Expert Systems for Crash Data Collection

Final Report

Publication No. FHWA-RD-99-052

Prepared by

Calspan, An Operation of Veridian
4455 Genesee Street
P.O. Box 400
Buffalo, NY 14225

Contract No. DTFH61-95-C-0007

Prepared for

Office of Safety and Traffic Operations R&D
Federal Highway Administration
6300 Georgetown Pike
McLean, Virginia 22101-2296

FOREWORD

A. George Ostensen, Director
Office of Safety and Traffic Operations
Research and Development

Technical Report Documentation Page

1. Report No. FHWA-RD-99-052	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Expert Systems for Crash Data Collection		5. Report Date
		6. Performing Organization Code
7. Author(s) Carol Y. Thielman		8. Performing Organization Report No.
9. Performing Organization Name and Address Calspan, An Operation of Veridian 4455 Genesee Street P.O. Box 400 Buffalo, NY 14225		10. Work Unit No. (TRAIS) 3A3B
		11. Contract or Grant No. DTFH61-95-C-0007
12. Sponsoring Agency Name and Address Office of Safety and Traffic Operations R&D Federal Highway Administration 6300 Georgetown Pike McLean, VA 22101-2296		13. Type of Report and Period Covered Final Report April 1995-October 1998
		14. Sponsoring Agency Code

15. Supplementary Notes

Contracting Officer's Technical Representative (COTR) - Michael S. Griffith, HSR-20
Clarence W. Mosher, King K. Mak, and TARAS Inc. were subcontractors. King K. Mak and John Painter of TARAS Inc. were members of the Expert Panel.

16. Abstract

There is a demand by the highway safety community for better quality crash data to meet a wide variety of needs. The goal of the Federal Highway Administration (FHWA) Expert Systems for Crash Data Collection Program was to use expert systems technology to improve the accuracy and consistency of police-reported data. The program included the development and evaluation of three expert systems: (1) Seat Belt Use Derivation; (2) Vehicle Damage Rating, including Extent of Deformation; and (3) Roadside Barrier Problem Identification.

Police officers used pen-based computers, containing the expert systems, to collect on-scene crash data. Embedded in the expert systems are data collection knowledge derived from experts in crash data collection and analysis. The expert systems use this knowledge to intelligently select the data to collect and assign values to elements. This knowledge is also included in on-line help screens that aid the officer in accurately identifying the physical characteristics of the crash scene.

The expert systems were evaluated during two field tests. The field test results showed that the expert systems: (1) were well accepted by the officers, (2) were validated by experts in the expert system domain areas, and (3) the officers collected data on an average of approximately 2 minutes per expert system.

17. Key Words Accident data collection, accident data reporting, crash data collection, crash data reporting, expert systems, data collection systems, police accident report, police crash report.	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 73	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGMENTS

Expert Panel Members

The author would like to thank the expert panel members for their participation in the design, development, and evaluation of the expert systems. Their knowledge of highway safety analysis, police operations, and crash data collection was essential to the success of the program.

Line Sergeant David Bloome, North Carolina Highway Patrol
Sergeant David Karney, Erie County Sheriff's Office
Sergeant Thomas Lampe, Iowa State Patrol
Joseph C. Marsh IV, Principal Research Engineer Associate, Ford Motor Company
Robert A. Romberg, NASS Training Coordinator, Transportation Safety Institute

Field Test Participants

The author would also like to thank the individuals and organizations that supported the expert systems' field tests.

Terry Dillinger, Site Coordinator, Director, Office of Driver Services, Iowa Department of Transportation (DOT)
Bobbie Davis, Field Test Operations Coordinator, Administrative Assistant, Iowa DOT
Lieutenant Robert Messelheiser, Site Coordinator, Iowa State Patrol
Sergeant Ronald Turner, Site Coordinator, Iowa State Patrol
Trooper Larry Grant, Field Test Operations Coordinator, Iowa State Patrol
Jack Latterell, Safety Program Manager, Federal Highway Administration, Iowa Division Office
Federal Highway Administration, Office of Research and Development
Tadd E. Geis, Iowa Officer Information System Program Manager, American Management Systems
Malcolm H. Ray, Ph.D., P.E., University of Iowa
Jeffrey A. Hopp, University of Iowa

Field Test Officers - Iowa State Patrol

Trooper Kent Brown
Trooper Robert Hansen
Trooper Michael Horrihan
Trooper David Hughes
Trooper Karl Kluender
Trooper Brent Meadows
Trooper Mark Miller
Trooper Chad Peters
Trooper Darin Sneddin
Trooper Glen Swanson
Trooper Brett Tjepkes
Trooper Neil Wellner

TABLE OF CONTENTS

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

1.0 BACKGROUND

Highway safety data analysts desire better quality data to meet a wide variety of needs. Many of the data elements currently collected are not of sufficient quality to meet the needs of data analysts. A primary source of highway safety data is crash data collected by police officers at the scene. Police are unique in their ability to collect on-scene crash data shortly after the crash occurs, as well as the transient data that may erode (i.e., tire marks) or be removed from the scene. In addition, police collect crash data from a wider spectrum of crashes compared with special investigation teams. Due to their vast and varied experience, police provide the potential to improve the quality of data for less severe crashes.

Although police are in a unique position to collect crash data, data collection is not their only responsibility. Their primary on-scene responsibilities include securing the crash site, caring for injured persons, and re-establishing traffic flow. Therefore, on-scene data collection systems must consider the officer's needs when implementing new technologies.

Police officers across the nation are now using computers in their vehicles for a variety of applications. Many police officers use mobile computers to directly encode the State police crash report. Officers also use in-vehicle computers to access data from State and national databases. Unlike the mobile data terminals previously used by police, the current mobile computers support standard operating systems (e.g., Microsoft Windows) and software. In addition, these computers support multiple input devices, including electronic pen and touchscreen.

2.0 INTRODUCTION

The Federal Highway Administration (FHWA) Crash Data Collection Expert System program expands the use of in-vehicle police computers. The program utilizes expert systems to increase the accuracy and consistency of police-reported data at the time the officer collects it. The primary results of this program are the development and evaluation of these three expert systems:

- Seat Belt Use: Determines whether a vehicle occupant wore his or her seat belt during a crash.
- Vehicle Damage Rating: Collects the data needed to determine the severity of a crash based on vehicle damage.
- Roadside Barrier: Identifies the type of barrier involved in the crash and the point of impact.

The development and evaluation of these expert systems resulted from three main program objectives:

- Identify the crash data elements needed for analysis.
- Develop crash data collection software that utilizes expert system technology.
- Assess the utility of applying expert system technology to the crash data collection process.

The utility of applying expert system technology to the crash data collection process was assessed during two field tests. The field tests were performed in cooperation with the Iowa Department of Transportation (DOT) and the Iowa State Patrol. Iowa was chosen for the field test site since it was the first State to deploy a mobile crash reporting system that collects State-reported data and since it is currently a test-bed for highway safety technologies on the National Model for the Statewide Application of Data Collection & Management Technology to Improve Highway Safety (National Model) program. The National Model effort is a program for sharing information, resources, and technologies to improve highway safety. The goal of the National Model is to demonstrate, in a statewide operational environment, how new technologies and techniques can be cost-effectively used to improve highway safety data collection and management processes. The Crash Data Collection Expert System project was part of the larger National Model effort.

A feature of the Crash Data Collection Expert System is the ability to share common data elements with the various crash data collection systems that collect State-reported data. This ensures that the officer does not have to collect and input the same data element multiple times. It also allows the State-reported data and the expert system data to be linked. Section 4.1 identifies the shared data elements. Details on each of the three expert systems are in sections 4.2 through 4.4.

The Crash Data Collection Expert System documentation includes two unpublished reports: the *Users Guide* and the *Maintenance Guide.* The *Users Guide* provides: (1) installation procedures, (2) information a software developer needs in order to interface a computer system collecting State-reported data with the expert systems, and (3) the training manual. The *Maintenance Guide* is intended for the software developer who will maintain the expert systems software. The document focuses on the two primary maintenance tasks: (1) adding a new data element for crash data collection and (2) adding a new value for an existing data element. Copies of these reports can be obtained from FHWA.

2.1 EXPERT SYSTEMS TECHNOLOGY APPLIED TO CRASH DATA COLLECTION

Expert systems are computer programs that contain knowledge in a specific domain. The expert system often uses this knowledge to perform tasks that a human can do. The three previously mentioned expert systems were implemented using the rule-based expert system technology. The knowledge of highway safety experts was encoded into rules that were used by the system to determine which data to collect and to reach a conclusion that an expert would reach. Data collection systems utilizing expert systems technologies can provide these benefits:

- Intelligently collect only relevant data.
- Intelligently assign values to crash data elements.
- Intelligently validate data.

The first two features were implemented in the expert systems: (1) intelligently collect only relevant data and (2) intelligently assign values to crash data elements. The full implementation of intelligent data validation was beyond the scope of the program. Nonetheless, validation was implemented in the Seat Belt Use Expert System by enabling the system to identify conflicting seat belt use evidence.

The expert systems intelligently collect only the relevant data elements by dynamically requesting the data, based on the crash scene data that has been collected, allowing the expert system to request only the data needed for a specific crash type. This case-by-case data collection is particularly useful for special studies where additional crash data is desired for particular crash types.

The expert systems intelligently assign a value to a crash data element by reaching the same conclusion that a human expert would, based on the crash evidence collected. Many of the data elements that aid the highway safety analyst in evaluating crash circumstances often require judgment; the expert system has embedded rules that a crash investigator or reconstructionist would use when analyzing the crash scene, such as determining whether the vehicle occupant wore his or her seat belt during a crash.

The experts' knowledge is also included in on-line help screens that aid the officer in accurately identifying the physical characteristics of the crash screen. Included in the help screens are photographs showing the salient physical evidence and descriptive text. For example, the Seat Belt Use Expert System includes the following information for each indicator of occupant loading on the seat belt: (1) a photograph showing the specific belt evidence, (2) a description of the salient evidence, (3) a description of where in the vehicle the evidence is typically found, and (4) the conditions under which occupant belt loading typically occurs.

2.2 EXPERT PANEL PARTICIPATION

Throughout the program, a panel of experts in crash data collection and analysis were relied on to provide the knowledge that is embedded in the three expert systems, including officers who provided the knowledge needed to ensure that the systems met police needs. Two types of knowledge were acquired from the expert panel: (1) knowledge of the specific crash data areas selected for expert systems development and (2) knowledge of police operations. The panel was composed of the following types of experts:

- Traffic officer.
- Crash investigation trainer.
- Highway safety analyst.
- Crash reconstructionist.
- Vehicle safety engineer.
- Guardrail designer/highway engineer.

The experts were separated into two panels. One panel participated in the design and development of the Vehicle Damage Rating and Seat Belt Use expert systems. This panel included traffic officers, a crash investigation trainer, a highway safety analyst, crash reconstructionists, and a vehicle safety engineer. The other panel participated in the design and development of the Roadside Barrier Expert System and included a traffic officer, a highway safety analyst, a crash reconstructionist, and a guardrail designer/highway engineer.

In the beginning of the program, an initial panel provided insights into areas where the quality of highway safety data could be improved. They identified a need for better crash severity data, including vehicle deformation data. As one example, the vehicle safety engineer stated that current crash data does not provide an adequate measure of severity for low-impact crashes. These data would aid in analyzing the in-service performance of vehicle components such as airbags. This initial panel was then expanded to include experts in the specific safety data areas selected for expert system implementation.

Throughout the remainder of the program, members of the expert panel provided knowledge in their specific areas of expertise. This knowledge was included in the expert systems' design and implementation. The panel's responsibilities also included verifying and validating the expert systems during design and implementation, and recommending system enhancements. The panel participated in focus group meetings, reviewed design documents, participated in design review meetings, reviewed the expert system software, and participated in software review meetings. This process included both panel meetings, which were used to develop consensus among the expert panel members, and individual member meetings.

2.3 PROGRAM TASKS AND PROCESSES

The primary tasks performed on the Crash Data Collection Expert System program are shown in figure 1. During the first task, Identify and Select the Highway Safety Data Areas, three highway safety areas were identified and selected for expert systems development. These are areas where there is a need by the highway safety community for better quality data (see section 3.0). The second task, Select Experts in These Areas, involved choosing experts in the specific data areas chosen. This panel was included in the three remaining phases of the expert system development process.

The Design, Implementation, and Test tasks were iterative and continuous throughout the expert system development process, as shown in figure 1. The project included the delivery of multiple system versions to allow the panel members and/or field test officers to use the system and suggest modifications. The arrows in figure 1 indicate that the system design and implementation were modified as a result of the subsequent Implementation and Test tasks. These modifications reflected additional information acquired from the expert panel members and field test officers.

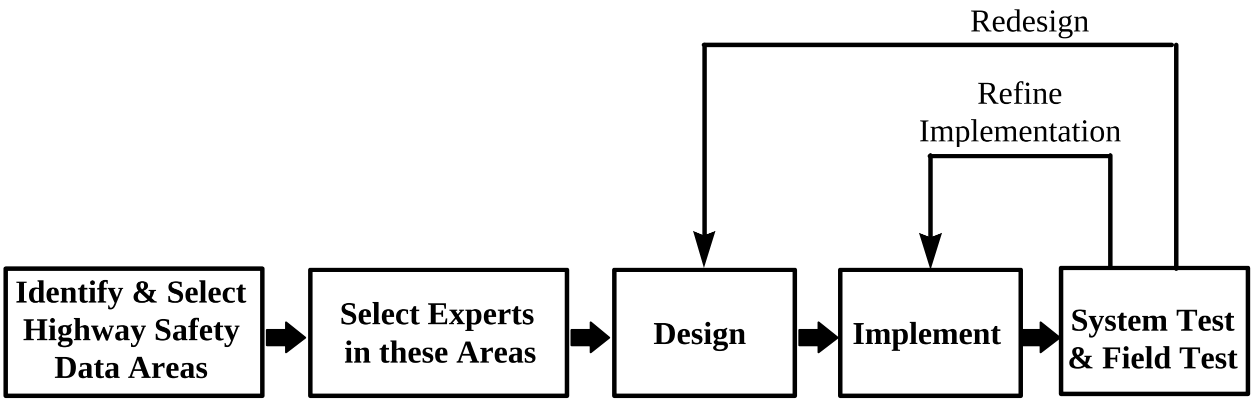


Figure 1. Crash Data Collection Expert System development process.

3.0 IDENTIFY THE HIGHWAY SAFETY DATA AREAS AND ELEMENTS NEEDED FOR ANALYSIS

There are three elements of a crash that are coded by police officers:

- Driver and vehicle.
- Location.
- Circumstances.

The Crash Data Collection Expert System program focused on collecting data to better determine the crash circumstances. Increasing the accuracy and consistency of the other two areas (driver/vehicle and location data collection) is currently being addressed by technologies other than the expert systems. The quality of driver and vehicle data can be improved by technologies such as bar codes, remote database access, and vehicle identification number (VIN) decoding software. The quality of location data can be improved by technologies such as the Global Positioning System (GPS) and the Geographical Information System (GIS). As such, many police agencies are beginning to experiment with these technologies to increase the accuracy of collected driver, vehicle, and location data.

During the first phase of the program, three highway safety areas were selected for expert system development and evaluation. Initially, a number of areas were identified where crash data elements were needed for highway safety analysis, including crash severity, injury severity, occupant injury evidence, seat belt usage, seat belt type, child restraint usage, child restraint type, run-off-the-road crashes, in-service performance of roadside barriers, and work-zone crashes. The selection was narrowed down to three highway safety areas based on these criteria:

- Multiple types of highway safety users desire the data.
- Some data elements are currently collected in police crash reports, yet users desire that the quality of the data be improved.
- Some data elements are not typically collected in police crash reports.

- It is feasible that an officer with many on-site responsibilities will be able to accurately collect the data.
- A sufficient number of crashes of this type will occur during the field test to adequately evaluate the system.

The three highway safety areas selected for expert system implementation were:

- Seat belt use derivation.
- Crash severity, based on vehicle damage.
- Roadside barrier problem identification.

The specific criteria used in selecting areas for expert system implementation are described in the following sections: 3.1 Seat Belt Use, 3.2 Vehicle Damage Rating, and 3.3 Roadside Barrier.

3.1 SEAT BELT USE

Currently, police-reported seat belt usage in crashes reflects a higher than actual usage rate. This is because much of this data is based on occupant interviews. The data user community has a need for accurate identification of whether a restraint was used in a particular crash or type of crash. The expert system will collect additional data elements in order to more accurately identify whether an occupant wore his or her seat belt. These data elements are intended to indicate an occupant's belt usage during the crash, rather than frequency of seat belt usage. Table 1 summarizes the rationale used to select seat belt use as a data area for expert systems implementation.

Table 1. Rationale for selecting the Seat Belt Use highway safety data area and elements.

Criteria	Rationale
Multiple types of users desire the data	• Aids in assessing crash severity independent of restraint usage. These data are desired by law enforcement agencies, traffic safety administrations, highway and public works departments, motor vehicle administrators, vehicle manufacturers, insurers, independent researchers, and legislators/regulators. • Collected in some form by all States. • Occupant Protection System Used is both a Model Minimum Uniform Crash Criteria (MMUCC)[1] and a Critical Automated Data Reporting Elements (CADRE) data element.[2]
Data accuracy can be improved	• Police-reported seat belt usage reflects a higher usage rate than that determined from roadside observation studies. • Occupant Protection System Used is a CADRE data element.
Officer can accurately collect the data in the current time constraints	• National Automotive Sampling System (NASS) investigators can accurately determine seat belt use. • NASS investigators can quickly inspect a vehicle for seat belt use evidence.
Enough crashes will occur to evaluate the expert system	• Some seat belt use evidence is available in all crashes. • Most seat belt use evidence is available in severe crashes.

3.2 VEHICLE DAMAGE RATING

The Vehicle Damage Expert System addresses the need for a better measure of crash severity than is typically collected on police crash reports. Crash severity is typically measured by two methods: vehicle damage and overall occupant injury severity. The vehicle damage data collected by most States does not provide the detail needed to determine the severity of a crash. Therefore, currently, injury severity is often the only measure of crash severity available in police-reported data.

State reporting systems have a broad spectrum of methods to identify vehicle damage location or severity, including whether the vehicle was towed, estimated repair costs, and the Traffic Accident Data (TAD) Scale.(3) In most State reports, the severity of vehicle damage cannot be rated. Table 2 summarizes the rationale used to select vehicle damage rating as a data area for expert systems implementation.

Table 2. Rationale for selecting the Vehicle Damage Rating highway safety data area and elements.

Criteria	Rationale
Multiple types of users desire the data	• Aids in assessing crash severity, which is desired by law enforcement agencies, traffic safety administrations, highway and public works departments, motor vehicle administrators, vehicle manufacturers, insurers, independent researchers, and legislators/regulators. • Collected in some form by all States. • Extent of Deformity is a CADRE data element.(2)
Data accuracy can be improved	• States use a variety of methods. The best method is TAD (used in North Carolina), which has not been adopted by other States. • Extent of Deformity is a CADRE data element.
Data is not typically collected in police crash reports	• Extent of Deformity is a CADRE data element.
Officer can accurately collect the data in the current time constraints	• Vehicle Damage Indicator (VDI) was evaluated in comparison to TAD. VDI was shown to be more accurate than TAD.(3) • TAD is currently accurately collected by police. • Six additional data elements are collected.
Enough crashes will occur to evaluate the expert system	• Vehicle damage data can be collected, at some level, for all crashes.

3.3 ROADSIDE BARRIER PROBLEM IDENTIFICATION

The Roadside Barrier Expert System addresses the need for in-service performance measurement of barrier crashes. The expert system collects data that would be collected in a particular area over a specific period of time and included in a special study. Therefore, this system proves the concept of using expert systems technology for special studies.

The objective of the barrier problem identification area is to collect the data required to identify the problems associated with particular longitudinal barrier types. Currently, little data is collected in police reports to aid a highway safety engineer in assessing barrier performance. Typically, State reports only tell whether the barrier is a guardrail or concrete barrier and whether the barrier is located in the median. However, this data is not sufficient to determine problems associated with particular barrier types.

As barrier standards are being enforced, the State DOT must replace existing substandard barriers and barrier end treatments with those meeting the standards. The barrier standards are based on available data, primarily crash test results. States believe the standard may not apply to all roadway types (e.g., wide-open spaces in Wyoming). Therefore, States feel there is a need for in-service performance testing of barriers. There are several types of in-service data collectors that can be used to collect these data, including police, DOT maintenance staff, and independent trained investigators.

The Roadside Barrier Expert System was chosen to prove the concept of using expert systems for special studies such as these cases. Table 3 summarizes the rationale for selecting roadside barrier classification and problem identification as a data area for expert systems implementation. The biggest obstacle to be overcome for this area is the limited number of barrier crashes that typically occur; only 1.5 percent of all crashes involve roadside barriers. However, this was a problem for nearly every highway safety area identified for a special study.

Table 3. Rationale for selecting the Roadside Barrier highway safety data area and elements.

Criteria	Roadside Barrier
Multiple types of users desire the data	• Aids in assessing crash severity, which is desired by traffic safety administrations, highway and public works departments, legislators/regulators, and independent researchers.
Data is not typically collected in police crash reports	• States collect few data elements for barrier crashes.
Officer can accurately collect the data in the current time constraints	• A maximum of seven data elements are collected for crashes that impact the main section of the barrier. Seven data elements are collected for crashes involving a W-beam barrier. • A maximum of 13 data elements are collected for crashes that impact the barrier end or transition to the end. Thirteen data elements are collected for crashes involving a thrie-beam barrier.
Enough crashes will occur to evaluate the expert system	• Approximately 1.5% of all crashes involve roadside barriers.(5) This made it difficult to collect a large number of barrier crashes. To increase the number of barrier crashes, the police agreed to collect data that would have been unreported[1] and the second field test duration was extended to 5 months. As a result, data was obtained on nine barrier crashes.

4.0 EXPERT SYSTEMS IMPLEMENTATION

The second objective of the Crash Data Collection Expert System program was to develop crash data collection software that utilizes expert system technology. The expert systems were developed utilizing a rule-based methodology. The rules are used to dynamically select what data to collect, based on crash type, from previously entered data. This allows a case-by-case data collection system.

---

[1] The unreported crashes include crashes that did not meet the Iowa police crash reporting criteria.

4.1 INTEGRATED EXPERT SYSTEMS AND STATE CRASH REPORTING SYSTEM

The expert systems were designed and developed to allow the officer to collect both State-reported data and expert systems data in a single application. This integration provides benefits for both the officer and the data analysts. The officer is able to invoke the expert system via a seamless user interface combining the two applications. The officer will typically invoke the expert system via an action in the State data collection system.

The expert systems share common data elements with systems that collect State-reported crash data. In addition, data elements that are used in more than one expert system are shared. This sharing feature ensures that the officer will not have to enter the same data element multiple times. The data analyst benefits from the ability to link the State-reported data and expert systems data for data analysis.

Documentation describing the method of integrating a State crash reporting system with the expert systems is described in the unpublished report *Expert Systems for Crash Data Collection: Users Guide.* This document includes a complete list of the data elements typically collected by State data collection systems that are also needed in the expert systems. However, none of the data elements collected in the Roadside Barrier Expert System is typically collected by the States, because the barrier identification expert system was designed to collect special study data that is not collected at all by most States.

Iowa Crash Report Data Sharing

The Iowa State Patrol currently uses pen-based computers to collect their State crash report data. Therefore, the officers field tested an integrated Iowa crash reporting system and expert systems. The Iowa crash reporting system application was modified to seamlessly integrate with the expert systems. Tables 4 and 5 show data shared with the Iowa crash reporting system. Each data value is classified as one of three data-sharing types:

- Input and output: The data value directly translates to the expert systems data element value. Therefore, the value is input to the expert system and output from the expert system.
- Output from expert system only: A data element value collected in the expert systems is not a valid value for the corresponding Iowa crash report data element. Therefore, this value cannot be used by the Iowa crash reporting system.
- Input to the expert system only: The data element value is input to the expert systems, but is not output from the expert systems. This may be for one of two reasons:

  (1) The expert system does not collect the data and the data value is used for display purposes. For example, the data element Person Name is displayed at the top of each expert system data collection screen, but is not collected in the expert systems.

(2) The Iowa crash reporting system data element value and the expert systems data element value do not translate directly. For example, the data element Seat Position values—rear left, rear middle, and rear right—translate to a single value: rear. In this case, the expert systems return value—rear—cannot be used by the Iowa crash reporting system.

Data elements in italics indicate data elements that are not explicitly included in the Iowa crash report, but are input to the expert system from the Iowa crash reporting system. For example, the data element "Registrant Address Equals Driver Address" is derived in the Iowa crash reporting system when the addresses of the registrant and the driver are the same.

Table 4. Iowa crash report data elements shared with the Seat Belt Use Expert System.

Iowa State Crash Report Data Element	Data-Sharing Type	Data Values
Ejection	Input and Output	Not Ejected Partially Totally Unknown
Injury Severity	Input to Expert System Only	Unknown (K) Killed (A) Incapacitating (B) Non-Incapacitating (C) Complaint of Pain
Seat Position	Input and Output	Front, Left Seat (Driver)
	Input and Output	Front, Middle Seat
	Input and Output	Front, Right Seat
	Input and Output	Center, Left Seat
	Input and Output	Center, Middle Seat
	Input and Output	Center, Right Seat
	Input to Expert System Only	Rear, Left Seat
	Input to Expert System Only	Rear, Middle Seat
	Input to Expert System Only	Rear, Right Seat
	Input and Output	Unknown
Person Name	Input to Expert System Only	Text
Vehicle Number	Input to Expert System Only	Number
Protective Device	Input to Expert System Only	Airbag Deployed
	Output From Expert System Only	Unknown
Registrant Address Equals Driver Address	Input to Expert System Only	True/False
Vehicle Year	Input and Output	Number

Note: Data elements in italics indicate data elements that are not explicitly included in the Iowa crash report, but are input to the expert system from the Iowa crash reporting system.

Table 5. Iowa crash report data elements shared with the Vehicle Damage Rating Expert System.

Iowa State Crash Report Data Element	Data-Sharing Type	Data Values
Collision Type	Input to Expert System Only	Head-On
	Input and Output	T-Collision
	Input to Expert System Only	Rear End
	Input and Output	Single Vehicle
Damage Area of Vehicle	Input to Expert System Only	Top
Vehicle Number	Input to Expert System Only	Number
Vehicle Year	Input to Expert System Only	Number

Note: Data elements in italics indicate data elements that are not explicitly included in the Iowa Crash Report, but are input to the expert system from the Iowa crash reporting system.

Expert System Data Sharing

The Seat Belt Use Expert System and Vehicle Damage Rating Expert System share three data elements:

- General Area of Deformation.
- Extent of Deformation (Depth of Crush).
- Vehicle Year.

Vehicle Year, however, is not used for expert system processing in the Vehicle Damage Rating Expert System. It is displayed at the top of each input screen to help the officer identify the vehicle for which he or she is entering data.

4.2 SEAT BELT USE DERIVATION

The Seat Belt Use Expert System collects the data, based primarily on physical evidence gathered at the scene, that a crash reconstructionist or investigator would use to determine whether the occupant wore a seat belt. Based on the input, the Seat Belt Use Expert System reaches one of these seat belt usage conclusions: (1) used, (2) not used, (3) probably used, (4) probably not used, (5) unknown because the evidence is conflicting, or (6) unknown because there is not enough evidence. Table 6 identifies the data elements collected in the Seat Belt Use Expert System, the evidence gathered, and the conclusion the expert system reaches based on the evidence.

Table 6. Seat Belt Use data elements and expert system results.

Data Element	Officer's Observation	Conclusion on Use	Data Reliability Rating
Belt Used Statement	Occupant stated he or she did not wear a belt during the crash.	Not Used	High
Occupant Ejected or Displaced From Seat	Occupant is fully ejected or displaced from his or her seat. Officer also inspects the belt to ensure that belt failure did not occur during the crash.	Not Used	High
Seat Belt Was Not Usable Before the Crash	Belt was in an unusable position or unusable condition before the crash. Examples include: belt damaged, buckle will not latch, or belt is stowed under seat.	Not Used	High
Observed Belt Use	Officer observed that the belt was used, while the occupant was not conscious.	Used	High
Seat Belt Loading	Seat belt damage caused by occupant loading on the seat belt. Examples include: belt stretch, D-ring transfer, latch plate abrasion, loop mechanism deployed, tissue or fabric transfers, and trim panel damage. See figure 2.	Used	High
Injury Caused by Belt Loading	Band-like injury patterns typically occurring when the belt is worn in a high delta velocity crash. Injured areas include: (1) chest, (2) shoulder, or (3) abdomen.	Used	High
Other Observation	Other evidence, not requested in the expert system, that the seat belt was either used or not used.	Probably Used or Probably Not Used	Medium
Body Contact With Vehicle Interior	Occupant contacted the interior of the vehicle due to displacement from his or her seating position during a crash. Points of contact for a frontal impact include: A-pillar, windshield, windshield header, steering wheel, instrument panel, and knee bolster or lower instrument panel. See figure 3.	Probably Not Used	Medium
Citation for Not Wearing a Belt	Citation was issued to the occupant for not wearing his or her belt.	Probably Not Used	Medium
Belt Dirt Pattern Shows Non-Usage	Lower part of the shoulder belt is dirty and the retracted upper part is clean. This is evidence that the belt has remained in a retracted position and is not used frequently. See figure 4.	Probably Not Used	Medium
Routine Wear Marks on Belt	Latch plate does not show routine wear marks and the vehicle is new. See figure 5.	Probably Not Used	Medium

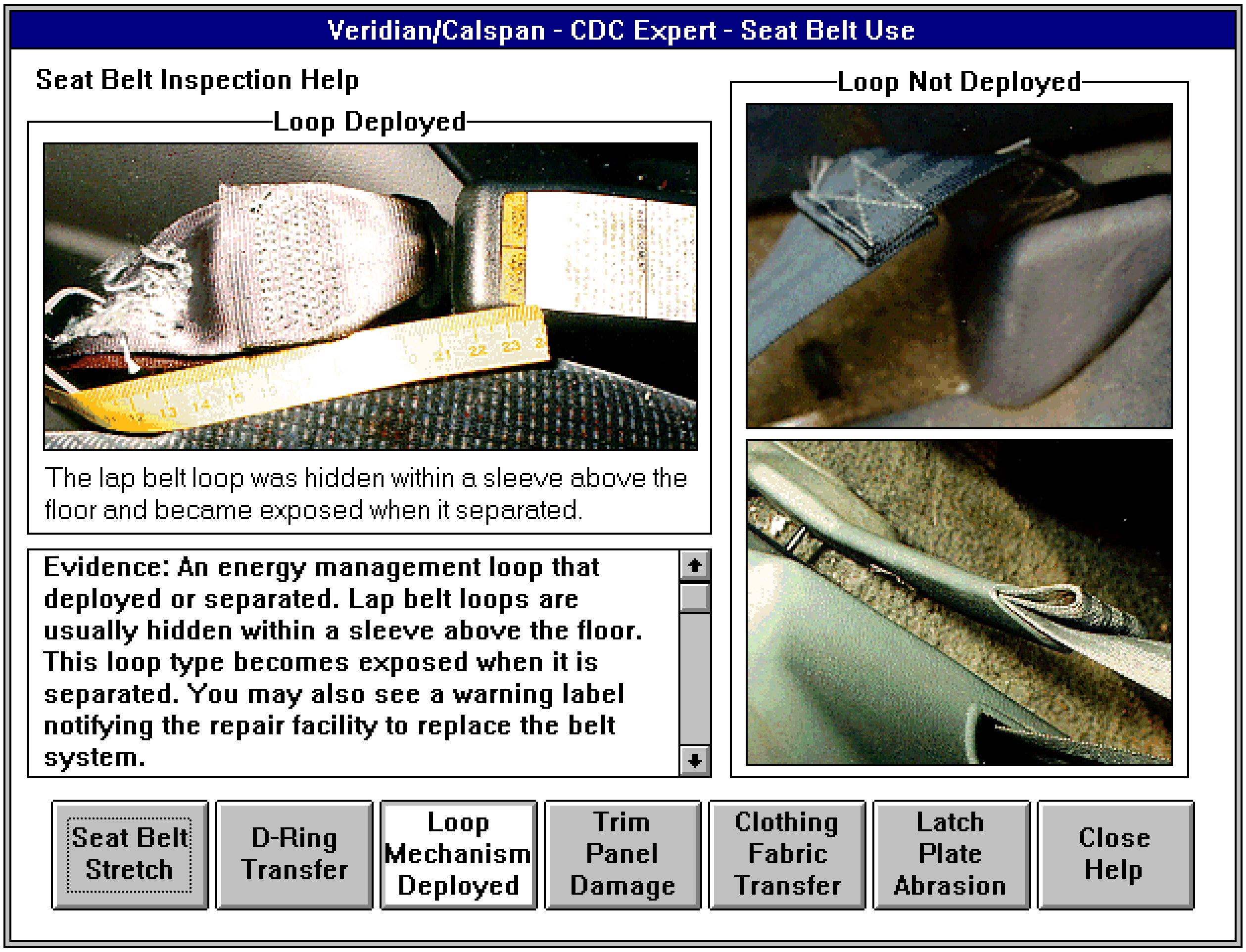


Figure 2. Seat belt loading evidence help screen.

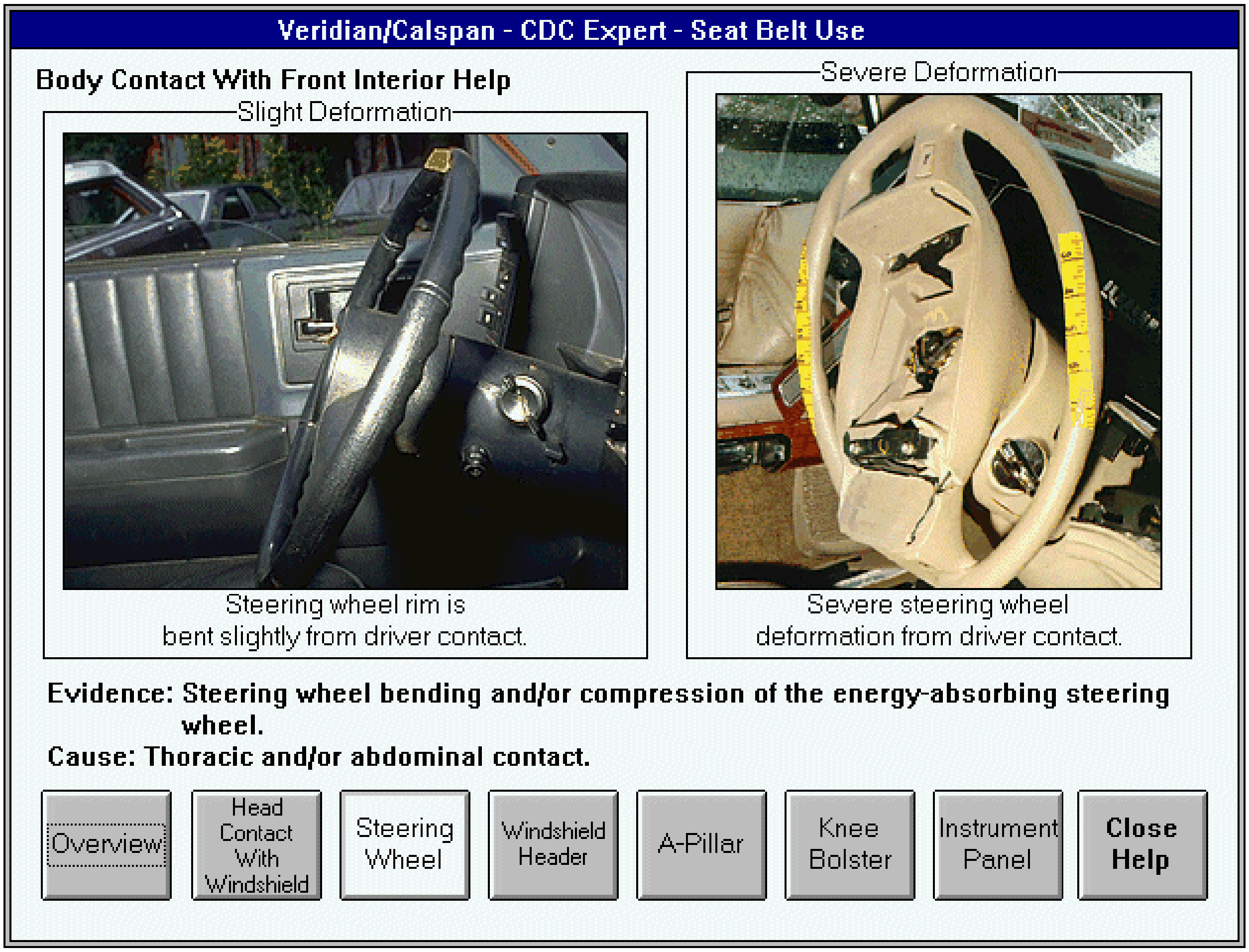


Figure 3. Body contact with vehicle interior help screen.

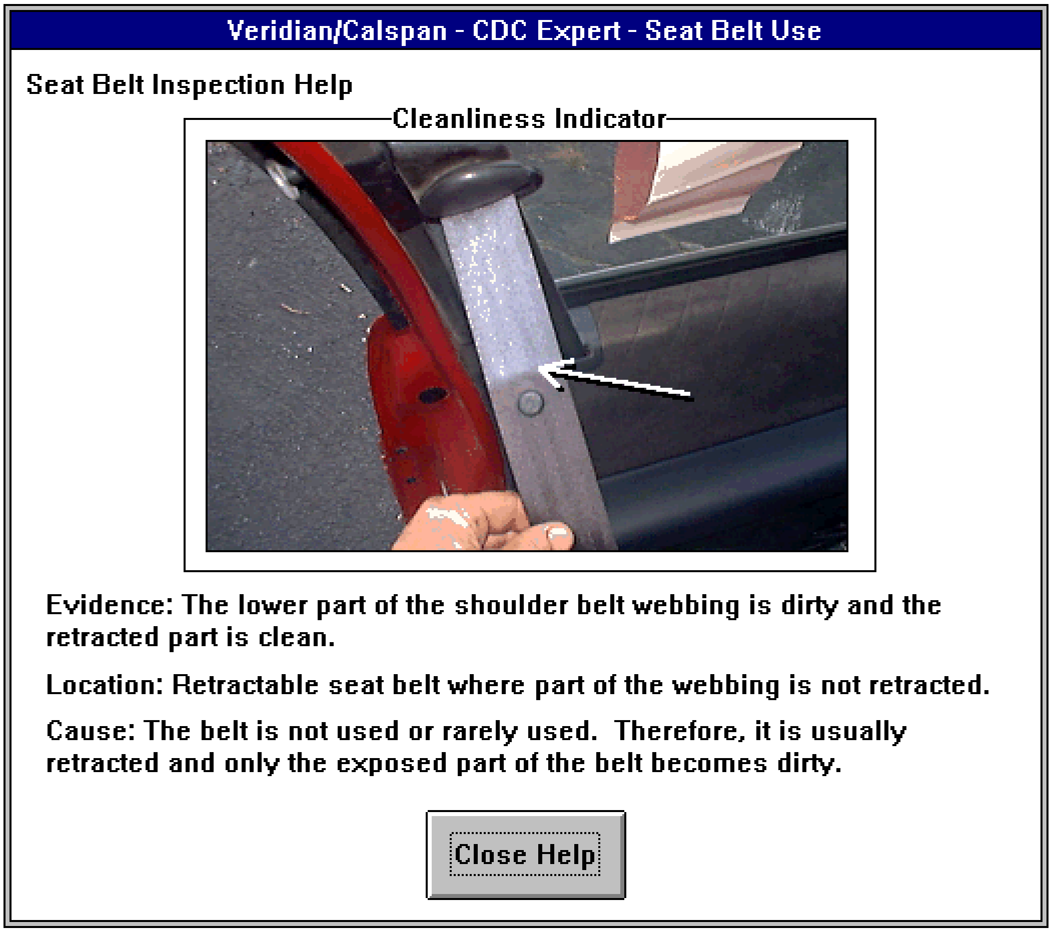


Figure 4. Belt dirt pattern shows non-usage help screen.

Figure 5. Routine wear marks on belt help screen.

One area that the panel agreed was outside the expert system's scope was evidence indicating seat belt misuse or failure. The panel cited two cases of seat belt misuse or failure: (1) where the occupant wore the shoulder harness behind his or her back, and (2) where an occupant wore a seat belt, but was ejected from the vehicle. For example, one particular vehicle type, with an automatic belt, does not keep the occupant in place if the door opens during a crash. However, one failure case was included in the system. This is where the occupant is ejected or displaced from their seat position and the belt shows evidence of damage during the crash (e.g., belt torn or belt anchors torn out).

The following subsections provide details concerning the Seat Belt Use Expert System implementation. Section 4.2.1 describes how case-by-case data collection is applied to the Seat Belt Use Expert System, including the conditions under which each data element is collected. Section 4.2.2 provides a detailed system design, including a decision tree depicting the system design and implementation. Section 4.2.3 documents system extensions identified by the expert panel that were outside the scope of the project.

4.2.1 Crash Conditions Controlling the Data Elements Collected

One of the objectives of the expert systems is to minimize the officer's time to collect the data required by an expert system. This concept is particularly applicable to the seat belt usage area. To limit the data collection time, an officer is asked to collect seat belt use data elements:

- Until a conclusion on whether the seat belt was used or not used is reached.
- When the evidence is likely to exist and is likely to be valid.

The amount of data required to determine whether an occupant wore his or her seat belt during a crash is based on whether the data provides a reliable indication of seat belt use. The expert panel classified the reliability of each of the data elements as an indicator of seat belt use. The Seat Belt Use Expert System utilizes the reliability of the data as follows:

- High-Reliability Data Elements: Data are sufficient to determine seat belt use and no additional data needs to be collected to reach a conclusion.
- Medium- to Low-Reliability Data Elements: Data collection continues until: (1) two identical conclusions are reached (e.g., two "not used" conclusions), (2) conflicting conclusions are reached (e.g., a "probably used" and a "probably not used" conclusion), or (3) all data are collected.

Table 7 shows the reliability of each of the data elements.

The Seat Belt Use Expert System collects the highly reliable and easy-to-collect data elements first, thereby minimizing the officer's data collection time. For example, a highly reliable and easy-to-collect indicator of belt use is a statement by the occupant that he or she did not wear his or her seat belt. Therefore, this is one of the first data elements collected by the system. Table 7 shows the order in which data elements are collected, along with the expert panel assessment of how reliable an indicator of seat belt usage the data element is and how easy the data is for an officer to collect.

Table 7. Seat Belt Use data collection order.

Data Element	Collection Order	Reliability	Easy to Collect
Belt Used Statement	1	High	Easy
Belt Use Observed	2	High	Easy
Seat Belt Was Not Usable Before the Crash	3	High	Somewhat Difficult
Occupant Ejected or Displaced From Seat	4	High	Somewhat Difficult, need to determine whether the belt was damaged during the crash
Seat Belt Loading	5	High	Somewhat Difficult
Injury Caused by Belt Loading	6	High	Difficult, must be collected at the medical facility
Body Contact With Vehicle Interior	7	Medium	Somewhat Difficult
Belt Dirt Pattern Shows Non-Usage	8	Medium	Somewhat Difficult
Routine Wear Marks on Belt	9	Medium	Somewhat Difficult
Citation for Not Wearing a Belt	10	Low	Easy
Other Observation	11	Low	Easy

The expert system's second method of minimizing the officer's data collection time is to request only the data that is likely to exist for that particular crash type. In addition, a data element is collected only when it is pertinent evidence for the crash type. For example, much of the physical evidence indicating seat belt use is most likely to exist in high delta velocity crashes. Therefore, many data elements are not requested for low delta velocity crashes. Table 8 shows the crash conditions under which each of the data elements are collected. This table shows that for the data element Body Contact With Vehicle Interior, instrument panel damage is evidence requested in low delta velocity crashes, but is not requested in medium to high delta velocity crashes. This is because even a belted driver can contact and damage the instrument panel in a medium to high delta velocity crash. One of the Vehicle Damage Rating Expert System data elements, Extent of Deformation (see section 4.3.2.3), is used to differentiate between a low versus a medium to high delta velocity crash.

Table 8. Crash condition under which Seat Belt Use data element is collected.

Data Element	Crash Condition
Belt Use Statement	All Crashes
Observed Belt Use	All Crashes
Seat Belt Was Not Usable Before the Crash	All Crashes
Occupant Ejected	All Crashes
Occupant Displaced From Seat	Occupant is Unconscious
Seat Belt Loading	Medium to High Delta Velocity And Airbag is not deployed in that seat position
Injury Caused by Belt Loading	High Delta Velocity And Injury Condition is Known and Occupant is Injured
Body Contact With Vehicle Interior:	
Case 1 Evidence: Windshield Windshield Header A-Pillar Steering Wheel Knee Bolster Instrument Panel Other in-vehicle contact points	Low Delta Velocity And Frontal Impact Steering Wheel Contact is not collected if the airbag is deployed
Case 2 Evidence: Windshield Windshield Header A-Pillar	High Delta Velocity And Frontal Impact
Case 3 Evidence: Contact points between the occupant and vehicle are consistent with the vehicle movement and principal direction of force (PDOF)	Not Frontal Impact
Belt Dirt Pattern Shows Non-Usage	Occupant is the driver And Driver lives at the address of the registrant
Routine Wear Marks on Belt	Occupant is the driver And Driver lives at the address of the registrant And Vehicle is new
Citation for Not Wearing a Belt	All Crashes
Other Observation	All Crashes

4.2.2 Decision Tree

The Seat Belt Use Expert System decision tree is shown in figure 6. The decision tree shows all of the data elements collected by the Seat Belt Use Expert System. The expert system requests a data element if it has not been previously entered in either: (1) the State crash reporting system or (2) the Vehicle Damage Rating Expert System. There is, however, one data element shown in the decision tree that is not collected in the expert system: injury severity (KABCO). Many States use the KABCO scale as a measure of injury severity. The Seat Belt Use Expert System uses the KABCO values to derive whether the driver was conscious or unconscious. If the KABCO values are not entered in the State accident reporting system, then the Seat Belt Use Expert System collects the conscious or unconscious status, rather than KABCO.

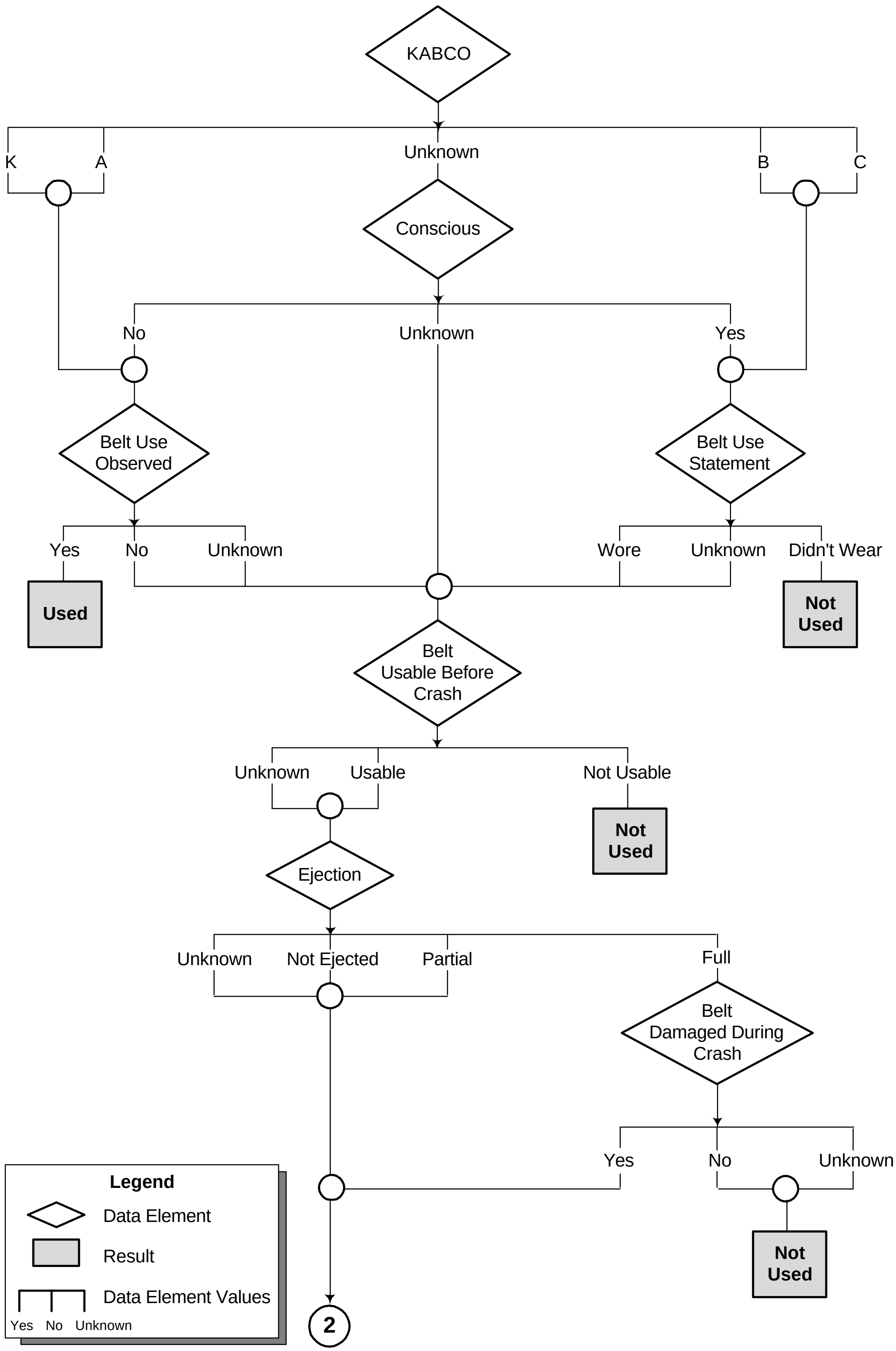


Figure 6. Seat Belt Use decision tree.

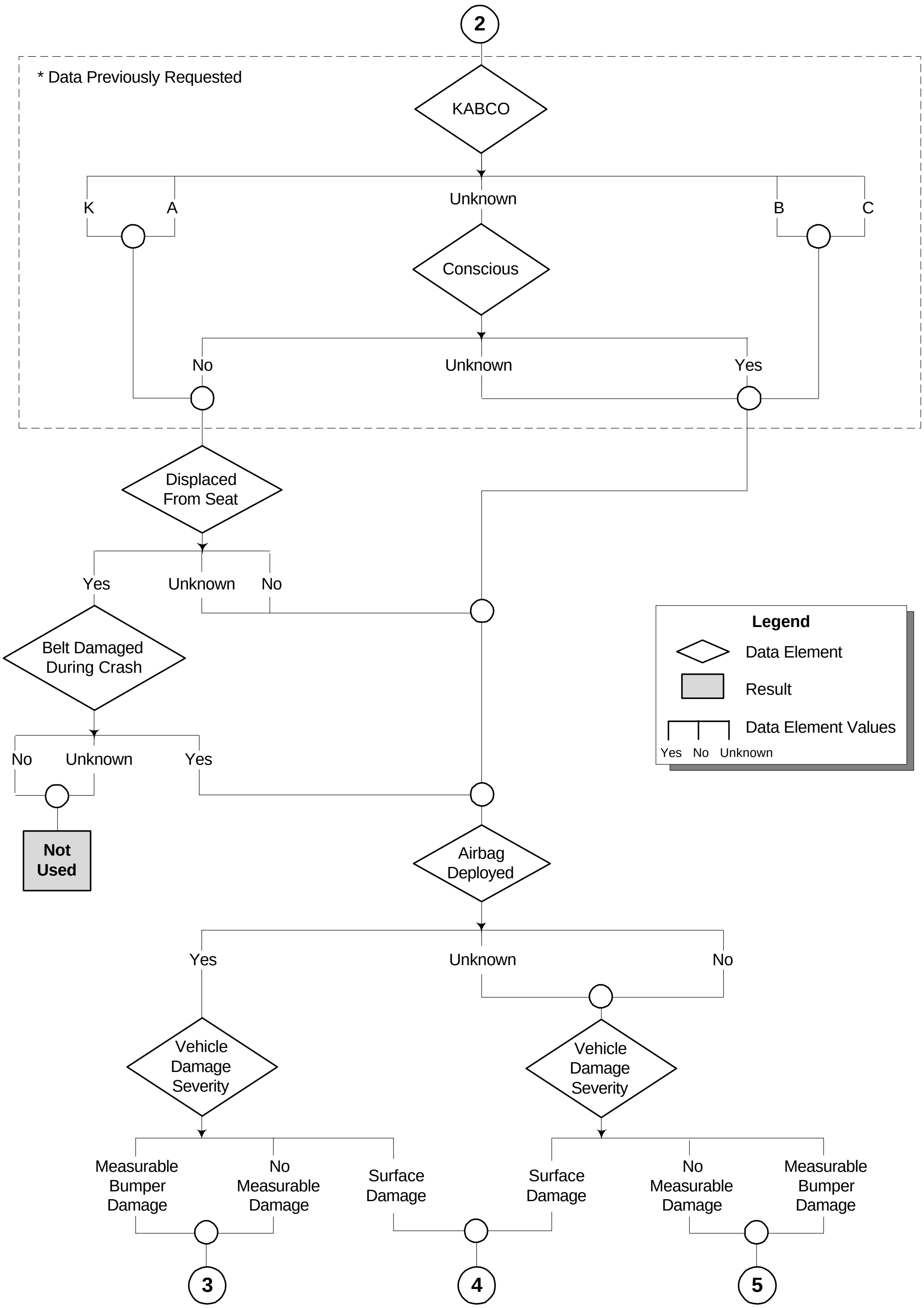


Figure 6. Seat Belt Use decision tree (continued).

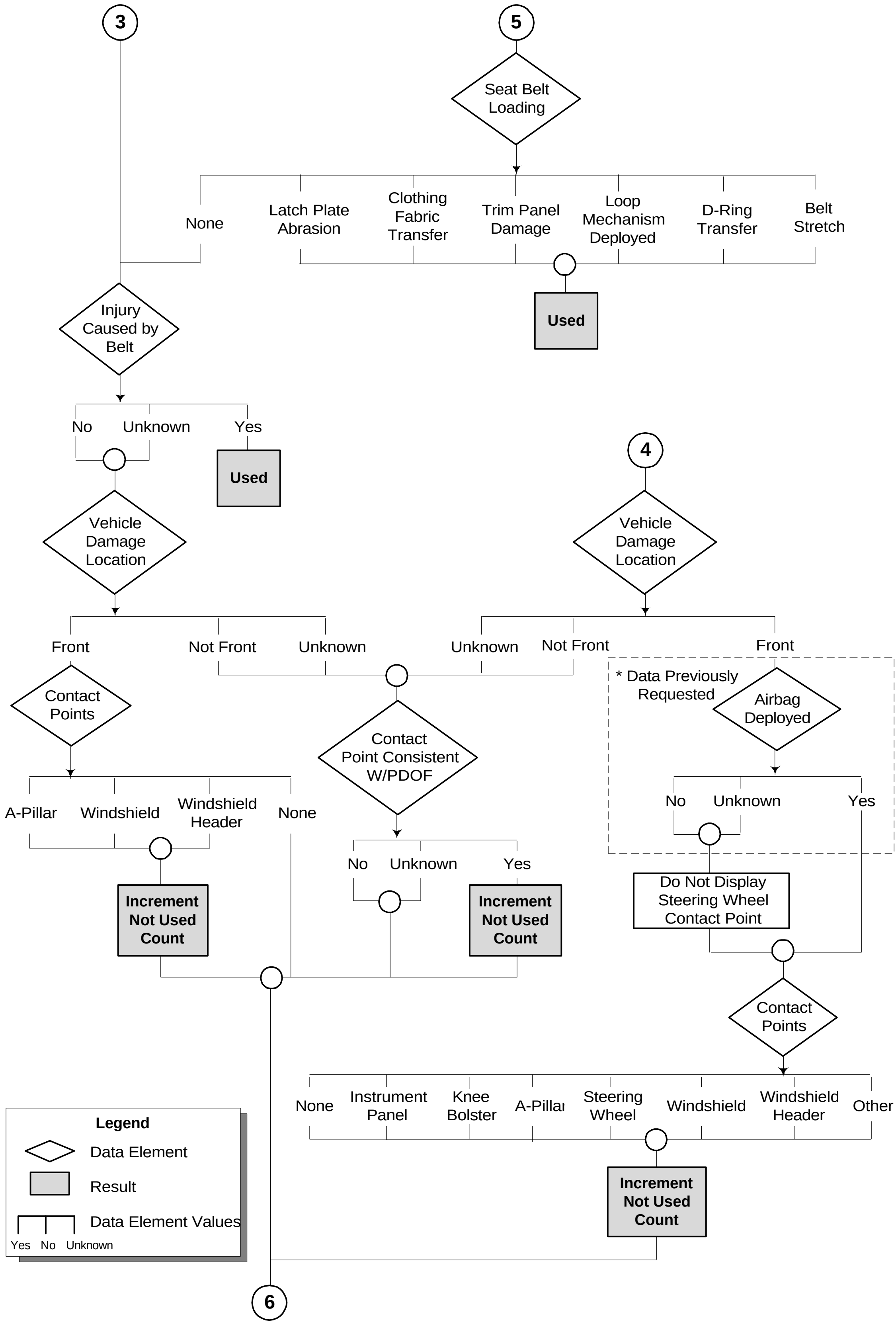


Figure 6. Seat Belt Use decision tree (continued).

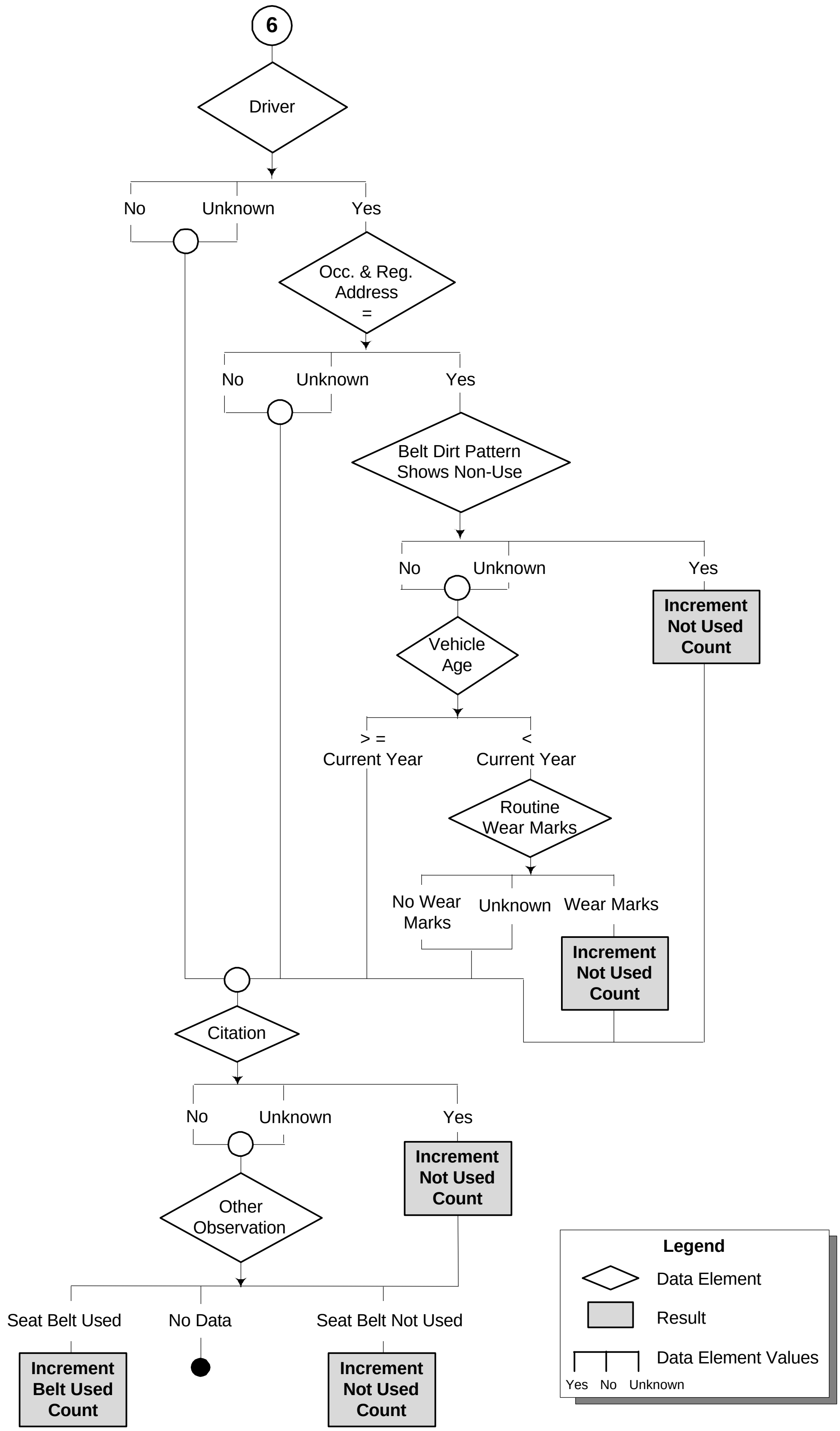


Figure 6. Seat Belt Use decision tree (continued).

4.2.3 Extensions

Throughout the program there was knowledge derived from the experts that is not included in the current design and implementation. Some data elements identified by the experts were not included because they were considered either too difficult or time consuming for an officer to collect and did not occur in a significant number of cases. However, these data are appropriate for officers performing in-depth investigations:

- Body Contact With Vehicle Interior: The evidence that an occupant contacted the vehicle’s interior is a medium- to low-reliability indicator of seat belt use since a person’s size, seat position, and vehicle type (e.g., small vehicle) affect the presence and validity of this evidence. For example, a large person in a small car can be restrained and still strike the steering wheel or lower dash of the vehicle, leaving contact-point evidence. A possible extension of the system would be to specify all of these conditions and include them as data elements. However, this would require the officer to collect additional data that may not significantly increase the validity of the conclusion reached.
- Belt Loading: Currently, the officer is not asked to examine the belt for evidence that the occupant loaded the seat belt in low delta velocity crashes. This condition may be too stringent a requirement for a person who is heavy, since a heavy person can significantly load the belt even in a low delta velocity crash. A possible extension would involve always prompting the officer to examine the belt for belt loading. However, this requires the officer to collect additional data that may not significantly increase the validity of the conclusion reached.

4.3 VEHICLE DAMAGE RATING

The Vehicle Damage Rating Expert System collects data to aid the highway safety analyst in determining the severity of a crash, based on the physical damage to the vehicle. These data, shown in table 9, are based on data elements included in the Collision Deformation Classification (CDC) code currently used by NASS researchers and crash reconstructionists performing special studies.(6) A more detailed description of these data elements are presented in the subsections that follow.

Table 9. Vehicle Damage Rating Expert System data elements.

Data Element	Definition
General Area of Deformation	Broad definition of the area of the vehicle containing the deformation, including front, right side, back, left side, top, undercarriage, and unknown.
Lateral Area of Damage	Lateral areas containing the damage for front, right side, back, or left side collisions.(6) For example, for a frontal collision, the damage areas are defined by three equal sections on the front of the vehicle: left (driver side), center, and right (passenger side).
Extent of Deformation (Depth of Crush)	Approximate crush depth measured in inches. For damage that cannot be measured, two levels of damage are utilized (see section 4.3.2.3).
Principal Direction of Force (Direction of External Force)	Direction from which the external force impacts the motor vehicle, utilizing a 12-point clock system for determination of direction.(7)

In addition to the data elements listed in table 9, two data elements are collected to aid the officer in collecting General Area of Deformation and Principal Direction of Force data:

- Collision Type: Set of pre-defined collision types that combine the manner of collision (e.g., head-on, rear end, etc.) with the vehicle's direction of travel.
- Side With Deepest Crush: Judgment by the officer as to whether there is more crush to the vehicle's front or side.

The General Area of Deformation information is often difficult to collect when the point of impact is near the corner. The Collision Type and Side With the Deepest Crush can often aid the officer in differentiating between frontal collisions and side collisions. For example, if the General Area of Deformation is the front, then the officer identifies the collision type as head-on. In cases where the collision type does not determine the General Area of Deformation, the data element side with the deepest crush is collected. The officer checks the displacement of the corner and compares the ratio between the depth of crush on the side and the depth of crush on the front. If the front of the vehicle has more crush, then it is a frontal collision. Similarly, if the side of the vehicle has more crush, then it is a side collision.

We implemented the Vehicle Damage Rating Expert System for frontal collisions. This implementation is sufficient to evaluate whether officers can accurately collect these data, and these data collection methods can also be applied to side and rear collisions. Therefore, the system can be extended later to include side and rear collisions, utilizing the same approach.

In addition to side and rear collisions, there are other crash types that are beyond the scope of the Vehicle Damage Rating Expert System's vehicle rating data elements:

- Rollover.
- Override and underride.

The Vehicle Damage Rating Expert System's data elements are not collected for rollover crashes since these data are not pertinent in rollover crashes. These data are also not collected for override and underride crashes since accurate data collection requires additional data elements. A possible extension to the Vehicle Damage Rating Expert System is the inclusion of override and underride crashes.

The data collected in the Vehicle Damage Rating Expert System can be used to derive two currently used measures of vehicle damage: equivalent barrier speed and the TAD rating scale.(3) Equivalent barrier speed is the delta velocity of a vehicle that would have occurred if the vehicle struck a barrier. It is the combination of the expert system data elements and the State crash reporting data, such as vehicle make, model, and year, that allows analysts to calculate equivalent barrier speed. In a prior study, an approximate crush measurement was assigned to the seven TAD ratings, shown in table 10. Using this comparison, the Extent of Deformation value can be translated to a TAD rating.(8)

Table 10. Deriving a TAD rating from Extent of Deformation.

TAD	Approximate Crush
1	6 in
2	10 in
3	15 in
4	25 in
5	33 in
6	45 in
7	> 51 in

1 in = 25.4 mm

The following subsections provide details concerning the Vehicle Damage Rating Expert System: Section 4.3.1 describes the conditions under which the data elements are collected; section 4.3.2 provides a detailed system design, including examples of the data input screens; and section 4.3.3 documents system extensions identified by the expert panel that were outside the scope of the project.

4.3.1 Crash Conditions Controlling the Data Elements Collected

Of the four data elements collected, General Area of Deformation, Lateral Damage Area, and Extent of Deformation are collected for all crashes that are within the scope of the Vehicle Damage Rating Expert System. The Principal Direction of Force and the data elements collected to aid the officer in determining the Principal Direction of Force (described in section 4.3.2.4) are not collected in low delta velocity crashes. Extent of Deformation (described in section 4.3.2.3) is used to differentiate between a low versus a medium to high delta velocity crash.

4.3.2 Implementation

4.3.2.1 General Area of Deformation

The General Area of Deformation data values are:

- Front.
- Left front corner: Left side and front.
- Right front corner: Right side and front.
- Left side (driver).
- Right side (passenger).
- Back.
- Undercarriage.
- Top.
- Unknown.
- No damage.

The Vehicle Damage Rating Expert System currently collects data for frontal collisions. Therefore, the expert system continues processing only if the damage area selected is: (1) front, (2) left front corner, or (3) right front corner.

4.3.2.2 Lateral Area of Damage

The lateral damage areas for end-plane collisions are divided into three equal zones. Figure 7 depicts the damage areas for a frontal collision collected as lateral damage area values in the Vehicle Damage Rating Expert System.

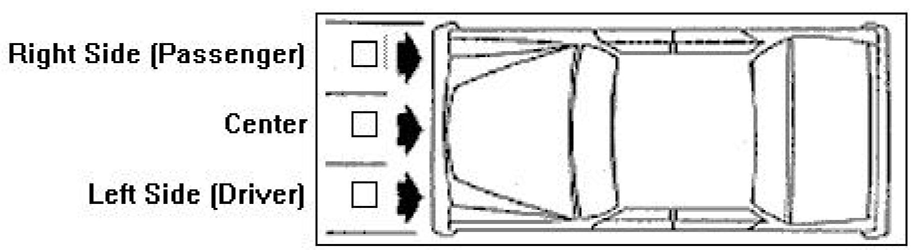


Figure 7. Lateral Area of Damage for frontal collisions.

4.3.2.3 Extent of Deformation

NASS researchers and crash reconstructionists currently collect Extent of Deformation by measuring the vehicle's crush. However, measuring vehicle damage is time consuming and, therefore, not practical for police officers. In the Vehicle Damage Rating Expert System, instead of measuring the crush, the officers use a computer drawing program to sketch the vehicle damage profile on a vehicle schematic (shown in figure 8). The officer estimates the crush on any of six equally spaced guide lines, shown in figure 8 as dashed lines and lines contouring the vehicle's sides. The officer sketches the damage by dragging arrows from the bumper toward the back of the vehicle, approximating crush depth. The vehicle schematic contains the critical reference points for the officer to utilize to provide a profile as accurate as possible. These critical vehicle reference points include axle positions, wheel/fender openings, structural pillars, and base of the windshield. The Vehicle Damage Rating software calculates the depth of crush along the guide lines. The depth of crush is calculated as the distance from the pre-crash undamaged bumper to the arrow.

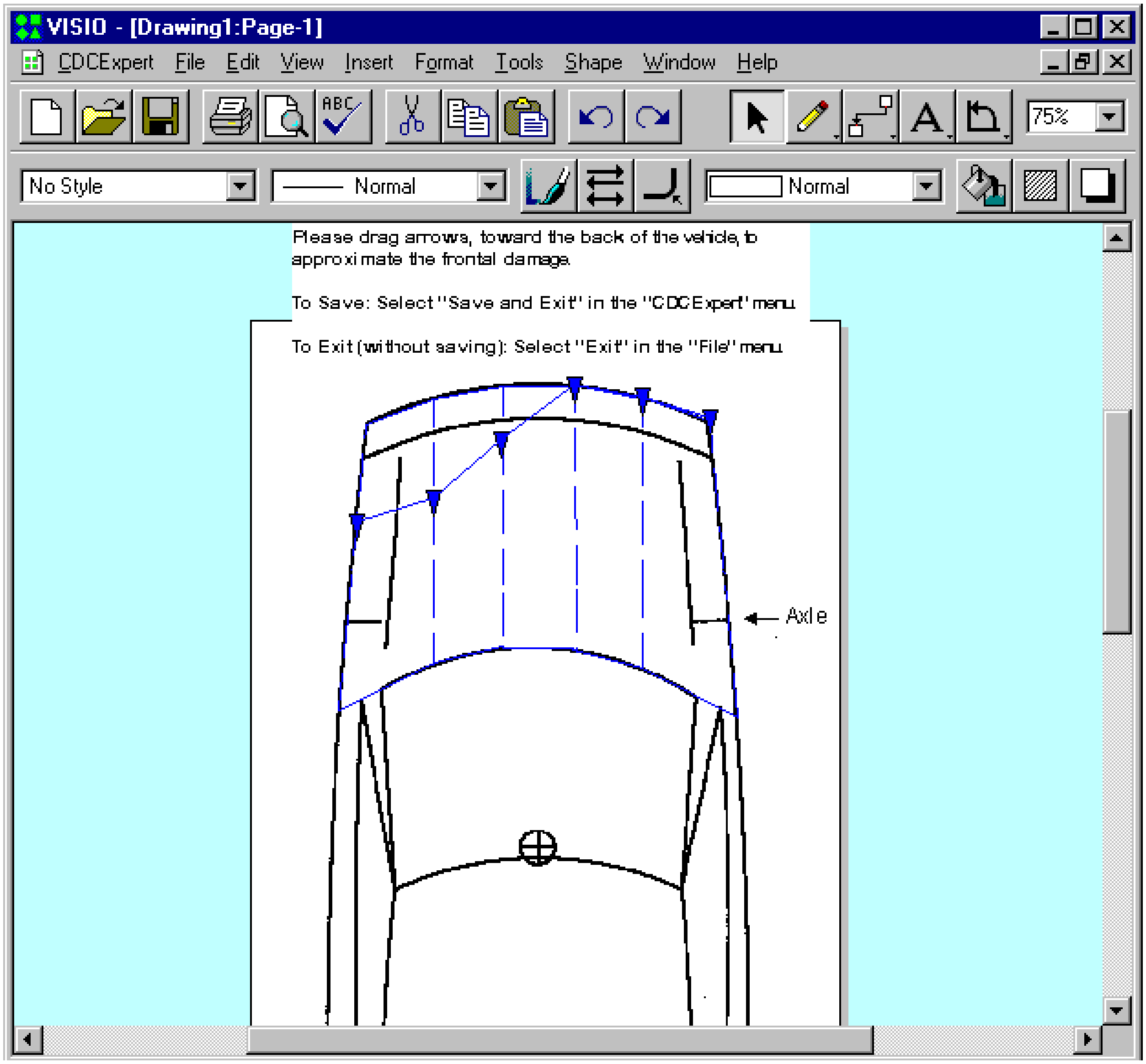


Figure 8. Extent of Deformation drawing tool.

However, there may not be enough vehicle damage for an officer to measure using the drawing tool. For these lower delta velocity crashes, another screen allows the officer to select one of two crush levels: (1) surface damage only (scratches and surface damage without bumper displacement) or (2) no measurable bumper crush (bumper displacement, but the crush cannot be measured).

As previously mentioned, some of the data elements in the Seat Belt Use Expert System and the Vehicle Damage Rating Expert System are collected only in medium to high delta velocity crashes. Extent of Deformation is used to differentiate between the low and medium to high delta velocity crashes.

4.3.2.4 Principal Direction of Force

Principal Direction of Force (PDOF) is often difficult for an officer to determine. To aid the officer in collecting PDOF, the expert system utilizes the knowledge that in certain collision types, the PDOF can be narrowed down to a few probable values. Figure 9a shows the right-hand turn collision type an officer selected. For this collision type, the PDOF is most likely at the 11 o'clock position. Figure 9b shows the subsequent PDOF screen. This screen shows an asterisk next to 11 o'clock, identifying the preferred PDOF value.

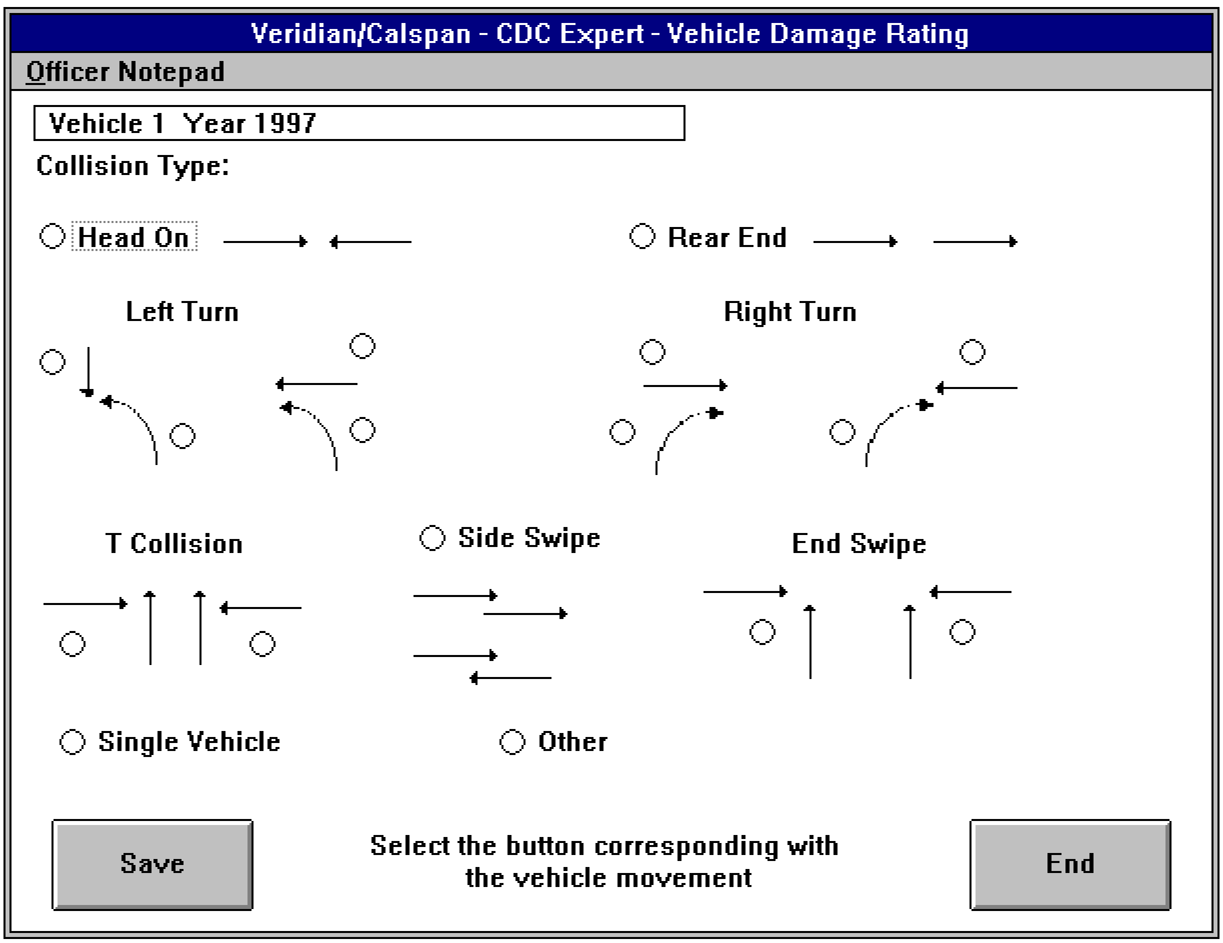


Figure 9a. Collision Type screen.

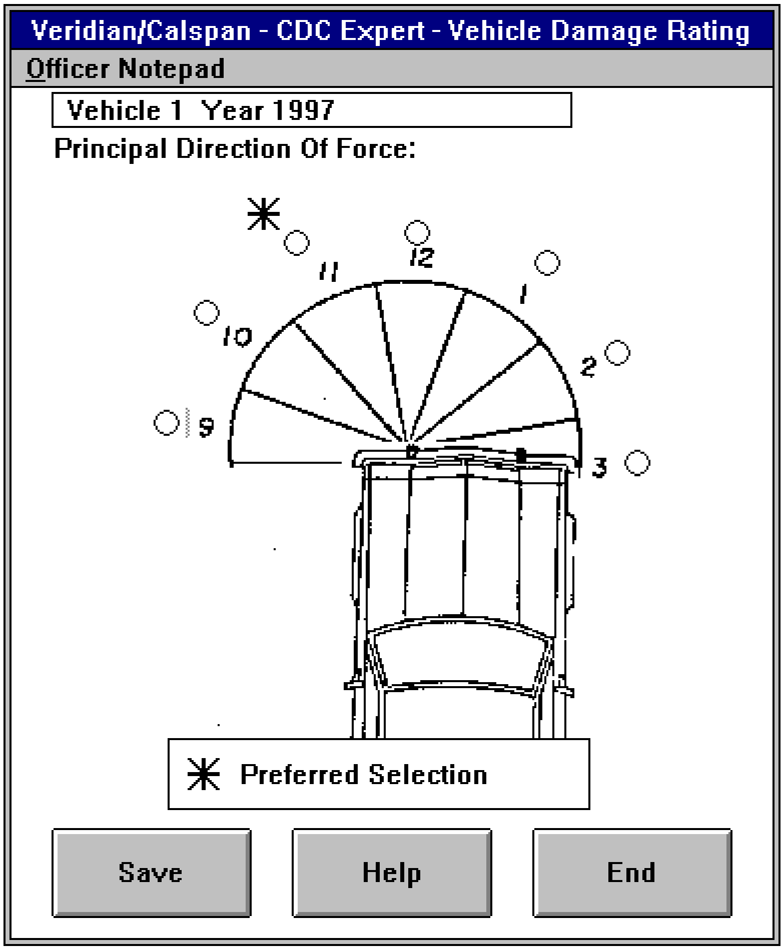


Figure 9b. Principal Direction of Force screen.

As previously mentioned, PDOF is often difficult for officers to determine. However, by requesting Collision Type and Side With the Deepest Crush, the accuracy can be improved. Table 11 shows the Principal Direction of Force values recommended by the Vehicle Damage Rating Expert System based on the Collision Type, the General Area of Deformation, and Side With the Deepest Crush. In table 11, N/A is used to identify the crash types for which the Vehicle Damage Rating Expert System does not collect Side With the Deepest Crush. Side With the Deepest Crush is not collected for all crash types. The reason for collecting this data element is to distinguish corner crashes as either front or side collisions. Therefore, Side With the Deepest Crush is not collected if General Area of Deformation equals Front. In addition, Side With the Deepest Crush is not collected for End Swipe collisions, since these are clearly side collisions, and Head-On collisions, since these are clearly frontal collisions.

Table 11. Determining Principal Direction of Force.

General Area of Deformation *Note: previously asked*	**Collision Type**	**Which Location Has the Deepest Crush**	**Probable Principal Direction of Force**
Front	Head-on or Rear-end	N/A	11,12,1
	Left Turn - Turning Left	N/A	1
	Left Turn - Going Straight	N/A	11,12
	Right Turn In same direction traveling straight or In opposite direction turning	N/A	12, 1
	Right Turn In same direction turning	N/A	11
	Right Turn In opposite direction traveling straight	N/A	11,12
	T- collision on Passenger Side	N/A	1
	T- collision on Driver Side	N/A	11
	Other	N/A	11,12,1
	Single Car	N/A	11,12,1
Front and Driver Side	Head-on or Rear-end	N/A	11,12
Front and Passenger Side	Head-on or Rear-end	N/A	12,1
Front and Side	Left Turn - Going Straight	Front	11
		Side	10
	Left Turn - Turning Left	Front	1
		Side	2
	Right Turn In same direction turning	Front	11
	Right Turn In same direction turning	Side	10
	Right Turn In same direction traveling straight or	Front	1
	In opposite direction turning	Side	2
	Other	Front	11,12,1
		Side	9,10,2,3
	Single Car	Front	11,12,1
		Side	9,10,2,3
	T- collision on Passenger Side	Front	1
		Side	2
	T- collision on Driver Side	Front	11
		Side	10
Front or Front and Side	End Swipe on Driver Side	N/A	9
	End Swipe on Passenger Side	N/A	3
	Side Swipe	N/A	12

4.3.3 Extensions

The most important future extension to the Vehicle Damage Rating Expert System is implementing rear and side collisions, since the current implementation is for frontal collisions. The expert panel agreed that all crash types are important for highway safety analysis. In addition, the expert panel agreed that extending the Vehicle Damage Rating Expert System to include override and underride crashes is also important.

One additional data element that should be considered for later versions of the Vehicle Damage Rating Expert System is whether the impact area is wide or narrow. This information is included in the definition of the CDC data element Type of Damage Distribution.[6]

4.4 ROADSIDE BARRIER

The Roadside Barrier Expert System collects the data required to identify the problems associated with particular longitudinal barrier types. To determine the barrier type, the officer is asked to observe readily identifiable barrier characteristics, which are used by the expert system to classify the barrier.

Barrier data are not collected for events that may not accurately depict the barrier's performance. The expert system does not collect data under the following conditions:

- If the events before the barrier impact were more harmful than the barrier impact itself, barrier data are not collected.
- If there were multiple barrier impacts, barrier data are collected only for the first barrier impact.

4.4.1 Data Elements Collected and Results

Three types of data are collected to aid the highway safety analyst in identifying barrier problems:

- Type of roadside barrier involved in the crash.
- Point of Impact (POI) when impacting the barrier.
- Barrier Location: The location of the struck barrier in relation to the roadway, including the vehicle's direction of travel (i.e., off the left side of roadway and off the right side of roadway). Barrier Location values include: (1) median, (2) left roadside, (3) right roadside, (4) T-intersection, (5) other, and (6) unknown.

The Roadside Barrier Expert System collects the data required to identify the main barrier type, as well as guardrail end treatment type. The data collected to identify the main barrier type and POI are depicted in the figure 10a decision tree. The data collected to identify the end treatment type are depicted in the figure 10b decision tree. As shown in the decision trees, the barrier types included in the expert system are: (1) cable, (2) box, (3) W-beam, (4) thrie-beam, (5) concrete median barrier, (6) temporary, and (7) bull nose. Three types of barriers are not included: (1) older barriers that are no longer being manufactured; (2) median barriers, with the exception of concrete and bull nose; and (3) temporary barriers, typically used at construction zone sites. The bull nose median barrier type was included in the system since they are used extensively in the field test area in Iowa.

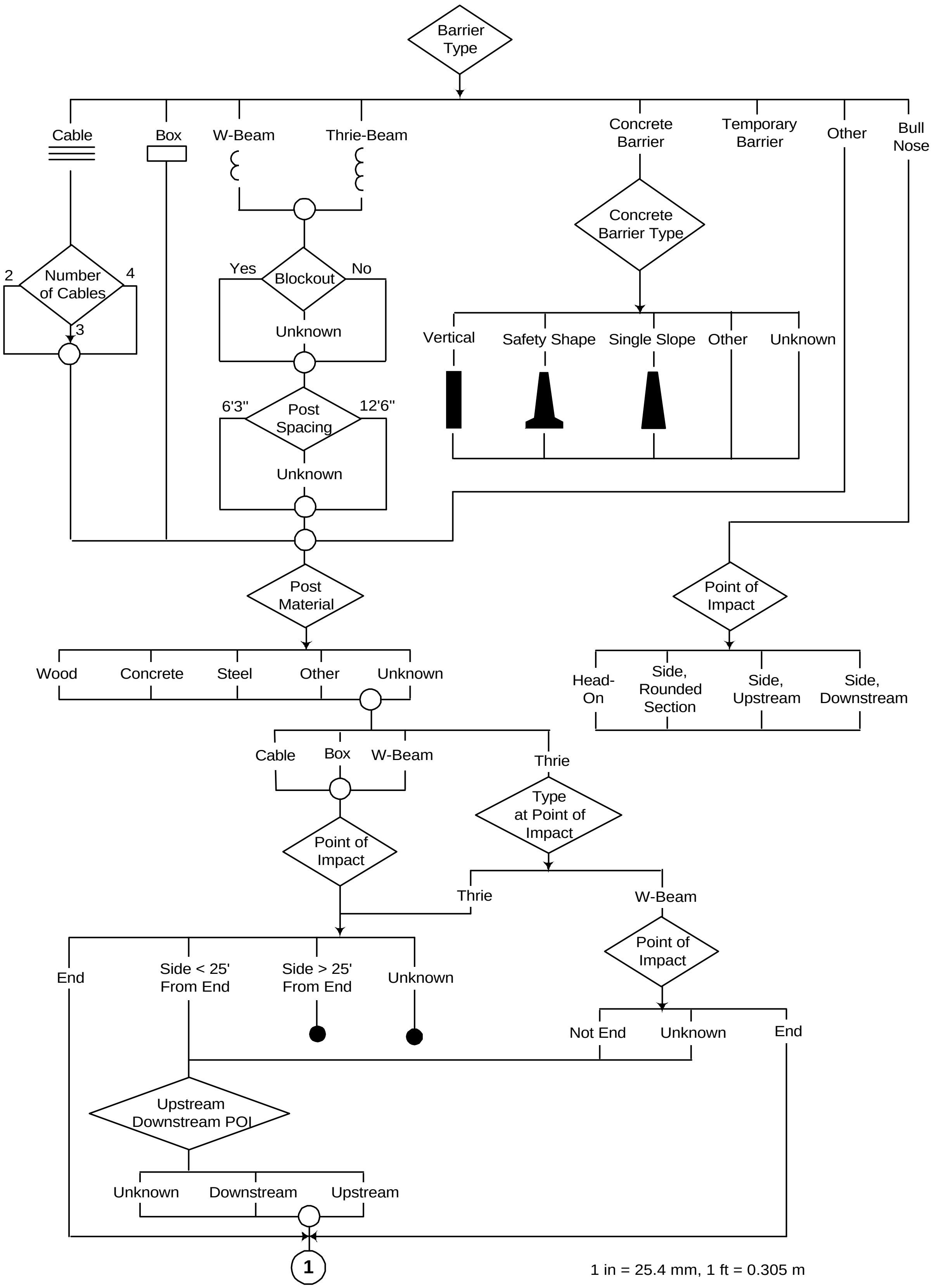


Figure 10a. Roadside Barrier main section type and point of impact.

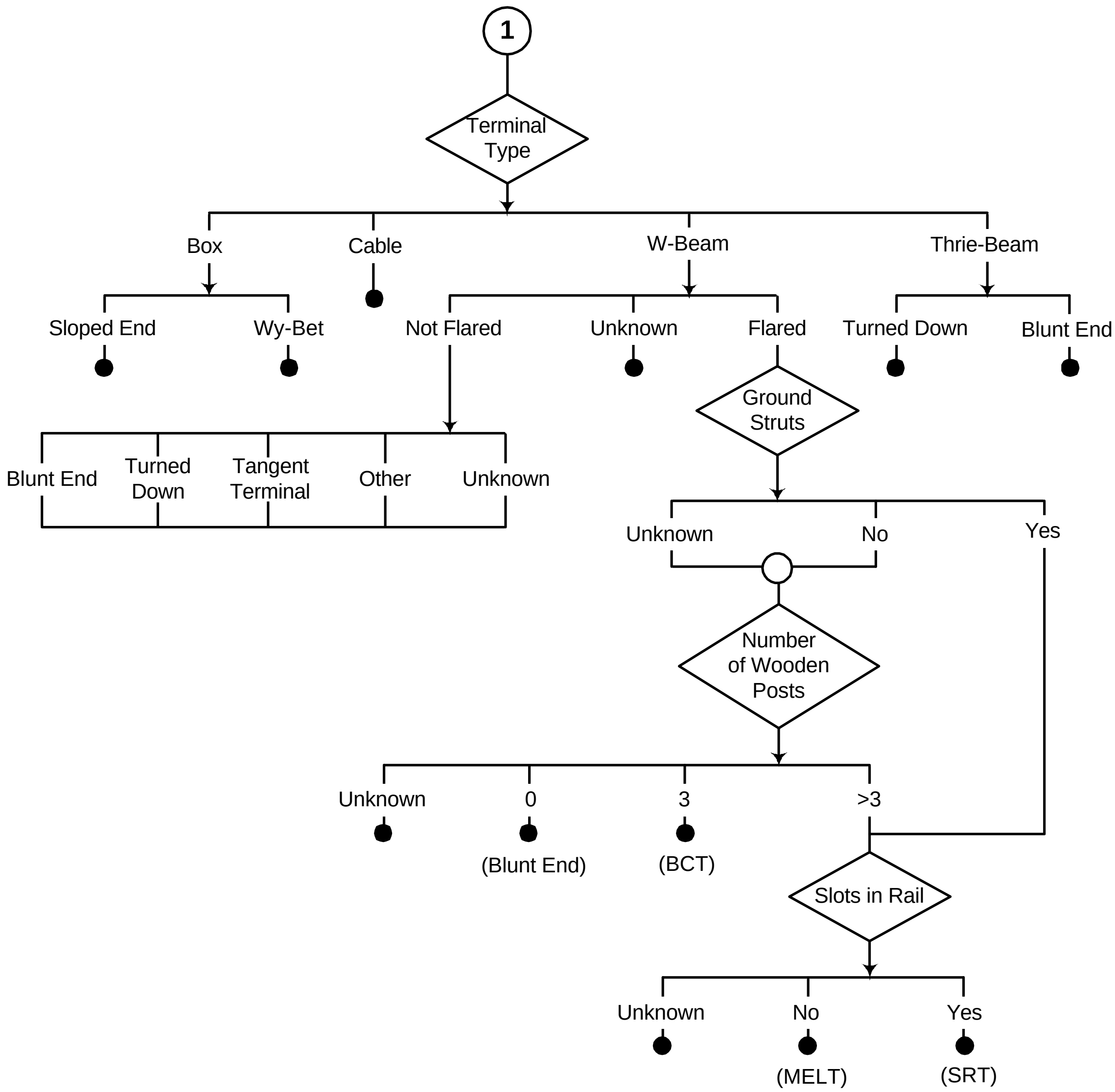


Figure 10b. Roadside Barrier terminal section.

To minimize the officer's time in collecting data, the data elements collected by the expert system are specified depending on the type of barrier struck. The characteristics of each barrier type determine which data elements are collected. The specific data for each type are shown in the decision trees (see figures 10a and 10b).

The primary results of the Roadside Barrier Expert System are identification of: (1) the type of roadside barrier involved in the crash and its important characteristics, (2) the barrier location, and (3) the point of impact and the direction of travel when impacting the barrier. The expert system identifies these W-beam guardrail end treatment types: blunt end, turned down, tangent terminal, modified eccentric loader terminal (MELT), breakaway cable terminal (BCT), and slotted rail terminal (SRT). These end treatment types are shown in figure 10b at the bottom of the decision tree.

4.4.2 Extensions

The expert panel members identified a number of extensions to the Roadside Barrier Expert System. For example, they specified roadside and trajectory data elements that can be added to the expert system, providing a more complete understanding of the crash scene. Many of these data elements were included in a NASS Longitudinal Barrier Special Study.[9]

In assessing what data can be collected by an officer, a critical decision was whether an officer should be required to measure scene evidence. Since many officers do not carry a measurement device in their vehicle and measuring scene evidence is time consuming, it was decided not to require precise measurements for any of the expert systems' data elements. Any data elements indicating size could either be estimated or measured. For most of these data elements, the appropriate ranges for size estimation have been defined.

4.4.2.1 Roadside Data

This section identifies the roadway characteristics, at the initial point of impact, that affect the outcome of longitudinal barrier crashes. This data will aid the highway engineer in determining the effect roadway attributes such as curb type and type of roadside slope have on crashes involving longitudinal barriers. Table 12 lists the roadside data elements identified by the expert panel as extensions to the Roadside Barrier Expert System, including the definition, data values, and conditions under which the data are collected.

Table 12. Roadside Barrier extensions—roadside data elements.

Data Element	Definition	Values	Crash Condition
Median Barrier Function	Function of a barrier located in the median. See figure 11.	1) Median barrier 2) Roadside barrier 3) Other	Barrier Location is Median
Lateral Offset	Perpendicular distance from the edge line to the barrier. Edge line is the line on the pavement marking the roadway edge. If no edge line exists, the pavement edge is used. Three examples are shown in figure 12.	Measurement Or 1) < 6 ft 2) 6 ft to < 12 ft 3) 12 ft to < 18 ft 4) 18 ft to < 24 ft 5) ≥ 24 ft 6) Unable to estimate	All Crashes
Curb Type and Presence	Presence or absence of a curb between the struck barrier and the edge of the roadway at the roadway cross section. Figure 13 shows a diagram of typical curb types.	1) No curb 2) Barrier curb 3) Mountable curb 4) Other	All Crashes
Effective Barrier Height	Vertical distance between the base or environmental surface immediately below the barrier to the top of the rail, cable, or, in the case of the concrete median barrier, the top of the barrier. This data element requires measurement.	Measurement Or 1) < 18 in 2) 18 in < 21 in 3) 21 in < 24 in 4) 24 in < 27 in 5) 27 in < 30 in 6) ≥ 30 in 7) Unable to estimate	All Crashes
Environmental Surface	Environmental surface immediately below the barrier.	1) None 2) Snow or ice 3) Gravel 4) High pavement 5) Dirt 6) Other	All Crashes
Roadside Slope	Number of different slopes between the roadway edge and the struck barrier. See figure 14.	1) No slope, barrier at roadway edge 2) One 3) Two 4) Three 5) More Than Three	All Crashes

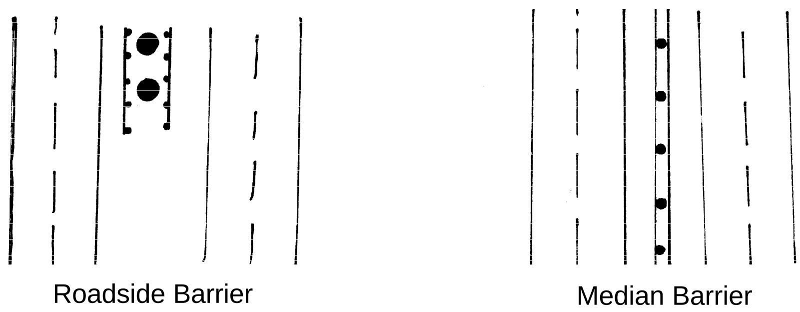


Figure 11. Function performed by barriers located in the median.

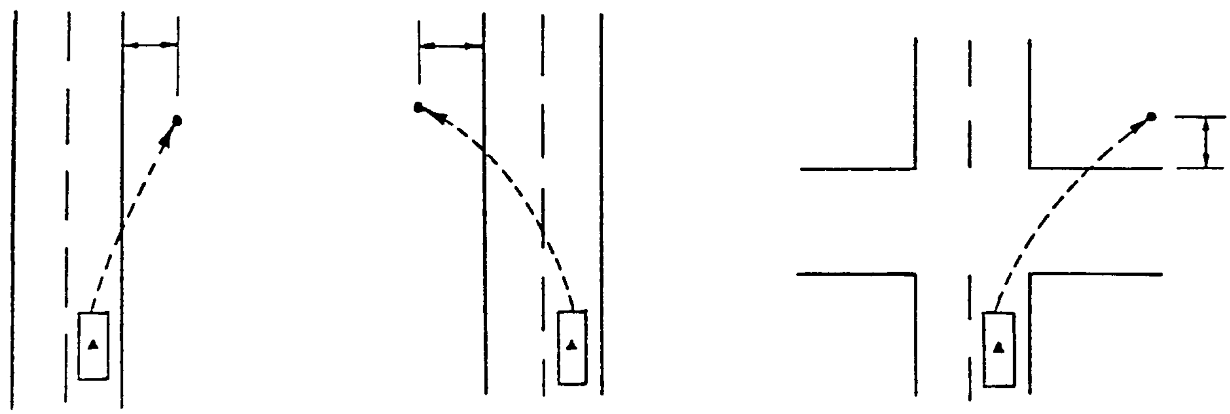
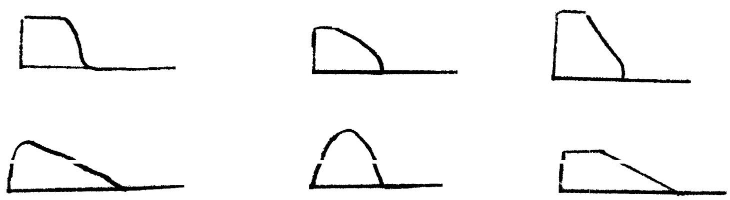


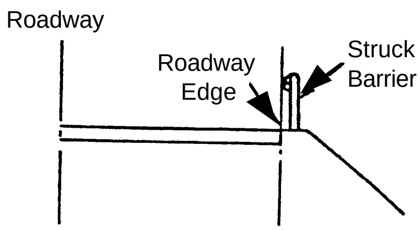
Figure 12. Lateral offset examples.

Barrier curbs.

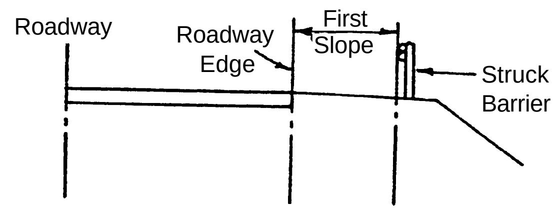


Mountable curbs.

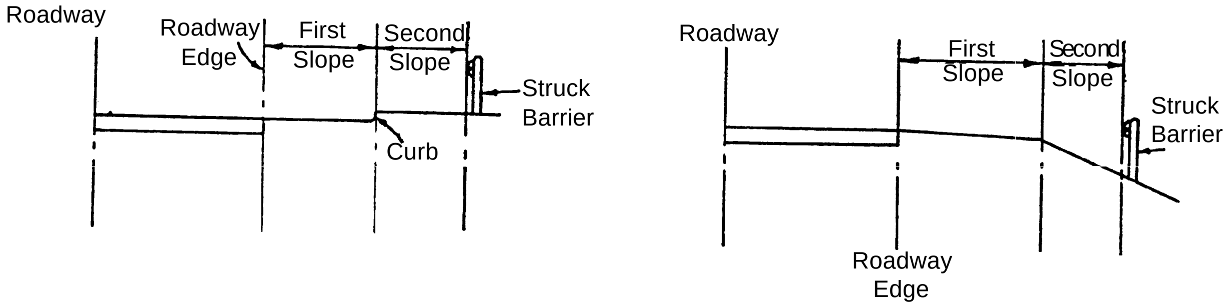
Figure 13. Typical highway curbs.



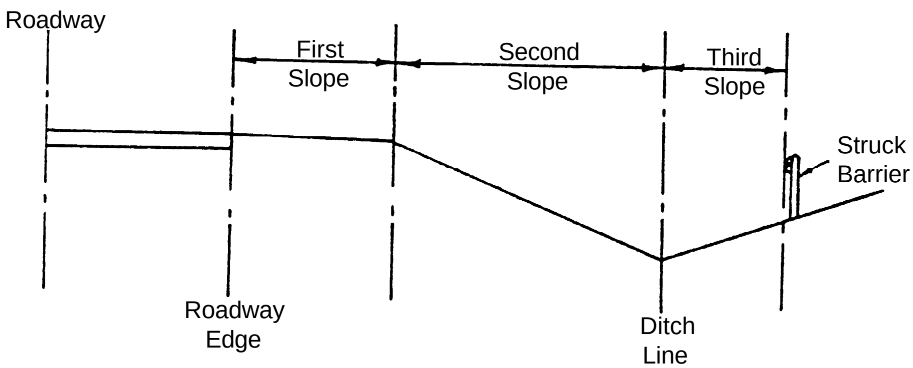
No slope.



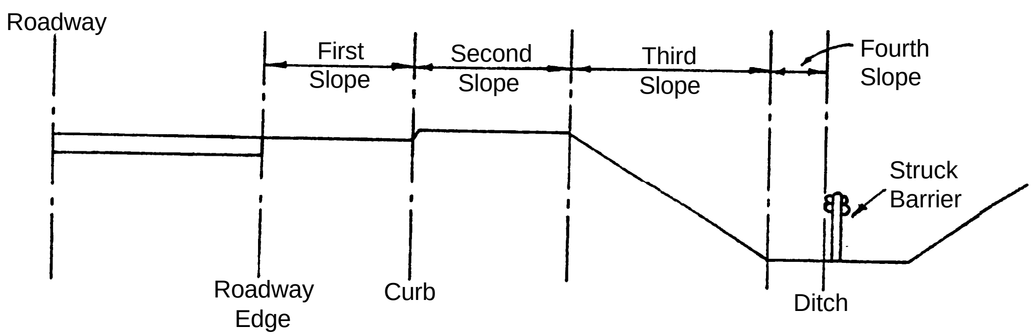
One slope.



Two slopes.



Three slopes.



More than three slopes.

Figure 14. Typical roadway slope types.

4.4.2.2 *Impact and Trajectory Data*

The impact and trajectory data elements identified in this section are required to determine how the barrier and roadway characteristics affected the outcome of this particular crash. The data collected are based primarily on physical evidence, indicating the damage to the longitudinal barrier; barrier performance; and vehicle dynamics and trajectory. The damage to the longitudinal barrier is determined by the length, shape, and depth of the barrier damage. Barrier performance indicates how the vehicle and barrier interacted during impact. Table 13 identifies the impact and trajectory data elements identified by the expert panel as extensions to the Roadside Barrier Expert System. This table includes the data element definition, data values, and conditions under which the data are collected.

Table 13. Roadside Barrier extensions—impact and trajectory data elements.

Data Element	Definition	Values	Crash Condition
Barrier Damage Length	Length of direct damage to the barrier, plus induced damage.	The number of posts in increments of 1/4 post spacing.	Barrier Type is Box, W-Beam, or Thrie-Beam Guardrail
Barrier Damage Shape	Shape of the guardrail damage. Generally, 70 percent of guardrail crashes where the vehicle did not penetrate the barrier result in symmetric damage patterns.	1) Symmetric 2) Asymmetric damage shapes	• Barrier Type is Box, W-Beam, or Thrie-Beam Guardrail And • Barrier Performance is not vehicle penetrated barrier
Barrier Damage Depth	Depth of deformation on the longitudinal barrier. Depth is the perpendicular distance from the line of the pre-crash barrier placement to the deformed barrier. Maximum depth of deformation on the longitudinal barrier is collected.	Measured Or 1) < 2 ft 2) 2 ft < 5 ft 3) 5 ft < 10 ft 4) 10 ft < 15 ft 5) 15 ft	• Barrier Type is Box, W-Beam, or Thrie-Beam Guardrail And • Barrier Performance is not vehicle penetrated barrier
Barrier Performance	Impact performance of the struck barrier. Values are based on the initial point of impact and barrier type.		All Crashes
Barrier Performance Case 1	Initial Point of Impact is Main Section.	1) Vehicle redirected by barrier to shoulder 2) Vehicle redirected by barrier onto roadway 3) Vehicle pocketed barrier 4) Vehicle overrode barrier 5) Vehicle vaulted on barrier 6) Vehicle penetrated barrier 7) Other	

Table 13. Roadside Barrier extensions—impact and trajectory data elements (continued).

Data Element	Definition	Values	Crash Condition
Barrier Performance Case 2	Initial Point of Impact is End And Barrier Type is Blunt End	1) Vehicle redirected by barrier to shoulder 2) Vehicle redirected by barrier onto roadway 3) Vehicle redirected to off roadway side of barrier 4) Vehicle impaled on barrier 5) Vehicle vaulted on barrier 6) Other	
Barrier Performance Case 3	Initial Point of Impact is End And Barrier Type is Turn-Down	1) Vehicle redirected by barrier to shoulder 2) Vehicle redirected by barrier onto roadway 3) Vehicle redirected to off roadway side of barrier 4) Vehicle overrode barrier 5) Vehicle vaulted on barrier 6) Other	
Barrier Performance Case 4	Initial Point of Impact is End And Barrier Type is BCT or Tangent	1) Vehicle redirected by barrier to shoulder 2) Vehicle redirected by barrier onto roadway 3) Vehicle redirected to off roadway side of barrier 4) Vehicle vaulted on barrier 5) Other	
Barrier Performance Case 5	Initial Point of Impact is End And Barrier Type is Other or Unknown	1) Vehicle redirected by barrier to shoulder 2) Vehicle redirected by barrier onto roadway 3) Vehicle redirected to off roadway side of barrier 4) Vehicle overrode barrier 5) Vehicle impaled on barrier 6) Vehicle vaulted on barrier 7) Other	

4.4.2.3 Vehicle Dynamics and Trajectory

These data elements describe the vehicle dynamics and trajectory during the pre-impact, impact, and post-impact phases of the crash.

Table 14. Roadside Barrier extensions—vehicle dynamics and trajectory.

Data Element	Definition	Values	Crash Condition
Vehicle Orientation	Whether the tires of the vehicle are sliding sideways parallel to the axle (yaw) or tracking before impact with the barrier. Tracking is when the rear wheels travel in the same track as the front wheels. Yawing is when the rear wheels are not traveling in the same track as the front wheels.	1) Yaw 2) Track 3) Unknown	All Crashes
Pre-Impact Travel Distance	Pre-impact travel distance measured along the roadway, not the actual distance traveled. Distance from the point where the vehicle departed the roadway to the intersection of the edge line with the line perpendicular to the edge line from the initial point of impact, shown in figure 15. This distance is used to determine the impact angle.	Distance is measured in feet	• Barrier Performance is Vehicle redirected by barrier onto roadway And • Guardrail Type is Box, W-Beam, or Thrie-Beam Guardrail And • Barrier Damage Shape is Symmetric
Vehicle Rotation Angle	Degree of rotation that occurred during the barrier impact with respect to the pre-impact vehicle direction. This element is used to determine whether snagging occurred.	1) > 90° 2) ≤ 90° 3) Unknown	• Initial Point of Impact is Main Section And • Barrier Performance is: 1) Vehicle redirected by barrier onto roadway Or 2) Vehicle pocketed barrier
Direction of Vehicle Rotation	Direction the vehicle rotated during the barrier impact with respect to the pre-impact vehicle direction.	1) Clockwise 2) Counterclockwise 3) Unknown	• Initial Point of Impact is Main Section And • Barrier Performance is: 1) Vehicle redirected by barrier onto roadway Or 2) Vehicle pocketed barrier
Distance From Point of Departure to Point of Return to Roadway	Distance on the roadway from the point that the vehicle left the roadway to the point where the vehicle returned to the roadway. This distance is used to determine the impact and departure angles. See figure 16.	Distance is measured in feet	• Barrier Performance is Vehicle redirected by barrier onto roadway And • Barrier Type is Box, W-Beam, or Thrie-Beam Guardrail And • Barrier Damage Shape is Asymmetric

Table 14. Roadside Barrier extensions—vehicle dynamics and trajectory (continued).

Data Element	Definition	Values	Crash Condition
Post-Impact Travel Distance	Distance from the last guardrail impact point to the point of return to roadway, measured along the roadway, rather than the actual distance traveled. Distance from the point where the vehicle returned to the roadway to the intersection of the edge line with the line perpendicular to the roadway from the last point of impact with the barrier, shown in figure 16. This distance is used to determine the roadway departure angle.	Distance is measured in feet	• Barrier Performance is Vehicle redirected by barrier onto roadway And • Barrier Type is Box, W-Beam, or Thrie-Beam Guardrail
Subsequent Impact	Type of impact, if any, subsequent to the impact being reported. The values are based on barrier performance and barrier location.		Barrier Performance is: 1) Vehicle redirected by barrier to shoulder 2) Vehicle redirected by barrier onto roadway 3) Vehicle redirected off roadway side of barrier 4) Vehicle vaulted on barrier 5) Vehicle penetrated barrier
Subsequent Impact Case 1	• Barrier Performance is Redirection onto roadway Or • Barrier Performance is Vaulted on barrier and Barrier Location is Left side of the roadway Or • Barrier Performance is Vehicle penetrated barrier and Barrier Location is Left side of the roadway	1) None 2) Vehicle 3) Another roadside structure/object 4) Same barrier 5) Another barrier 6) Bridge rail/end 7) Rollover 8) Other	
Subsequent Impact Case 2	• Barrier Performance is Vehicle redirected off roadway side of barrier Or • Barrier Performance is Vaulted on barrier and Barrier Location is right side of the roadway Or • Barrier Performance is Vehicle penetrated barrier and Barrier Location is Right side of the roadway	1) None 2) Fixed object 3) Rollover 4) Other	
Post-Impact Trajectory	Trajectory of the vehicle from the point where the vehicle separated from the barrier to either the point of final rest, if there is no subsequent impact, or the point of impact of the subsequent impact.	1) Close to rail 2) Returned to roadway 3) Crossed roadway and ran off opposite side 4) Crossed median to other roadway/ travelway 5) Other	Barrier Performance is: 1) Vehicle redirected by barrier to shoulder 2) Vehicle redirected by barrier onto roadway

Table 14. Roadside Barrier extensions—vehicle dynamics and trajectory (continued).

Data Element	Definition	Values	Crash Condition
Rollover Type	Type of rollover where rollover is defined as any vehicle rotation of 90 degrees or more about any true longitudinal (end-over-end) or lateral (side-over-side) axis.	1) Side-over-side ¼ turn 2) Side-over-side ½ turn 3) Side-over-side ¾ turn 4) Side-over-side 4 or more complete turns 5) End-over-end 6) Other/unknown	Barrier Performance is Rollover

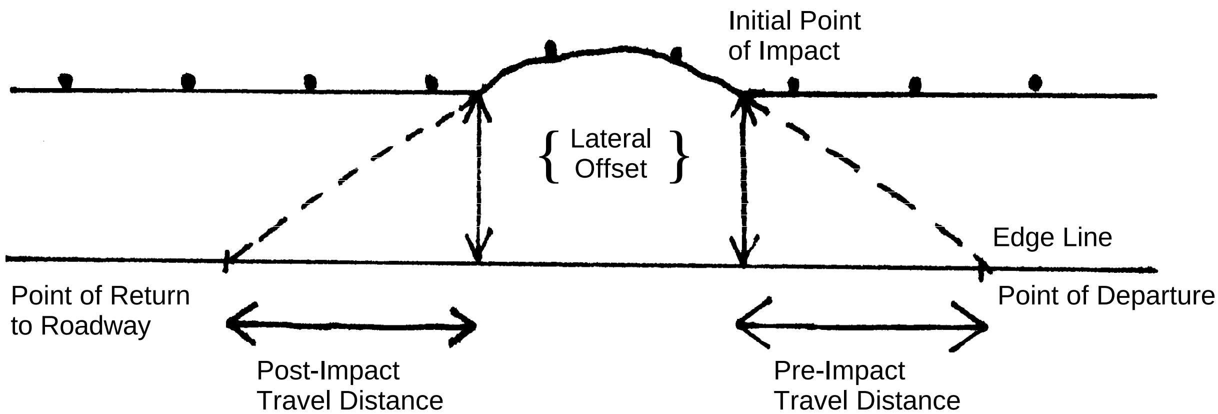


Figure 15. Distance data required for crashes producing symmetric guardrail damage patterns.

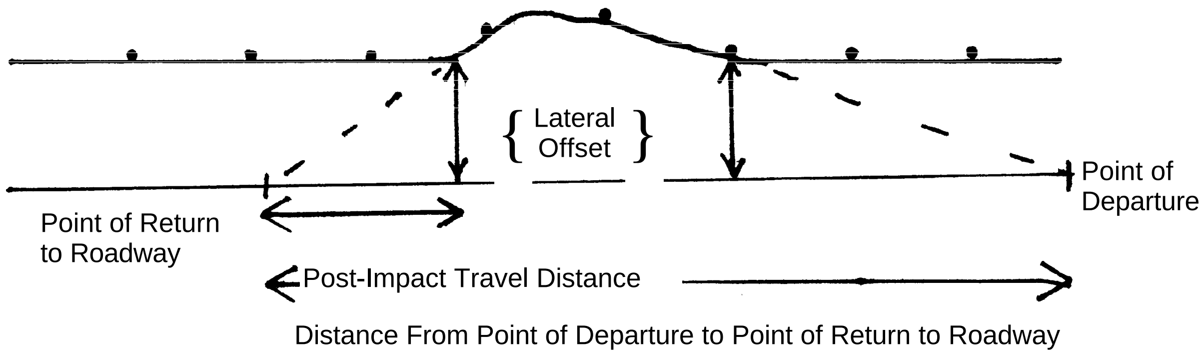


Figure 16. Distance data required for crashes producing asymmetric guardrail damage patterns.

5.0 ASSESS THE UTILITY OF APPLYING EXPERT SYSTEM TECHNOLOGY TO THE CRASH DATA COLLECTION PROCESS

An objective of the Crash Data Collection Expert System program was to assess the utility of applying expert system technology to the crash data collection process. The evaluation of the crash data collection expert systems was conducted for the following factors:

- Acceptance of the system by the officers.
- Crash data quality.
- Crash data collection time.

The system was evaluated during two 5-month field tests. These field tests were performed in cooperation with the Iowa Department of Transportation and the Iowa State Patrol. State Patrol officers used pen-based computers, containing the expert systems, to collect the crash scene data. The Iowa State Patrol normally uses pen-based computers to collect their State crash report data; therefore, the Iowa Crash Reporting System was seamlessly integrated with the expert systems.

5.1 ACCEPTANCE OF THE SYSTEM BY THE OFFICERS

The primary purpose of the first field test was to solicit suggestions from the officers participating in the field test on how the system could be improved. The results of the first field test were used to select changes to be included in the final version of the expert systems.

The primary purpose of the second field test was to evaluate the acceptance of the system by the officers. One component of user acceptance that was evaluated was the usability of the system. This evaluation addressed how well, from the officer's perspective, the system facilitated the task of collecting the crash data. For example, were there any system requests or instructions that were difficult to understand and, if so, how could the instructions be made clearer? Another component of user acceptance addressed how long it took the officer to collect the data and what data, if any, were difficult for the officer to collect. The data used to analyze the acceptance of the system by the officers included:

- Responses to questionnaires completed by the officers.
- Discussions during focus group meetings.

The results of the officer surveys, included in section 5.1.1, and focus group meetings show that the system is easy to learn and use. Officers can use the system infrequently, approximately once a month, without forgetting how to use the system. The officers stated that it did not take them too long to collect the data and the majority of the officers did not think the data were difficult to collect. However, two data elements collected in the Vehicle Damage Rating Expert System—Principal Direction of Force and Extent of Deformation—were identified as data elements that were difficult to collect without training and required the use of on-line help screens.

5.1.1 Officer Questionnaire

The officers were asked to complete a questionnaire to assess the acceptance of the system. The officers filled out the survey several times during the two field tests. This document includes the questionnaire responses collected after the final field test.

The questionnaire was designed to allow the officer to include comments pertaining to each evaluation topic. The reason for this is that many officers prefer to include written comments rather than answering a question with an itemized list of pre-determined responses (e.g., yes, no). Therefore, the officer was not required to answer the question by choosing one of the itemized responses. The questionnaire included:

- A general question, identifying the type of information to be obtained.
- A specific question, including an itemized list of responses.
- One or more related questions that solicit written comments.

The questionnaire each officer completed during the field test follows. Eight field-test officers completed the survey. Several other officers participated in the field test; however, they did not complete the survey since they only collected data for one or two crashes. The first two paragraphs are the instructions included with the original questionnaire. Following the instructions are the questions as written in the questionnaire presented to the officer. The general question is listed first (e.g., 1. How clear are the expert system requests, instructions, and messages?) and is followed by the more specific questions. Two-level numbering is used to relate the general question and the specific questions. The first specific question (e.g., 1.1 Were there any expert system requests, instructions, or messages that were difficult to understand? Yes/No) is followed by a table indicating the officers' responses and an overall metric derived from these responses. Following the remaining specific questions are the officers' comments. In general, this document does not include comments that repeat a preceding itemized response.

Crash Data Collection Expert System Officer Questionnaire

Name ____ Date _______________

The questionnaire each officer will complete during the field test follows. Each set of questions in the questionnaire contains one general question or topic followed by specific questions. The general question identifies the type of information we are trying to obtain. The specific questions are used for system evaluation and to request the detailed information needed to identify what changes to make in the next version of each expert system.

We encourage you to provide comments relating to the general question either on the questionnaire or during the focus group meetings. If you feel you cannot answer the specific questions, you may provide comments instead.

User Interface

1. How clear are the expert system requests, instructions, and messages?
   - 1.1 Were there any expert system requests, instructions, or messages that were difficult to understand?

Table 15. Rating the clarity of system requests, instructions, or messages.

Response	Count
1. Yes	2
2. No	5

   - 1.2 If Yes, do you recall the request, instruction, message, screen, etc.?
   - 1.3 Do you have any suggestions on how to make any request, instruction, and/or message clearer?

     Officers' Comments:

     - Fairly easy to understand, although on barriers we need a diagram of a "bull nose" design and then you could just mark on it where it was impacted so the company could decide how to record information.
     - I had some problems at first with the direction of force. I understand it now, but when I show other officers that is the only one they have problems with.
     - At first I had a problem with where the damage occurred on the barrier. The phrase was a little confusing. I can't recall how it asks the question. Maybe if it said something like "leading edge (or within 6 feet of the front, middle, and last 6 feet)."
     - Barrier identification on direction arrows mark "this is your vehicle" on one arrow so they don't have to try and figure out which arrow applies to them. Better way to get accurate information.

2. How clear are the window controls (e.g., buttons, check boxes, etc.) in the expert system user interface?

   2.1 Were there window controls (e.g., buttons, check boxes, etc.) in the user interface that were confusing to operate?

Table 16. Rating the clarity of window controls.

Response	Count
1. Yes	0
2. No	7

   2.2 If Yes, do you recall which were confusing?

   2.3 Do you have any suggestions on how to change this window or operation so that it is easier to understand (e.g., redesign the window control, provide more training, etc.)?

   Officers' Comments:

   - System was easy to use.
   - Very clear, easy to use.

3. How clear is the meaning of each of the data input values (e.g., label on the radio button or check box)?

   3.1 Did you have any problems understanding what each of the data input values in the user interface, such as a label on a button or check box, represented or meant?

Table 17. Rating the understanding of data input values.

Response	Count
1. Yes	0
2. No	8

   3.2 If Yes, can you recall which data input value was not clear?

   3.3 Do you have any suggestions on how the meaning of the data input value(s) can be made clearer (e.g., change the label, add help menus, provide more training, etc.)?

   Officers' Comments:

   None.

4. Did the system ever keep you from performing an action you wanted to perform?
   4.1 Were there any situations where you wanted to perform an action, but the system prohibited you from performing the action? Actions could include: enter desired data, change data already entered, save the data, end expert system processing, or restart expert system processing.

Table 18. Rating ease of access to operations.

Response	Count
1. Yes	0
2. No	8

   4.2 If Yes, is there any information about the situation you can recall (e.g., the action that was being performed, what screen was displayed at the time, or what operation you had last performed)?
   4.3 Do you have any suggestions on how to change the user interface to make these or other actions easier to perform?

   Officers' Comments:

   None.

5. Does the system force you to perform unneeded operations or actions that interfere with the crash data collection process?
   5.1 Were there any situations where you were forced to perform an operation (close, save, enter data, etc.) that seemed unnecessary or a particular action that you did not want to perform at that time, such as extra button clicks to get to a particular screen?

Table 19. Rating user control over operations.

Response	Count
1. Yes	1
2. No	7

   5.2 If Yes, is there any information about the operation or action you can recall (e.g., what action or operation you were performing, what screen was displayed at the time, or what operation you had last performed, etc.)?
   5.3 Do you have any suggestions on how to change the user interface to eliminate an unnecessary operation or action?

   Officers' Comments:

   - Utilize keyboard along with the pen option.

     Author's Note: The expert systems were designed and developed to allow the officer to enter data into the expert systems using the keyboard as the only input device. However, since data input is facilitated by a pen input device, the use of the keyboard for data entry was not emphasized in the training class.

6. How would you rate the overall ease of use of the system (this is whether system was easy to use, not was it difficult to determine the value of a data element)?

6.1 The system is user friendly and the user interface was intuitive.

Table 20. Rating overall ease of system use.

Response	Count
1. Strongly Disagree	
2. Somewhat Disagree	
3. Somewhat Agree	7
4. Strongly Agree	1
No Rating	

6.2 Were there operations or actions that you performed that were particularly difficult or were not user friendly? An example could be exiting a screen or editing data.

6.3 Do you have any suggestions to make this or other operations easier?

Officers' Comments:

- I showed it to other officers and they thought it was easy to use and understand.
- This system was easy to use, although a lot of time is needed [for the officer] to put into the accident investigation [to investigate the accident in order to properly collect the expert systems' data].
- Could you somehow make the "expert" tab flash to alert the officer that the info needs [to be] collected at the scene, especially on minor 10-50's [an accident] when belt info is requested?

Seat Belt Use Expert System

7. Did the system make it easy for you to keep track of the accident case, vehicle, and vehicle occupant pertaining to the data you were entering?

Table 21. Rating context maintenance in the Seat Belt Use Expert System.

Response	Count
1. Yes	5
2. No	0

7.1 For the Seat Belt Use Expert System: Please explain any situations where you had trouble keeping track of the accident case, vehicle, and vehicle occupant for which you were entering data.

7.2 Do you have any suggestions to make it easier for you to track this information? Is there any additional data that could be added to the screen to make it easier for you to keep track?

Officers' Comments:

- I had an accident with several occupants and had problems keeping track of individuals after selecting all. It would be nice if the name of the subject could be found easily.

Author's Note: Currently, when an officer edits Seat Belt Use data and selects "all individuals," the occupant and vehicle tracking information is not displayed on the edit window. The edit window displays all of the data previously entered by the officer (described in Appendix A). The occupant and vehicle tracking information is displayed on each input window. A system extension is to display the occupant and vehicle information on the edit window. We suggest that integrators of State-reported crash data collection systems do not implement the "all individuals" option.

8. Another use for the Seat Belt Use Expert System is as a training tool. As a training tool, officers would use the system until they are familiar enough with the indicators of seat belt usage that they will look for them without using the system.

8.1 Do you think the Seat Belt Use Expert System could be used as a training tool?

Table 22. Rating the Seat Belt Use Expert System as a training tool.

Response	Count
1. Strongly Disagree	
2. Somewhat Disagree	1
3. Somewhat Agree	4
4. Strongly Agree	2
No Rating	

8.2 Provide any comments you have on whether or not you think the Seat Belt Use Expert System could be used as a training tool.

Officers' Comments:

- I think it's good to keep an officer aware and up to speed. So it's good to keep the officer aware of what to look for. (I forgot this time, but I'll get it next time.) I would think a training program would be best, before the expert system is used, but good follow-up.
- The graphics are very good. It is easy to use and is helpful to tell you what to look for. I think it would remind officers what to look for to determine if the seat belt was used.
- The system explained the different evidence types where seat belts are concerned.
- I feel it makes you look closely at seat belts, but it would not be worth using just for training.
- A lot of the items that are checked are rarely seen.
- I think that seat belt use would be a great tool. The only problem would be the photos on monochrome screens, which are very hard to see certain objects, such as clothing or skin transfer.

Author's Note: The Seat Belt Use Expert System help screens were not designed for a monochrome display. A system extension is to include schematic drawings for computers with monochrome displays. This method was implemented in the Roadside Barrier Expert System.

Vehicle Damage Rating Expert System

9. Did the system make it easy for you to keep track of the accident case and vehicle pertaining to the data you were entering?

Table 23. Rating context maintenance in the Vehicle Damage Rating Expert System.

Response	Count
1. Yes	4
2. No	

9.1 For the Vehicle Damage Rating Expert System: Please explain any situations where you had trouble keeping track of the accident case and vehicle about which you were entering data.

9.2 Do you have any suggestions to make it easier for you to track this information? Is there any additional data that could be added to the screen to make it easier for you to keep track?

Author's Note: The system displays the vehicle number, make, and model on each input screen. The officers gave suggestions on additional data that could be added.

Officers' Comments:

- I don't remember problems in tracking a certain vehicle. It's helpful to have a little box that describes the vehicle in question when you answer the question for that vehicle (example: '93 Gray Pontiac).
- Whenever you have numerous vehicles, it is helpful to list car type or driver beside the items you are asked to enter.
- For accident case, not really; but for vehicle it was fine.
- Maybe by putting the location of the accident along with the vehicle description at the top of the screens you are working on.

Roadside Barrier Expert System

10. Did the system make it easy for you to keep track of the accident case pertaining to the data you were entering?

Table 24. Rating context maintenance in the Roadside Barrier Expert System.

Response	Count
1. Yes	2
2. No	

10.1 For the Roadside Barrier Expert System: Please explain any situations where you had trouble keeping track of the accident case for which you were entering data.

10.2 Do you have any suggestions to make it easier for you to track this information? Is there any additional data that could be added to the screen to make it easier for you to keep track?

Officers' Comments:

None.

11. Do the diagrams in the Barrier Identification Expert System clearly represent the barrier type?

11.1 Are there any situations where you were not sure what to enter for a barrier type element, because the diagram of the barrier type did not clearly represent the barrier?

Table 25. Rating the clarity of on-line help diagrams.

Response	Count
1. Yes	
2. Probably Yes	
3. Probably No	
4. No	6

11.2 If Yes, do you recall what data element you were collecting?

11.3 If Yes, do you recall what diagram was not clear and/or what value you entered?

11.4 Do you have any suggestions for improvement to the diagrams?

Officers' Comments:

- First-class identification. Expert system diagrams are very helpful and easy to understand. No or very little classroom [training] needed to use Barrier Identification Expert System.

Data Elements

12. In each of the three tables below, identify up to three data elements that are particularly time-consuming to collect. Do you have any suggestions on how to make them easier to collect or do you think they should be eliminated?
    Authors Note: The times shown in table 26 are judgments made by an officer and are not based on actual data collection times. The actual data collection times were calculated for each expert system and does not include an estimate per data element.

Table 26. Seat Belt Use data elements.

Data Item	Difficult or Time-Consuming to Collect	
1. Occupant Stated Belt Was Used	0.5 minutes	
2. Observed Seat Belt Usage	0.5 minutes	
3. Seat Belt Damaged During Crash	1-2 minutes (see below)	
4. Ejection	0	
5. Displaced From Seat	0.5 minutes	
6. Belt Loading Evidence • Belt Stretch • D-Ring Transfer • Loop Mechanisms Deployed • Trim Panel Damage • Material Transfer • Latch Plate Peening • Belt Inspection Other	• Somewhat time-consuming, a pass option on minor accidents. • I felt on these items it was unnecessary to show why or what was damaged. • 1-2 minutes [for] each vehicle.	
7. Belt Loading Injury	0.5 minutes	
8. Body Contact With Vehicle Interior		Total of 1-2 minutes [for] each vehicle.
9. Body Contact With Front Interior • Head Windshield Contact • Steering Wheel • Windshield Header • A-Pillar • Knee Bolster • Instrument Panel • Contact Points Other	• Bypass in minor accidents. • 1-2 minutes [for] each vehicle.	
10. No Wear Marks on Latch Plate		Total of 1-2 minutes [for] each vehicle.
11. Lower Belt Dirty and Retracted Part Clean		
12. Seat Belt Citation Issued		
13. Conscious		
14. Airbag Deployed		
15. Depth of Crush	Not needed for routine investigation.	
16. Vehicle Damage Location		
17. Addresses Same as Registrant		
18. Seat Position		
19. Vehicle Year		

Officers' Comments:

- No problems collecting.
- Not hard to collect; very easy.
- All of these are easy to collect.
- No problems.

Table 27. Vehicle Damage Rating data elements.

Data Item	Difficult or Time-Consuming to Collect
1. Accident Events • Override • Underride • Rollover	
2. Collision Type	
3. Principal Damage Area	
4. Lateral Damage Area	Not needed unless done for Technical Investigation.
5. Depth of Crush	• Not needed unless done for Technical Investigation. • Hard to understand.
6. Deepest Crush	Not needed unless done for Technical Investigation.
7. Depth of Crush Drawing Tool	• Was very slow. • Not needed unless done for Technical Investigation.
8. Principal Direction of Force	Hard to understand.

Officers' Comments:

- [It took] 1-2 minutes.
- No problems collecting.
- Not very hard to collect; very easy.
- No problem.
- Easy to collect and show on system.

Table 28. Roadside Barrier data elements.

Data Item	Difficult or Time-Consuming to Collect
1. Non-Barrier Event Is More Severe	
2. Barrier Type	
3. Post Material	
4. Number of Cables	
5. Concrete Barrier Type	
6. Point of Impact	
7. Point of Impact on Thrie-Beam	
8. Blockout	
9. Post Spacing	
10. W-Beam End Type	
11. Number of Terminal Posts	
12. Slots in Rail	
13. Box Guardrail End Type	
14. Thrie-Beam Guardrail End Type	

Officers' Comments:

- Not very hard to collect; very easy.
- No problem.
- No problem collecting.
- Time-consuming, but I feel it is important information to collect unless minor accident, little or no damage.
- I did not feel any of these were necessary for my investigation. I understand they were needed for your study. It was easy to understand the type of barriers and answer all these questions.
- [It took] 2-5 minutes total.
- No problems collecting.

Officers' Overall Comment:

- There is not any one element that takes a lot of time to collect. But when you combine all of the elements, that is when you take the time.

13. Are there data values missing from any of the expert system selection lists that should be added?

   13.1 For those data items you entered as Not Known or Other, was the data value you wanted to enter missing from the selection list so that you were forced to enter Not Known or Other instead?

Table 29. Rating completeness of selection lists.

Response	Count
1. Yes	
2. Probably Yes	1
3. Probably No	1
4. No	4

   13.2 If Yes, can you recall the data element and/or data value?

   Officers' Comments:

   None.

14. Since you may not be able to collect all of the expert system data at the scene, we are trying to determine whether the system should be changed to make it easier to collect certain data elements at the scene.

   14.1 Are there any situations where you entered Not Known or Other for a data element because the data could not be collected at the scene? Do not include injury data that is collected at the medical facility.

Table 30. Rating ability to collect data at the scene.

Response	Count
1. Yes	
2. No	3

   14.2 Can you recall the data element and/or the data value?

   Officers' Comments:

   - Weather conditions and safety play a part.
   - A lot of the depth crushing and impact needed to be done at a later date, due to danger at a scene.

   Author's Note: The data analyst cannot expect all data to be collected at the scene. Officer training should include a discussion about the importance of on-scene data collection. The Officer Training Manual *identifies the data elements that do not have to be collected at the scene. The* Officer Training Manual *is included in the* Expert Systems for Crash Data Collection: Users Guide *as Appendix A.*

System Reliability

15. Does the system crash, freeze the screen, or fail in any other way, making additional data entry impossible?
    15.1 Were there any situations where the system erroneously made additional data entry impossible?

Table 31. Rating system reliability.

Response	Count
1. Yes	
2. Probably Yes	1
3. Probably No	2
4. No	4

    15.2 Please explain any of these situations where the system erroneously made additional data entry impossible, such as the screen freezing or other system crashes.
    15.3 Do you remember any of the error messages displayed? Please also try to remember what screen was open and what operation you were performing.

Officers' Comments:

None.

5.2 CRASH DATA QUALITY

Throughout the expert systems' design and development, the expert panel ensured the quality of the crash data knowledge included in the expert systems. During and after system development, two common methods of validating the quality of the expert systems' data were used:

- Experts enter data into the expert system. The experts compared the conclusions they reached with the expert system's results.
- Individuals trained in the use of the expert systems entered data into the expert systems and experts collected data for the same crash. The expert systems' results were compared with the expert's results.

The expert panel members validated the expert systems utilizing the first method described above. In addition, accident reconstructionists applied the first validation method to the Seat Belt Use Expert System. The second validation method was used to validate the Vehicle Damage Rating Expert System. The following sections describe the validation in detail.

5.2.1 Seat Belt Use

The final version of the Seat Belt Use Expert System was validated by three crash reconstructionists who collect data for special studies. These reconstructionists entered data collected while investigating a crash into the Seat Belt Use Expert System. Then they compared their assessment of whether the occupant wore his/her seat belt with the conclusion reached by the expert system. The results for the crashes in which the expert system reached a conclusion were:

- Expert matches expert system - 26.
- Expert does not match expert system - 3.

There are two types of crashes for which the expert and the expert system did not agree. Both crash types were identified by the expert panel members during system design. However, it was decided not to include these conditions in the expert system, since it would require the officer to collect additional data that may not significantly increase the validity of the conclusion reached. The first crash type is where the occupant is seated in the front seat close to the steering wheel and impacts the interior of the vehicle. The expert system concluded that the seat belt was probably not used. However, the reconstructionist obtained additional evidence that was beyond the scope of the expert system, indicating that the seat belt was used. The second crash type is where the occupant wears an automatic shoulder belt and does not wear a manual lap belt. This is a case of seat belt misuse.

The reconstructionists using the Seat Belt Use Expert System also noted that belt loading evidence, such as band-like bruises across the chest, is seen less frequently in crashes where the airbag deployed. In crashes where the airbag deployed, the reconstructionist looks for different medical evidence to determine whether the belt was used. Medical evidence such as crushed ribs, along with other evidence, can indicate that the occupant was not wearing a belt.

5.2.2 Extent of Deformation

The Vehicle Damage Rating Expert System data element, Extent of Deformation, was validated by an Iowa State Patrol technical investigator. A technical investigator, trained in crash investigation, measured the Extent of Deformation. An officer used the expert system to draw the Extent of Deformation for a small sample of damage cases (six cases). Figure 8, in section 4.3.2.3, shows the Extent of Deformation drawing tool used by the officer to estimate the crush. The damage is estimated along six equally spaced lines, as shown by the triangles and dotted lines in figure 8. These data were compared to help determine whether an officer, trained only in the use of the Vehicle Damage Rating Expert System, can accurately collect Extent of Deformation data.

Table 32 shows the number of inches an accident reconstructionist believes is an acceptable difference between the officer's estimated measurements and the technical investigator's actual measurements.

Table 32. Acceptable difference in crush measurements.

Crush	Acceptable Difference	Delta Velocity
6 to 8 in	≤ 2 in	11-15 mph
9 to 19 in	≤ 5 in	16-20 mph

1 in = 25.4 mm, 1 mph = 1.61 km/h

Although only six vehicles were compared, the results showed that for most of these vehicles, an officer can estimate the Extent of Deformation within acceptable limits. In addition, the comparison identified crush profiles that are difficult to estimate and therefore require additional officer training. Table 33 shows the results of comparing the technical investigator's measurements and the officer's estimates for each of the vehicles. The measurements that show a significant difference are highlighted in bold font.

Table 33. Comparison of measured and drawn Extent of Deformation.

		Difference at Each Crush Line					
	Maximum Crush	1	2	3	4	5	6
Vehicle 1	6.0 in	1.0 in	**3.4 in**				
Vehicle 2	10.2 in	2.3 in	1.2 in	2.3 in	1.8 in	2.3 in	0.4 in
Vehicle 3	14.3 in	1.9 in					
Vehicle 4	14.4 in	**8.8 in**	**7.9 in**	4.7 in	1.7 in	2.4 in	3.9 in
Vehicle 5	14.5 in				0.6 in	1.4 in	4.0 in
Vehicle 6	14.7 in	0.3 in	1.1 in	**7.8 in**			

1 in = 25.4 mm

The officer underestimated the extent of the damage in the lateral direction for vehicle 1 and vehicle 6. Therefore, although the deformation estimate at the point of impact was accurate, the estimate at the lateral edge of the damage was not. Also, vehicle 6 was particularly difficult to estimate at the lateral edge since it was an underride crash where the bumper was pushed back, but the grill was not. Underride and override crashes are currently outside the scope of the

Vehicle Damage Rating Expert System. Therefore, the method of estimating the deformation in an underride or override crash was not included in the training.

Vehicle 4 represents a damage profile that is particularly difficult to estimate and draw. The principal point of impact was at the corner of the front bumper and the bumper displacement was about 11 in (279 mm) in the 11 o'clock direction. There was some confusion about how to accurately draw this type of damage. Therefore, the officer should receive training in how to properly draw this type of crush profile using the Extent of Deformation drawing tool.

5.2.3 Roadside Barrier

During focus group meetings and training sessions, some officers had difficulty accurately collecting two of the Roadside Barrier Expert System data elements: (1) point of impact and (2) classifying a W-beam terminal as flared or not flared. Point of impact indicates whether the initial point of impact was at the main section of the guardrail, within 25 ft (7.6 m) of the end, or at the end. Some officers may have difficulty: (1) accurately estimating 25 ft (7.6 m) from the guardrail end and (2) remembering the definition of impacting the guardrail end. In addition, some officers may have difficulty differentiating between a flared W-beam guardrail and a W-beam guardrail that is bent away from the roadway.

Help screens and diagrams were included to aid the officer in accurately encoding both of these data elements. The trainer should explain these data elements and refer to the on-line help screens and diagrams.

5.3 CRASH DATA COLLECTION TIME

Throughout the program, expert systems were designed and developed to minimize the time an officer would need to collect the crash data. An important component of officer acceptance is the time it takes him or her to collect the expert systems data. The estimate of the impact of collecting expert system data is based on comparing data collection time for each expert system with the data collection time for State-required crash report data.

During the second field test, the computer stored the time it took the officers to collect data in each of the expert systems and in the State crash reporting system. Approximately 60 crash cases were collected. Figure 17 shows a chart comparing the average expert system data collection time with the average of the State crash report data. A single crash included data collection for all occupants and vehicles involved in the crash. The data collection times were calculated per crash. The officer collected the data on an average of about 2 minutes per expert system.

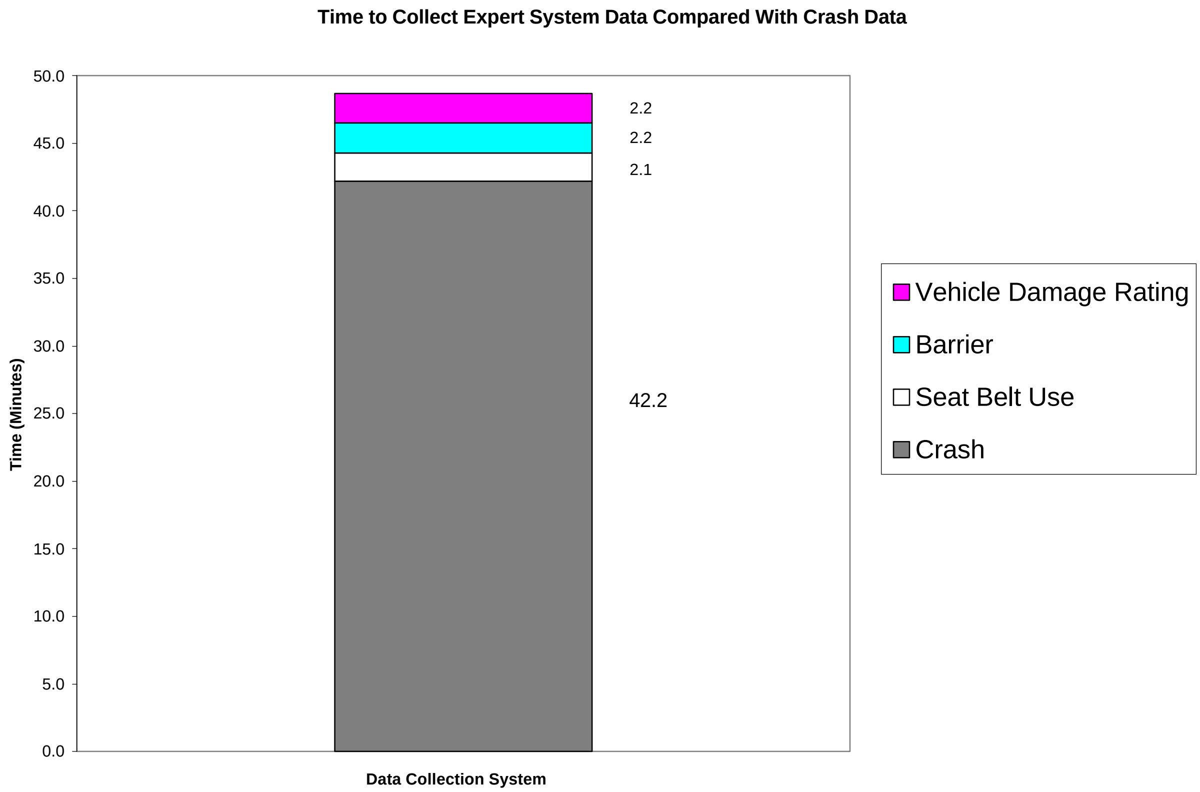


Figure 17. Average time to collect expert system data compared with State-reported crash data.

In figure 17, the number of crashes represented for each of the expert systems was: (1) Roadside Barrier, 9 crashes; (2) Vehicle Damage Rating, 14 crashes; and (3) Seat Belt Use, 31 crashes. Prior to analysis, these crash cases were filtered to exclude data that were: (1) outside of the scope of the expert systems (e.g., Vehicle Damage Rating Expert System data is not collected for rear-end collisions); (2) spuriously low, showing the officer entered the application, but did not collect data; and (3) spuriously high, showing the officer left his or her computer in the application while performing other tasks. Also, each crash represented in the Figure 5 chart does not necessarily include data from all three expert systems. As one example, since barrier crashes occur infrequently, there are crashes with corresponding Seat Belt Use data and Vehicle Damage Rating data, but without corresponding Roadside Barrier Expert System data.

6.0 SUMMARY

Police are unique in their ability to collect data for a larger number of crashes and a wider spectrum of crashes compared with special investigation teams. Police are also able to collect transient data that cannot be collected in follow-up investigations. Police are now using in-vehicle computers to perform their day-to-day operations. The Expert Systems for Crash Data Collection program extends the use of these computers with three expert systems that collect on-scene crash data. A primary goal was to develop expert systems that increase the accuracy and consistency of police-reported crash data.

The expert systems were evaluated during two field tests. The field test results show:

- Expert systems were well accepted by the officers. The questionnaire results showed that all of the officers rated the systems as easy to use. In response to the statement "The system is user friendly and the user interface is intuitive," the officers responded with either: somewhat agree or strongly agree (see section 5.1.1).
- Expert systems were validated by experts in the expert system domain areas. The expert systems were validated by the expert panel members during system design, development, and testing.
- Officers collected expert system data on an average of about 2 minutes per expert system. The focus group meeting and the officer survey results showed that the officers thought it did not take too much time to collect the data. However, they did feel that collecting more data would be excessive. Therefore, if more extensive data collection is required (e.g., more than approximately 6 minutes for special study data), it is recommended that a special investigation team whose primary responsibility is crash data collection be utilized.

The expert systems can increase the accuracy of data compared with the current State-reported police data. However, there are several data elements where training should be emphasized:

- Vehicle Damage Rating Expert System data element Extent of Deformation training should include: (1) how to draw damage where the bumper is displaced in the lateral direction and (2) how to draw the lateral extent of the damage.
- Vehicle Damage Rating Expert System data element Principal Direction of Force training should: (1) emphasize that the most likely choices for PDOF are highlighted on the input screen and (2) review each of the help screens.
- Roadside Barrier Expert System data element Point of Impact on W-Beam Guardrails training should include reviewing the help screen.
- Roadside Barrier Expert System data element Flared/Not Flared W-Beam Terminal training should include reviewing the help screen.

Expert systems for crash data collection are particularly applicable to special studies, such as a roadside barrier study. The combination of special study data and State-reported crash data can provide better quality data without requiring extensive data collection time for the officer.

The combination of better quality seat belt use and vehicle damage data provides a measure of crash severity that is not currently collected by the States. These data can be used to aid in analyzing a wider variety of crashes than is currently collected by crash investigators and reconstructionists. These data would aid in analyzing the in-service performance of vehicle components such as airbags.

The Seat Belt Use Expert System can also be used as a stand-alone training tool. Some officers stated that they were previously unaware of the seat belt use evidence requested by the expert system. The expert system would be particularly effective as a training tool for police officers who do not use computers for crash data collection. The system also executes on a desktop personal computer running the Windows 3.X through Windows 98 operating system.

Potential extensions to the program include:

- Using the expert systems to collect data for highway safety analysis.
- Extending the scope of these expert systems.
- Developing additional expert systems to collect data for analysis.

REFERENCES

(1) *Model Minimum Uniform Crash Criteria (MMUCC), Preview Edition.* National Highway Traffic Safety Administration, Federal Highway Administration, U.S. Department of Transportation, 24th International Forum on Traffic Records and Highway Information Systems, August 1998.

(2) *Critical Automated Data Reporting Elements*. National Highway Traffic Safety Administration, Federal Highway Administration, U.S. Department of Transportation, 1992.

(3) *Vehicle Damage Scale for Traffic Accident Investigators*. National Safety Council, 1984.

(4) Cromack, J. Robert, Southwest Research Institute, and Lee, Scott N., National Highway Traffic Safety Administration, U.S. Department of Transportation. *Consistency Study for Vehicle Deformation Index*. Society of Automotive Engineers, Inc., Report No. 740299, Automotive Engineering Congress, Detroit MI, February 25 - March 1, 1974.

(5) *Traffic Safety Facts 1995: A Compilation of Motor Vehicle Crash Data From the Fatal Accident Reporting System and the General Estimates System*. National Highway Traffic Safety Administration, National Center for Statistics and Analysis, U.S. Department of Transportation, Washington, DC, September 1996.

(6) *Collision Deformation Classification*. Society of Automotive Engineers J224, March 1980.

(7) *Data Element Dictionary for Traffic Records Systems.* States' Model Motorist Data Base, October 1993.

(8) Cromack, J. Robert, *Multidisciplinary Accident Investigation.* Volume 5, Supplementary Report (Final Report 1971-1974). Report No. SWRI-11-3075-F; DOT-HS-801 283. Southwest Research Institute, San Antonio, TX, November 1974.

(9) Mak, K.K., and Magaro, A., *National Accident Sampling System (NASS) Longitudinal Barrier Special Study*. *Coding/Editing and Field Procedures Manual,* Southwest Research Institute, San Antonio, TX, November 1984.