Truck tractor (bobtail)
Tractor/semi-trailer
Tractor/doubles
Tractor/triples
Unknown heavy truck, cannot classify
Motor home/recreational vehicle
Motorcycle
Bus (seats for more than 15 people, including driver)
Bus (seats for 7 - 15 people, including driver)
Other
Not reported
Unknown vehicle configuration

V13. **Total Occupants In Vehicle**

Definition: The count of occupants in this vehicle involved in the crash, including persons in or on the vehicle at the time of the crash.

Code: Total number of occupants including the driver
Unknown

V18. **Vehicle Authorized Speed Limit**

Definition: Authorized speed limit for the vehicle at the time of the crash. The authorization may be indicated by the posted speed limit, blinking sign at construction zones, etc.

Code: Subfield 1: Authorized Value

Subfield 2: Unit of Measurement
Miles per hour
Kilometers per hour
Not applicable
Unknown

V19. **Direction of Travel Before Crash**

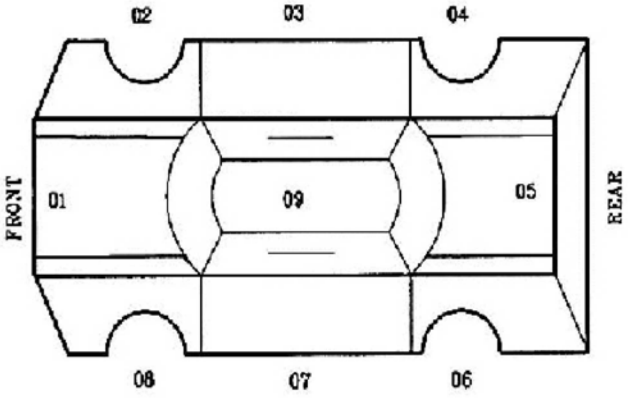
Definition: The direction of a vehicle’s normal, general travel on the roadway before the crash. Notice that this is not a compass direction but a direction consistent with the designated direction of the road. For example, the direction of a state designated north-south highway must be either northbound or southbound even though a vehicle may have been traveling due east as a result of a short segment of the highway having an east-west orientation.

Code:
- Northbound
- Southbound
- Eastbound
- Westbound
- Not on roadway
- Not reported
- Unknown

V22. **Point of Impact**

Definition: The portion of the vehicle that impacted first in a crash.

Code: See Figure B-1.



DAMAGE AREA

00	None
01	Center front
02	Right front
03	Right side
04	Right rear
05	Rear center
06	Left rear
07	Left side
08	Left front
09	Top and windows
10	Undercarriage
11	Total (All areas)
12	Other
99	Unknown

Figure B-1: Vehicle Impact and Damage Areas

V23. **Sequence of Events**

Definition: The events in sequence for this vehicle.

Code: Subfield 1: First Event

- Non-collision
  - Overturn/rollover
  - Fire/explosion
  - Immersion
  - Jackknife
  - Cargo/equipment loss or shift
  - Equipment failure (blown tire, brake failure, etc.)
  - Separation of units
  - Ran off road right
  - Ran off road left
  - Cross median/centerline
  - Downhill runaway
  - Other non-collision
  - Unknown non-collision
- Collision with person, vehicle, or object not fixed
  - Pedestrian
  - Pedalcycle
  - Railway vehicle (e.g., train, engine)
  - Animal
  - Motor vehicle in transport
  - Parked motor vehicle
  - Work zone maintenance equipment
  - Other movable object
  - Unknown movable object
- Collision with fixed object
  - Impact attenuator/crash cushion
  - Bridge overhead structure
  - Bridge pier or abutment
  - Bridge parapet end
  - Bridge rail
  - Guardrail face
  - Guardrail end
  - Median barrier
  - Highway traffic sign post
  - Overhead sign support
  - Light/luminaire support
  - Utility pole
  - Other post, pole, or support
  - Culvert
  - Curb
  - Ditch
  - Embankment
  - Fence
  - Mail box
  - Tree
  - Other fixed object (wall, building, tunnel, etc.)
  - Work zone maintenance equipment
  - Unknown fixed object

Other
Not reported
Unknown

Subfield 2: Second Event
See Codes in Subfield 1

Subfield 3: Third Event
See Codes in Subfield 1

Subfield 4: Fourth Event
See Codes in Subfield 1

V27. **Most Damaged Area**

Definition: The location of most damage on vehicle.

Code: See Figure B-1.

V28. **Extent of Damage**

Definition: Estimation of total damage to vehicle from crash

Code:
- None/minor damage
- Functional damage
- Disabling damage
- Severe/vehicle totaled
- Not reported
- Unknown

VL1. **Vehicle Identification Number**

Definition: A unique combination of alphanumeric characters assigned to a specific vehicle and formulated by the manufacturer. When the technology is available, this number also can be obtained by using a bar code reader while the vehicle is at the scene.

Code: A manufacturer assigned number permanently affixed to the vehicle.

VD1. **Vehicle Model Year**

Definition: The year which is assigned to a vehicle by the manufacturer.

Source: Derived from the 10th position of the **Vehicle Identification Number (VL1)** for 1981 to present**.** Prior to 1981, the position for the model year varied by manufacturer. This information also can be obtained separately from the Vehicle Registration File.

Code: Assigned by vehicle manufacturer

VD3. **Vehicle Body Type**

Definition: The general configuration or shape or a vehicle distinguished by characteristics such as number of doors, seats, windows, roof line, hard top or convertible.

Source: Derived from the **Vehicle Identification Number (VL1).**

Code: Passenger Vehicles

AM Ambulance
CB Cab & Chassis (Luv)
CP Coupe
CV Convertible
HB Hatchback*
HR Hearse
HT Hardtop*
LB Liftback
LM Limousine
NB Notchback
PK Pickup**
PN Panel**
RD Roadster
SB Sport Hatchback
SC Sport Coupe
SD Sedan*
SV Sport Van
SW Station Wagon
UT Utility**
WW Wide Wheel Wagon
2D Sedan, 2-door
2F Formal Hardtop 2-door
2H(81-03) Hatchback, 2-door
2L Liftback 3-door
2P Pillard Hardtop 2-door
2T Hardtop, 2-door
2W Wagon 2-door
3D Runabout 3-door
4D Sedan, 4-door
4H(81-03) Hatchback, 4-door
4L Liftback 5-door
4P Pillard Hardtop 4-door
4T Hardtop, 4-door
4W Wagon 4-door
5D Sedan 5-door

Trucks

AC Auto Carrier
AR Armored Truck
BU Bus
CB Chassis and cab
CC Conventional Cab
CG Cargo Van
CH Crew Chassis

CL Club Chassis
CM Concrete or Transit Mixer
CR Crane
CS Super Cab / Chassis Pickup
CU Custom Pickup
CV Convertible (Jeep Commando, Suzuki Samurai, Dodge Dakota)
CW Crew Pickup
CY Cargo Cutaway
DP Dump
DS Tractor Truck (diesel)
EC Extended Cargo Van
ES Extended Sport Van
EV Ext Van
EW Extended Window Van
FB Flat-bed or platform
FC Forward Control
FT Fire Truck
GG Garbage or Refuse
GL Gliders
GN Grain
HO Hopper
IC Incomplete Chassis
IE Incomplete Ext Van
LG Logger
LL Suburban and Carry All
MH Motorized Home
MP Multi-purpose
MV Maxi Van
MY Motorized Cutaway
PC Club Cab Pickup
PD Parcel Delivery
PK Pickup
PM Pickup with Camper mounted on bed
PN Panel
PS Super Cab Pickup
RD Roadster (Jeep, Jeep Commando)
SN Step Van
SP Sport Pickup
ST Stake or Rack
SV Sports Van
SW Station Wagon (Jeep Waggonneer, Dodge Sportsman A100, Toyota Landcruiser)
S1 One Seat
S2 Two Seat
TB Tilt Cab
TL Tilt Tandem
TM Tandem
TN Tank
TR Tractor Truck (Gasoline)
UT Utility (Blazer, Jimmy, Scout, etc.)
VC Van Camper
VD Display Van

    - VN Van
    - VT Vanette (including Metro and Handy Van)
    - VW Window Van
    - WK Tow Truck Wrecker
    - WW Wide Wheel Wagon
    - XT Travelall
    - YY Cutaway
    - 2W 2 Door Wagon
    - 4W 4 Door Wagon
    - 8V 8 Passenger Sport Van
- Motorcycles
    - AT All Terrain
    - EN Enduro
    - MK Mini-bike
    - MM Mini Moto Cross
    - MP Moped
    - MR Mini Road/Trail
    - MS Motor Scooter
    - MX Moto Cross
    - MY Mini Cycle
    - RC Racer
    - RS Road/Street
    - RT Road/Trail
    - T Dirt
    - TL Trail/Dirt
    - TR Trails

* Used only when number of doors is unknown.
** To code trucks commonly registered as passenger vehicles

Person Data Elements

P4. **Injury Status**

Definition: The injury severity level for a person involved in crash.

Code:
- Fatal Injury (K)
- Nonfatal Injury
    - Incapacitating (A)
    - Non-incapacitating (B)
    - Possible (C)
- No injury (O)
- Not reported
- Unknown

P6. **Seating Position**

Definition: The location for this occupant in, on, or outside of the motor vehicle prior to the impact of a crash

Code:
- Front seat - left side (or motorcycle driver)
- Front seat - middle
- Front seat - right side
- Second seat - left side (or motorcycle passenger)
- Second seat - middle
- Second seat - right side
- Third row - left side (or motorcycle passenger)
- Third row - middle
- Third row - right side
- Sleeper section of cab (truck)
- Passenger in other enclosed passenger or cargo area (non-trailing unit such as a bus)
- Passenger in unenclosed passenger or cargo area (non-trailing unit such as a pickup, etc.)
- Trailing unit
- Riding on vehicle exterior (non-trailing unit)
- Not reported
- Unknown

P7. **Occupant Protection System Use**

Definition: The restraint equipment in use by occupant at the time of the crash, or the helmet use by a motorcyclist.

Code:
- None used - vehicle occupant
- Shoulder belt only used
- Lap belt only used
- Shoulder and lap belt used
- Child safety seat used
- Helmet used
- Not reported
- Restraint use unknown

P8. **Air Bag Deployed**

Definition: Deployment status of an air bag relative to position of the occupant.

Code:
- Subfield #1: Deployment
  - Deployed-front
  - Deployed-side
  - Deployed-both front/side
  - Not-deployed
  - Not applicable
  - Not reported
  - Deployment unknown
- Subfield #2: Switch Status
  - Switch in ON position
  - Switch in OFF position

ON-OFF switch not present
Unknown if ON-OFF switch present
Not reported
Unknown position

P9. **Ejection**

Definition: The location of each occupant's body as being completely or partially thrown from the vehicle as a result of a crash.

Code: Not ejected
Totally ejected
Partially ejected
Not applicable
Not reported
Unknown

P14. **Contributing Circumstances**, **Driver**

Definition: The actions of the driver which may have contributed to the crash.

Code: Subfield 1: Driver Contributing Circumstances #1
No Improper driving
Failed to yield right of way
Disregarded traffic signs, signals, road markings
Exceeded authorized speed limit
Driving too fast for conditions
Made an improper turn
Wrong side or wrong way
Followed too closely
Failure to keep in proper lane or running off road
Operating vehicle in erratic, reckless, careless, negligent or aggressive manner
Swerving or avoiding due to wind, slippery surface, vehicle, object, non-motorist in roadway, etc.
Over-correcting/over-steering
Visibility obstructed
Inattention
Distracted
Fatigued/asleep
Operating defective equipment
Other Improper action
Not reported
Unknown

Subfield 2: Driver Contributing Circumstances #2
See subfield 1

Roadway Data Elements

RL2. **Horizontal Alignment**

Definition: The change in horizontal direction of a roadway, determined at the point of curvature (pc) and expressed in terms of direction, degree of curve and length.

Code: Subfield 1: Direction
- Right
- Left

Subfield 2: Curve Radius
Subfield 3: Length
Subfield 4: Superelevation
Subfield 5: Unit of Measure

RL3. **Grade**

Definition: The inclination of a roadway, expressed in the rate of rise or fall in feet (meters) per 100 feet (meters) of horizontal distance.

Code: Subfield 1: Direction of slope
- Up (+) or down (-)

Subfield 2: Percent of slope
- Nearest percent of slope

RL5. **Functional Classification of Highway**

Definition: The character of service or function of streets or highways. The classification of rural and urban is determined by state and local officials in cooperation with each other and approved by the Federal Highway Administration, U.S. Department of Transportation.

Code:
- Rural
  - Principal arterial-interstate
  - Principal arterial-other
  - Minor arterial
  - Major Collector
  - Minor Collector
  - Local
- Urban
  - Principal arterial-interstate
  - Principal arterial-other freeway or expressway
  - Principal arterial-other
  - Minor arterial
  - Collector
  - Local
  - Unknown

RL6. **Lanes**

Definition: Total number of lanes in the trafficway, regardless of function or direction of travel, at the particular cross section of the trafficway where the crash occurred.

Code: Total number of lanes in the trafficway

RL7. **Annual Average Daily Traffic**

Definition: The average number of vehicles passing a point on a trafficway in a day, for all days of the year, during a specified calendar year.

Code: Subfield 1: Calendar year
Subfield 2: Vehicles per day (AADT)

RL8. **Trafficway Description**

Definition: Indication of whether or not a trafficway is divided and whether it serves one-way or two-way traffic. (A divided trafficway is one on which roadways for travel in opposite directions are physically separated by more than an easily traversable centerline.)

Code: Two-way, not divided
Two-way, divided, unprotected median
Two-way, divided, positive median barrier
One-way, not divided
Not reported
Unknown

RL9. **Average Widths of the Shoulder(s) and Lane(s)**

Definition: Average widths of the lane(s) and of the shoulder(s) where crash occurred.

Code: Subfield 1: Average lane width in feet
Subfield 2: Average shoulder width in feet

RL10. **Average Width of Median**

Definition: Average width of portion of divided highway separating the traveled way for traffic in opposing directions where crash occurred.

Code: Average width of median in feet (meters)