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Evaluation of electronic collection of vehicle crash data in Iowa

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Evaluation of electronic collection of vehicle crash data in Iowa

by

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Signatures have been redacted for privacy

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CHAPTER 1 - GENERAL INTRODUCTION

1.1 Vehicle crash data, a key source for highway safety data

In 2001, there were 42,116 fatal, 3,033,000 injury, and 4,282,000 property damage only crashes in an estimated 6,323,000 police-reported traffic crashes in the United States (1). With this magnitude, highway traffic crashes remain one of the major causes of death in the United States. The National Center for Injury Prevention and Control reports that motor vehicle crashes are the leading cause of unintentional injury death in the United States for people aged 1-34 (2). These high numbers of casualties and socioeconomic losses have made 'highway safety' an important issue at all levels of government in the United States. Highway safety, based on the lexical meaning of 'safety' (3), can be defined as the state of being safe from the risk of experiencing or causing injury, danger, or loss as a result of crashes on highways. Therefore, vehicle crash data, which contain information about the characteristics of the crash, vehicles, persons involved (drivers, passengers, pedestrians, and other road users), environment, and roadway, are crucial for improved highway safety. Complete crash data are usually compiled from three sources:

- data collected at or away from the scene (e.g. an investigating officer may leave the scene and go to a hospital to collect additional data about injuries) (4);
- derived data (e.g. crash severity, derived from 'Injury Status', or number of vehicles, derived by counting the number of vehicles involved) (5); and,
- obtained data (e.g. some data such as grade, horizontal alignment, annual average daily traffic, etc. can be obtained by linking to roadway related files) (5).

These data play a vital role in the (i) identification of highway safety problems, (ii) evaluation of the effectiveness of laws, regulations and programs, and (iii) selection of countermeasures. However, although police are in a unique position to collect crash data, their primary on-scene responsibilities include securing the crash site, caring for injured persons if officers arrive before emergency services, and re-establishing impeded traffic flow (6, 7). Collecting and recording crash data usually begins after this time. However, some data and evidence may be lost, removed, replaced, or shielded during these routine police procedures; therefore, crash data collected and reported by police may not always meet needs of highway safety analysts (4, 6, 7).

1.2 Use of technology in crash data collection and reporting in Iowa

For years, the traffic safety community has been working to find better ways to facilitate and shorten the data collection process, increase officer efficiency, and improve the quality of crash data collected. Along with improvement strategies such as training crash data collectors, emerging technologies have been suggested to have the potential to improve the quality of data and to make the officers' job easier (8). Technologies such as mobile computers, optical scanners, form readers, Global Positioning Systems (GPS), Geographic Information Systems (GIS), digital cameras, printers, and magnetic stripe and barcode readers have been used in the collection and management crash data.

Iowa was the first state to deploy a mobile crash reporting system that collects state-reported data (7). In 1994, the Iowa Department of Transportation (Iowa DOT) worked with other state and local agencies to "develop an automated process for collecting, validating and transferring crash data in order to reduce the length of the crash report life cycle and to improve the overall quality of the information collected" (9). In 1995, the Mobile Accident Reporting System (MARS) was developed for Iowa's Officer Information Manager (OIM), an architecture that supported the data collection process for officers and the data processing requirements for the Iowa Motor Vehicle Division (10).

In 1997, Iowa DOT and the Federal Highway Administration (FHWA) partnered to develop a national model (11). The National Model:

> "...is a program for sharing information, resources, and technologies between state and local agencies to improve highway safety. The focus of the National Model is to improve data acquisition related roadway incidents, use of technology to assist law enforcement, streamline the communication of safety information to key stakeholders, and extend the use of this information for safety and law enforcement programs. The ultimate goal of the program is to increase the quality of the nation's safety data through investment in proven software and technologies".

1.3 Traffic and Criminal Software (TraCS)

The Mobile Accident Reporting System (MARS) was the first component developed for OIM. Application software combined with laptop or mobile computers, a central host workstation, and statewide communication network were the basic components of the system. MARS allowed the investigating officer to record crash data directly into the system. The application software provided pick-lists, crash scene templates, and automatic validation of some data. Once a report is completed, data are transferred to the host workstation, where they are reviewed, approved on-line, and transferred electronically to the state repository (9).

In 1996, Electronic Citations (ECCO), Mobile implied consent for Operating While Intoxicated (MOWI), commercial motor Vehicle Safety Inspection System (VSIS) components (electronic forms), and, in 1999, Incident-based Reporting Form (CIRF) component was added to the software. The Iowa State University Center for Transportation Research and Education (CTRE) added the Incident Location Tool, which locates crashes electronically. To simplify the transition of the software from one state to another, a Software Development Kit (SDK) was also added to the system in November of 2000. The SDK allows other states to customize the system environment to meet individualized data entry and reporting requirements. The SDK significantly reduces an agency's dependence on software developers. The name of the software was changed to Advantage Safety in 1998, and then to Traffic and Criminal Software (TraCS) in 2000 (11).

TraCS is designed so that all electronic forms (components) share data, eliminate duplicate entries, and provide immediate electronic transmission to remote sites at local and state levels. For example, once an officer completes a crash report and downloads it to an agency's workstation or network, it is transmitted to the Iowa DOT without user intervention. Similarly, citations are transmitted to the Iowa Court Information System, and to all databases of 100 Clerks of Court (11).

TraCS makes use of technologies, such as laptop computers, portable printers, imager/bar code scanners, digital cameras, GPS, and the Location Tool easily used by officers in the field. In addition to these technologies, laser measuring devices and voice recognition software are planned for future integration.

As of March 2003, TraCS is being used by 273 (of about 500) agencies in Iowa, and is licensed by 18 other states and the Virgin Islands. Some of these states are still testing TraCS, whereas others use only some components due to various reasons, such as lack of laptop computers or a statewide communications system.

1.4 Need for research and objectives

Although use of technology in crash data collection is purported to have facilitated the data collection process and improved the quality of data, no comprehensive analytical assessment has yet been conducted. Tools such as TraCS have been used in Iowa for nearly 10 years; however, only two studies are available which partially document the effectiveness of the systems.

McKnight et al.(12) evaluated emerging technologies for crash reporting in 5 states (including Iowa) in a study that was conducted from November 1995 through April 1996 (See chapter 2, section 2.5 for the results of this study). The technologies evaluated included computers, (standard laptop computer, pen-capable laptop computer, pen-capable computer with detachable keyboard), GPS technology, GIS technology, GPS and GIS combined, and collision diagrams (electronic ink diagram or drag and drop diagram). The tests performed included GPS/GIS accuracy, accuracy of paper forms vs. computerized forms, completeness of paper forms vs. computerized forms, practicality, sturdiness, and implementation costs.

Thielman (6) tested the Federal Highway Administration's (FHWA) "Expert Systems for Crash Data Collection" from April 1996 through October 1998. The Expert Systems were computer programs designed to help officers collect more accurate and consistent data on the determination of (i) whether a vehicle occupant wore seat belt during a crash, (ii) the severity of a crash based on vehicle damage, and (iii) the type of barrier involved in the crash and the point of impact. (See Chapter 2 for the results of this study).

Though the study by McKnight is very similar to this thesis, major changes in crash data collection systems in recent years require a new investigation. These changes include:

- Improved computer systems,
- Enhanced reporting software (software now supports more technologies such as mobile printers, scanners, magnetic stripe and barcode readers, and digital

cameras, and other software such as the Location Tool and diagramming software),

- Increased experience (more officers have used the software operationally).

It is commonly suggested that use of technology lessens the time to collect and report crash data. However, none of these studies measured the time to complete a crash report. This should be done for both paper and electronic reporting so that a comparison can be made between two reporting processes.

In conclusion, the objective of this thesis is to evaluate the efficiency of Iowa's electronic crash data collection system through field studies and database analyses based on the latest data and knowledge, and to document whether the system meets expectations such as better quality crash data (more accurate, complete, consistent, timely data), reduced data collection time in the field, and other suggested benefits.

1.5 Thesis organization

This thesis is comprised of 6 chapters. The remaining chapters in this thesis are: Literature Review, Documentation of Electronic Collection and Reporting Crash Data in Iowa, Methodology, Results, and Conclusions.

Chapter 2, Literature Review, discusses the components of data quality, crash data related problems, factors affecting the data quality, and then introduces some of the technologies used to collect and manage crash data in the United States. Findings of previous studies performed in Iowa evaluating the technologies used to collect crash data are also discussed in this chapter. In Chapter 3, Iowa's electronic crash data collection system, TraCS, is documented. The chapter briefly explains coding crash data on the MARS form, drawing collision diagrams, and locating a crash through Location Tool. Validation, an important function of TraCS is also briefly explained. Chapter 4 details the studies performed and the methodology used in the evaluation of Iowa's electronic crash data collection system. Each study and approach to analyze data collected throughout these studies are defined and explained in detail. Results of these studies and the conclusions are presented in Chapters 5 and 6, respectively.

CHAPTER 2 - LITERATURE REVIEW

This chapter is intended to convey what knowledge and ideas have been established on the quality of crash data and use of technology in crash data collection processes, and, thus, to prepare readers for the topics discussed and the studies performed. The chapter first documents knowledge about crash data quality, factors affecting crash data quality, and common problems. Second, a brief documentation of the efforts on the standardization of crash data is made. Finally, brief background information on the use of crash data collection technology in the United States is given, followed by the summaries of two studies evaluating similar systems used in Iowa.

2.1 Quality of crash data and common problems

Crash data collected at or away from the scene often have problems including errors, incomplete information, illegibility due to poor handwriting, and increased likelihood of errors due to multiple data entries at various levels (13). These problems usually have negative effects on the overall quality of crash data. What happens if the data are not of acceptable quality? More importantly, what does "quality" mean?

O'Day (14) defines data quality as "accuracy, precision, timeliness, and completeness of the data", and then lists eight components of quality: ascertainment (completeness of data coverage), consistency of coverage, missing data, consistency of interpretation, the right data, appropriate level of detail, correct entry procedures, and freedom from response error.

Similarly, Pfefer, et al. (4), define data quality "as a set of dimensions": accuracy, precision, completeness, coverage, timeliness, and consistency.

Hughes et al. (7), rather than defining quality, discuss the "deficiencies associated with the quality of the data" which are timeliness, legibility of reports, completeness of reports – missing data, errors/inconsistencies, and correct data (data accuracy).

A review of literature by other authors also tend to corroborate Pfefer et al. and Hughes et al. in their definition of quality. The most commonly observed attributes of data quality: accuracy, completeness, precision, consistency, and timeliness are discussed in this section.

2.1.1 Accuracy

Crash data, as one of the primary sources of traffic safety information, are collected and recorded by the police at the crash scene. The data typically includes the characteristics of the crash, environment, vehicles, and persons involved. However, collecting and recording crash data is not the primary task of police at a crash site. Police secure the crash site; care for injured persons; and re-establish traffic flow before all else (4, 6, 7, 12). It is suggested that some critical crash data and evidence might be lost, removed, or replaced during these routine police procedures. Hence, it is suggested that crash data collected and compiled by the police may potentially contain errors and may not be of sufficient quality to meet the needs of highway safety analysts.

Pfefer, et al define the accuracy component of quality as the "degree to which the crash data report is correct, both in terms of what is to be included on the report form, and what the collector reports". Accuracy, in this concept, includes "verification of reported facts and care in making observations" and accurate "retention/translation of crash reports in processing".

O'Day emphasizes the importance of the "correct entry procedures" in terms of having accurate data. He places emphasis on controlling the quality of data by manual and automatic edit checks during the data entry process.

With the crash report point of view, there are generally two fundamental accuracy problems: (i) location accuracy, and (ii) data accuracy. Location is the process of determining the location of a crash site using one or more referencing methods. Smith et al. (15) identified the most common traditional crash location methods as Route-Milepost, Route-Reference Post, Link-Node, Route-Street Reference. In these methods, crashes are located by referencing them to the nearest milepost, or to the signs indicating known locations, or to the nearest node number along a link, or to another street, respectively. All these methods are basically based upon measuring the distance of crash location from the references used. Another method of locating crashes is based on coordinate systems - Cartesian coordinates (x and y), or geographic coordinates (latitude and longitude). The coordinate systems requires either direct GPS readings by officers, or pre-established coordinates of roadway segments, nodes or other reference points to mechanically locate the traditionally collected location information at data coding level, usually at the state level.

Proper crash location is essential to the work of the traffic engineers and enforcement agencies because selective engineering measurements and enforcement programs are aimed at those locations. Nevertheless, locating crashes correctly has been one of the most difficult problems for police officers and locators.

Segal & Mallar (16) identify some interesting problems found in crash locating by the police officers in the State of Maine. It was found that officers have sometimes determined the crash locations based on business or residence name, or street or highway names that do not exist. Sometimes, Maine officers referenced the crash locations by utility poles, and indicate wrong directions from the landmark to the crash site.

Hughes et al, identified several other factors leading inaccurate location of crashes, which are:

- ambiguous instructions for determining the location information.
- incorrect estimation of distance from reference points by officers. Officers tend to estimate distances based on observation and their judgment of the distance rather than measuring distances.
- inappropriate reference points (routes, streets, mileposts, nodes, etc.).
- Poor handwriting, legibility, misspellings,
- Inadequate location information.

The second accuracy problem typically associated with a crash report is the accuracy of entered data. In traditional crash reporting processes, entering crash information in a crash report usually involves coding, writing or typing, and drawing. Information about crash, vehicles, injuries, damages, roadway, and environment are usually coded by selecting appropriate elements from pre-defined lists. However, personal and vehicle information, narrative, and location information cannot be coded because each individual crash has unique characteristics and locations as well as having different people and vehicles involved; hence, this data are written or typed on the form. All these data are supplemented by a diagram, which typically depicts the occurrence and the circumstances of a crash, such as movements of vehicles involved, positions of traffic signs, signals, or other fixed objects (if any). The diagram also includes information about street or highway names, distances, and a north arrow.

Pfefer et al. identified very few problems concerning data elements coded on a report form, including crash type, injury severity, surface conditions, light conditions, or seat-belt use. On the other hand, illegibility of narrative and lack of detailed information in the diagrams were identified in the study as the major problem areas on a crash report.

In most states, data on crash reports are reentered in order to record them in the state crash database. During this process, crash data are subject to arbitrary changes due to unreadable handwriting or incorrect data entry.

All errors in crash data, especially miscoding some data elements such as location, crash type, injury severity, surface condition, light condition, or seat-belt use, etc. can lead to either inappropriate conclusions or inability to use the data (4).

2.1.2 Completeness

Hughes et al. and O'Day refer to completeness problem as "missing data". According to Hughes et al. missing data may be a result of failing to (i) report, (ii) submit the report to central repository, (iii) enter data into system, or sometimes data are not found in the system.

Incompleteness or missing data usually occur when officers need to perform urgent duties, such as relieving congested traffic moving again, additional high priority calls, weather, or other factors. In addition, crash reports are sometimes completed at another location in the field or away form the scene, usually at an office later during the shift.

2.1.3 Precision

O'Day refers to precision as the "appropriate level of detail" needed in data reporting. The author indicates that the level of detail depends on the local needs, giving the following examples:

> "For vehicle identifications the level of detail may vary from a vehicle identification number (VIN) to the reporting officer's estimate of vehicle size, make, and model. Degree of injury varies from the common KABCO scale in most states to more sophisticated schemes that identify individual body regions and types of injury. Geo-coding varies from a precision of a few feet to large fractions of a mile".

Pfefer, et al defined precision similarly, as the "degree of detail and exactness provided" in data reporting. The KABCO scale (which classifies crash victims as K- Killed, A-Disabling injury, B- Evident injury, C- Possible injury, O- No apparent injury) was shown as an example to this issue. It is suggested that precision in the reporting of KABCO may be adequate for highway design personnel, but not for designers of vehicle interiors.

2.1.4 Consistency

O'Day refers to consistency as the uniform interpretation of data elements reported by different reporting agencies. The Model Minimum Uniform Crash Criteria (MMUCC) of 1998 identifies the lack of consistency as being a significant crash data related problem, and indicates that consistency problems typically occur due to (i) significant differences in crash element definitions and their attribute values, and (ii) the difference of reporting thresholds from one state to the next, or within state. It is also indicated that consistency problems stand as the major issue for statewide and national database systems since inconsistent data make analysis difficult and are the potential causes of incorrect interpretation.

Pfefer, et al. also refer to consistency as "uniformity". It was concluded that inconsistency, or lack of uniformity, in reporting thresholds or in definitions of data elements would make it difficult to combine data and perform a statewide crash analysis.

2.1.5 Timeliness

Pfefer, et al defined timeliness as the "availability of the data when needed by user". Authors indicated that accuracy, precision and completeness would not be sufficient for crash data to be useful unless data are available to users when they are needed.

In traditional methods of crash reporting, moving crash data into databases follows a series of time-consuming and labor intensive procedures. Hence, as illustrated in figure 2.1, the duration of time between the time crash data are recorded to the time these data are made available for analysis is usually 12 to 18 months (13). This time delay is one of the major problems for the highway safety community. The lack of the most recent data for safety analysis prevents engineers and police from locating safety problem areas and taking necessary measures in a timely fashion.

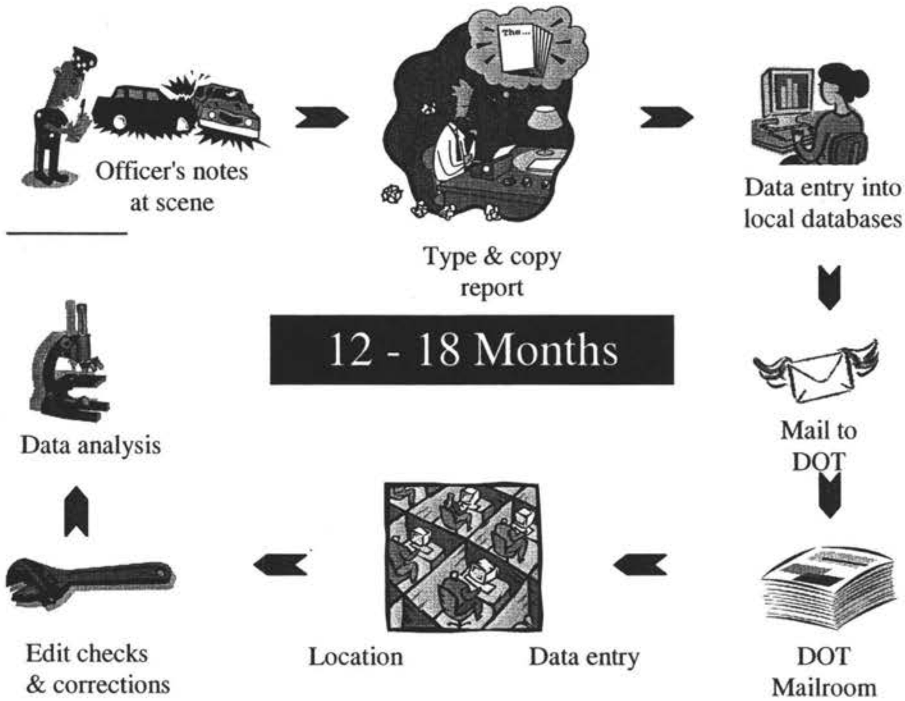


Figure 2-1. Historical life-cycle of crash data in Iowa (Source: TraCS documentation)

Any crash data of insufficient quality may not be adequate to promote the analysis of motor vehicle crashes, the identification of locations with unusually high crash occurrence, the evaluation of crash reduction programs, and the continued surveillance of the highway system (7).

2.2 Factors affecting data quality

There are various factors causing problems with crash data collection, recording, management, and analysis. In the light of literature reviewed, these problems can be grouped into three categories:

- institutional factors,
- officer-related factors, and
- other external factors

2.2.1 Institutional factors

Past literature states that institutional obstacles and problems can lead to a lack of quality crash data. A compilation of some institutional factors affecting data quality include:

- inadequate funding for such services as data collection, processing, etc. (4, 7).
- inadequate communication among various organizations in crash data collection and processing in a state (14).
- incompatible computer systems and insufficient database documentation due to diversity of users and providers of crash data (17).
- institutional memory loss due to change of people who compose or operate the database (18).
- failure to update data collection procedures as data needs and documentation vary over time, but not updated (18).
- inaccurate reporting of crashes due to lack of adequate codes or data elements in a crash report form for all possible conditions results in loss of information (4, 19).
- inconsistent data definitions (5, 14, 17).
- failing to provide adequate tools for collecting and reporting crash data (4).
- various tasks related to crash data collection and management require more funding, staff and other resources (7).
- inconsistent reporting of property damage crashes as thresholds differs from one state to the next (7), which yields biased samples by eliminating some crashes (4).
- lack of nationally standardized (uniform) crash report forms (7).
- few crash reports come into state data center are typed or computer generated (7).
- inadequate training of crash investigating and reporting officers (4).

2.2.2 Officer-related factors

Because police are in a unique position collecting crash data, data quality can be affected by each officer's unique way of approaching the crash and related matters. Some common officer-related factors affecting data quality include:

- a superficial and poor job in reporting if officers feel that accident reports are collected primarily for the insurance agencies (7).
- varying level of care given to reporting a crash depending on the severity of a crash (4).
- tendency to select and use only a few codes from pick-lists although more of them are available (4).
- tendency to estimate the distance of location site to the reference point rather than measuring it (7). This causes a clustering effect at specific locations such as mileposts or other reference points (20).
- officer's judgment about how the crash happened (7).
- miscoding data elements, or in some cases, conflicts among information given (e.g. time of accident conflicts with the light conditions) (4).

- failure to report some data elements (4). In most instances, the reports are returned to the local jurisdictions if some key information such as date, time, location, etc., is not provided (7).
- lack of details in collision diagrams, such as important measurements, reference points, identification of vehicle 1 vs. vehicle 2, and so forth (7).
- inaccurate or imprecise location information (4).
- poor handwriting, misspelled or incorrect street names, etc. (7).
- completing reports away from the crash scene. This may cause accuracy and completeness problems as the officer may forget details about the crash (4).

2.2.3 Other external factors

Besides institutional and officer-related factors, quality of crash data can also be affected by external factors. The most common external factors affecting crash data quality include:

- conflicts among officers' roles at the crash scene, such as controlling traffic, helping injured people, enforce other laws, securing the scene, etc.
- adverse weather conditions preventing thorough investigation.
- drivers involved hiding facts about the crash, or reluctance of witnesses to divulge information (4).
- perceived danger to an officer at the crash scene reduces the incentive to report a crash thoroughly (4).
- extensive time required filling out the crash report depending on crash severity level (7).

2.3 Standardization of highway safety data in the United States

Lack of uniformity between or within states makes nationwide analysis of highway safety data difficult. In an attempt to ensure uniformity and consistency in data elements/definitions, and to facilitate the exchange of data among states, the National Highway Traffic Safety Administration (NHTSA) and the FHWA announced the CADRE (Critical Automated Data Reporting Elements for Highway Safety Analysis) in 1990. (14)

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 required the Secretary of Transportation to "establish a highway safety program for the collection and reporting of data on traffic-related deaths and injuries by the states" and the states "to collect and report such data as the Secretary may require". The secretary was also required to establish minimum criteria for the program to ensure uniformity in the national data (21). The successor of ISTEA, the Transportation Equity Act for the 21st Century (TEA-21) provides incentives "to encourage states to adopt and implement effective programs to improve the timeliness, accuracy, completeness, uniformity, and accessibility of state data" (22).

The ANSI Standard D16.1-1996, Manual on Classification of Motor Vehicle Traffic Accidents, defines its primary purpose as "to promote uniformity and comparability of motor vehicle traffic accident statistics now being developed in states and local jurisdictions" by providing a common language for reporters, classifiers, analysts, and users (23). The ANSI Standard D20.1 Data Element Dictionary for Traffic Records Systems was developed to "provide a common set of coding instructions for data elements related to highway safety..." However, use of American National Standards is completely voluntary.

In addition to the above standards, in 1997, 42 private and public experts developed a collection of minimum crash data elements with the support of NTHSA, FHWA and the National Association of Governors' Highway Safety Representatives (NAGHSR). This collection was named the Model Minimum Uniform Crash Criteria (MMUCC), and was proposed to the highway safety community (24). After a 20-month evaluation and revision period, a final version of MMUCC was published in 1998. The goal of the MMUCC was to "help states collect consistent, reliable crash data that are more effective for identifying traffic safety problems, establishing goals and performance measures, and monitoring the progress of programs" (25).

2.4 Technologies used to collect crash data in the United States

As an alternative to the traditional data collection methods, the use of emerging technologies has been suggested to improve data quality and officer productivity. A variety of technologies have been tested and used by many law enforcement agencies throughout the county. The technologies used in crash data collection and processing include a variety of systems such as optical scanners, optical storage disks, form readers, Automatic Vehicle identification (AVI), portable computers, Global Positioning Systems (GPS), Geographic Information Systems (GIS), magnetic stripes/barcodes and readers, smart cards, Personal Digital Assistants (PDAs), and digital cameras.

In the 1990's, the Virginia Department of Transportation (VDOT) and the Anaheim, California Police Department used optical scanners and optical disk storage systems to scan and store their accident reports (7). Reportedly, the system had the capacity of 600 thousand images at that time. The system allowed the VDOT to retrieve and print a computer-generated copy of the entire report when needed. Anaheim PD indicated that the system has improved accessibility to files, reduced staff demands for filing and retrieving files, and enhanced the capability to process information within the police records division. (7)

In March 1992, the State of Michigan started using form readers to scan and extract data from crash reports. Prior to the implementation of the new system, they revised their crash report forms so that form readers could read them (7). The readers were then able to scan approximately 80% of data elements form Michigan's new crash report form. After that, there were only 20% of the forms left to be entered by the data entry staff at the DOT. (7)

Starting from late 1980's and early 1990's, portable computers were used for the crash-data-collection purposes. Many states and cities experimented with collecting crash data through portable computers, including laptop, notebook, pen-based computers, and palmtop computers. There is no specific data which state used computers in crash data collection first, but one agency was known to utilize portable computers at a crash scene. In 1991, the city of Clearwater, Florida started using portable computers in the reporting of crashes at the scene. Data collected in this manner could then be transferred to a personal computer at the station, and then transferred to the state via a tape (14). In Clearwater, this process did not reduce the time to collect crash data, but eliminated the data entry stage as well as improved the quality of data (7).

Computer technologies allowed officers to collect crash data at the scene, electronically transfer the information, provide on-line error checks, and subsequently eliminate the needs for reentering crash data. At the beginning these devices had many limitations, such as inability of collision diagramming due to graphical incapability, difficulties in data transfer, immaturity of optical character recognition software, etc. However, as technology and software programming advanced, officers had access to better technologies combined with more capable application software.

Magnetic stripe and barcode systems have also been integrated in data collection processes. Magnetic stripe systems have been in existence since the early 1970's. At first, these systems were used on paper, film-based ID cards and credit cards, but now are also used on driver's licenses to store information on the license. Information is placed on a layer of magnetic material, which is generally placed on the front or back of a paper or a plastic card. Likewise, PDF bar codes are also used on driver's licenses, vehicle documents and other areas. Unlike magnetic stripes, PDF barcodes consist of a series of black and white bars of varying thickness and patterns to represent alphabetic characters or numbers (7). Using specialized readers, officers can automatically obtain driver and vehicle data and transfer them onto report forms through application software.

Another technology used in crash data collection is GPS receivers. GPS is based on a constellation of 24 satellites orbiting the earth with 24-hour full coverage. These satellites serve as precise reference points from which GPS receivers can calculate the user's location based on the radio signals emitted from those satellites (26). A police officer can determine a crash location through latitude and longitude readings captured by a GPS receiver. However, during this process, an officer may incorrectly read location information or writing or keypunching errors may occur. The use of a GPS equipped computer may overcome these potential errors (7). Data collected through GPS has potential to reduce time, increase accuracy, and remove the potential for human error (20).

2.5 Past studies evaluating technologies used to collect crash data in Iowa

There are only two studies available to document the effectiveness of the electronic collection of crash data in Iowa. As part of a study to evaluate emerging technologies for crash reporting, McKnight et al. (12) chose to evaluate Iowa's electronic crash reporting software, MARS. The study was conducted from November 1995 through April 1996. One of the tests performed in this study evaluated the quality of attributes for 475 paper and 478 electronic crash reports. The study found an average of 3.24 errors per paper-based and 1.10 per computerized reports, with the difference in the means being statistically significant. Other findings of this study are displayed in figure 2.2.

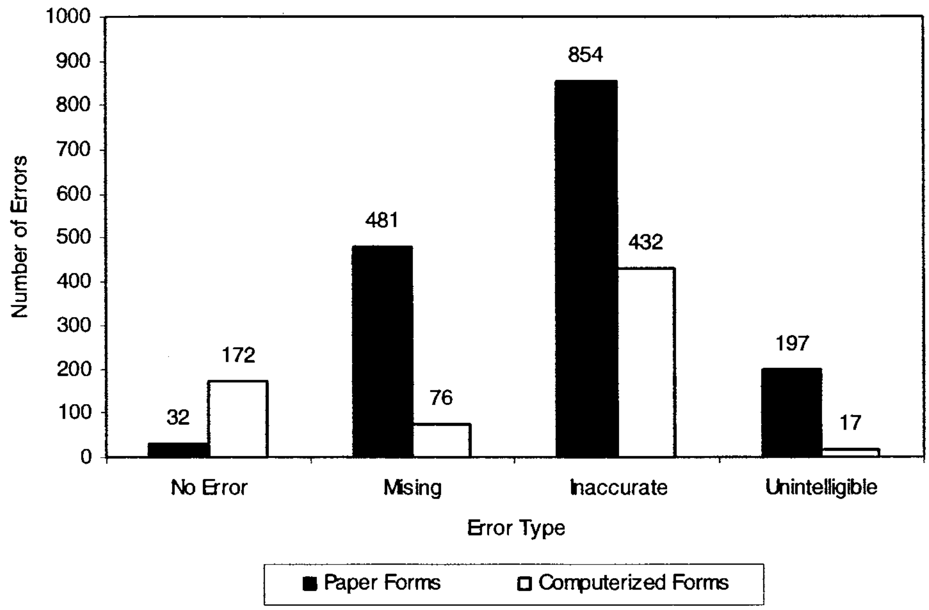


Figure 2-2 Comparison of errors by report type in Iowa (12)

In another test, McKnight et al. collected data on the total time spent at the crash scene, including the time spent reporting based on activity logs. The study found a mean time of 72 minutes for accidents reported using paper forms and 112 minutes for accidents reported electronically.

McKnight et al. also conducted a test on location accuracy by requesting that officers collect GPS readings from each crash location they respond to. Later, the researchers sent well-trained officers to the same locations to collect follow-up GPS readings, and then calculated the difference between the two readings. Table 2-1 gives the GPS disagreement found in the location accuracy test. The results indicate that at about 62-70 percent of disagreement found is between 30 to 152 meters. This range of distance may not be a big problem for locations on rural highways, but is a problem for locations in the city street network or at intersections.

Table 2-1. GPS Disagreement (12)

Group	Percent of cases	
	West Des Moines	Des Moines
Disagreement ≤ 15 m	8.8	6.4
Disagreement > 15 and ≤ 30 m	8.4	25.9
Disagreement > 30 and ≤ 152 m	69.9	62.4
Disagreement > 152 and ≤ 305 m	9.6	4.6
Disagreement > 305 m	3.4	0.7

In another study performed in Iowa from April 1996 to October 1998, Thielman (6) evaluated FHWA's "Expert Systems for Crash Data Collection" program, which was built on data collection knowledge derived from experts in crash data collection and analysis. The goal of the program was to improve the accuracy and consistency of police-reported data through three expert systems:

- Seat Belt Use Derivation: determines whether seat belt was worn during a crash.
- Vehicle Damage Rating: helps determine the crash severity based on vehicle damage.
- Roadside Barrier: identifies the type of barrier involved in the crash and the point of impact.

These systems were computer programs that contained knowledge to help officers collect data on each crash's circumstances. Accuracy and consistency in driver, vehicle, and location data collection were not addressed in this program.

The expert systems were designed so that officers were able to access expert systems through crash reporting applications, similar to accessing the Location Tool through TraCS application. This feature of the system allowed officers to collect both crash and expert data in a single application.

Thielman evaluated the Expert System technology during a two–month field test for the following:

- acceptance of the system by the officers,
- quality of Expert System's data
- time to collect crash data

The responses to surveys completed by officers, as well as discussions made during meetings indicated that the system was well accepted. It was easy to learn and use, and the data quality test results were as follows:

(i) Seat Belt Use: A comparison was made among the assessments of three reconstructionists' and Expert System's assessments over 29 seat belt use data collected during a crash investigating. In 26 cases, Expert System's assessments matched those of reconstructionists'.

(ii) Extent of Deformation: A technical investigator and an officer trained only in the use of the Vehicle Damage Rating expert system measured the extent of damages on six cases; a comparison between these measurements showed that an officer could estimate the extent of damage within acceptable limits.

(iii) Roadside Barrier: During focus group meetings and training sessions, it was concluded that some officers had difficulty in differentiating among some roadside barrier system data elements, such as point of impact, classifying a W-beam terminal as flared or not, and other elements.

Data collection times were measured for 60 cases. The results indicate that officers collected Expert System data on an average of 2 minutes per expert. In conclusion, it was reported that Expert Systems could increase the data accuracy as long as additional training was given on several data elements.

CHAPTER 3 - DOCUMENTATION OF ELECTRONIC COLLECTION AND REPORTING OF CRASH DATA IN IOWA

Currently, about 50 percent of the 65,000 annual crashes in Iowa are reported electronically, whereas the reminder of Iowa crashes is reported through paper forms. This chapter is documents the electronic process of collecting and reporting crash data.

Electronic crash data collection and reporting in Iowa is performed through Traffic and Criminal Software (TraCS), deployed on laptop computers and supported by other reporting devices. Such devices include imager and bar code scanners, digital cameras, Global Positioning Systems (GPS), and GIS location capture software. Investigating officers report crashes using the Mobile Accident Reporting System (MARS) component of TraCS. Recall that MARS is the electronic version of Iowa's crash report form designed to run on a laptop computer in the field, allowing the investigating officer to enter all required crash information directly into a database.

Regardless of the reporting method, paper-based or electronic, crash data are entered into crash forms by (i) coding, (ii) writing or typing, and (iii) drawing. Coded data elements are selected from provided lists, and include information about the crash, drivers, vehicle, injured persons, damaged objects, roadway, and environment, whereas a narrative explaining the crash is written or typed. The form is also supplemented by a collision diagram drawn by the crash investigator, where he or she typically depicts the occurrence and the circumstances of a crash such as movement(s) of vehicle(s) involved, positions of traffic signs, signals, or other fixed objects (if any). A collision diagram also includes information about street or highway names, distances, and a north arrow.

Electronic reporting added two more things to this traditional crash data collection and reporting process: (i) interaction with other software and relating the data obtained there to its environment (e.g. location software), and (ii) on-line data validation.

Taking as a starting point the above, this chapter is divided into five areas: data coding, location, collision diagramming, narrative, and validation.

3.1 Data Coding

Coding data in the TraCS environment (figure 3.1) involves entering required data by either typing or selecting from provided lists (figure 3-2 and 3-3). By either clicking the 'Next' button or pressing the ENTER key, data are automatically placed in the correct report field in the form (figure 3-4).

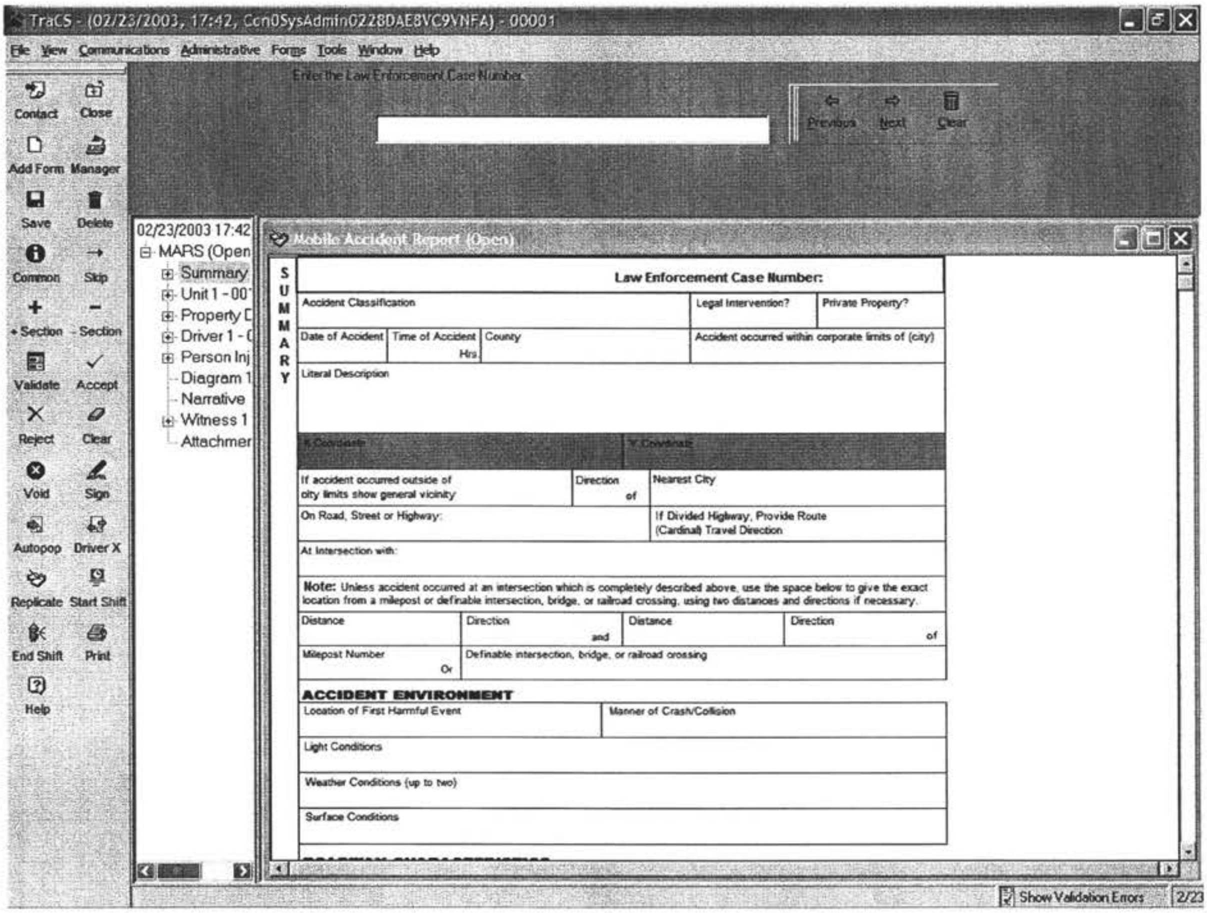


Figure 3-1. TraCS User Interface (MARS Component open)

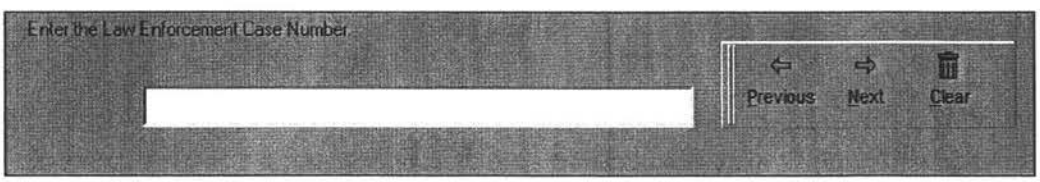


Figure 3-2. TraCS data entry interface

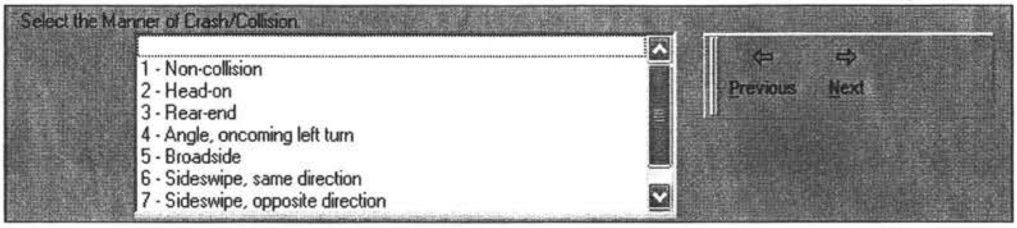


Figure 3-3. TraCS pick-list interface

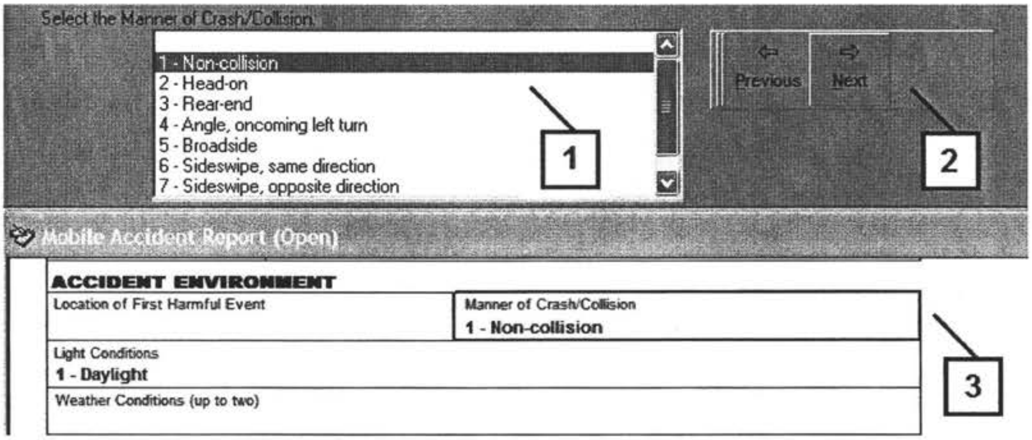


Figure 3-4. Example of data coding: (1) Select data, (2) Click NEXT or press ENTER, (3) Data automatically appears in its respective field.

TraCS helps officers during the data entry process in two ways: (i) graying out fields that are not required, and (ii) eliminating the copying of similar or redundant data elements to multiple forms by storing the data.

As illustrated in figure 3-5, the software shows the officer that fields that are grayed out are not required. In this example, data fields associated with the 'Commercial Motor Vehicle information' section will only be activated if the 'Is CMV?' field is coded 'Yes'. The same is also valid for the 'Property Damage' and other constituent fields.

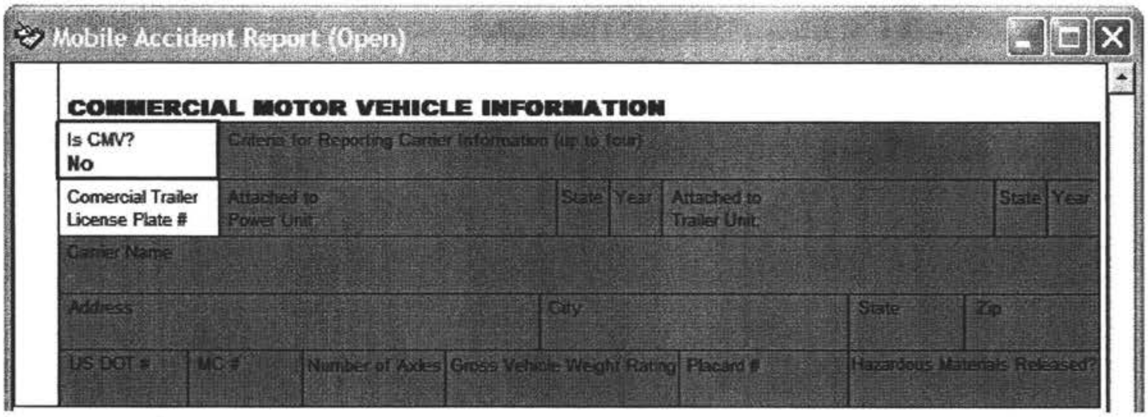


Figure 3-5. Grayed out fields indicating coding not required.

In a paper form environment, officers are often required to copy the same information, such as names, addresses, and vehicle information, to multiple paper forms. TraCS eliminates this repetition using a data structure called 'Common Information', which allows the user to enter certain types of data only once and use it many times. TraCS organizes common information into the following four categories (10):

- Individuals (e.g., name, address, phone number)
- Vehicles (e.g., make, model, license plate number)
- Commercial Carriers (e.g., carrier name, carrier address, DOT number)
- Location (e.g., X & Y coordinates, location description)

As illustrated by figure 3-6, TraCS stores the above listed information and provides it to other data collection forms' pick-lists when necessary. In this example, an individual's contact information concerning an individual was already entered in a MARS form, and is accessible to other forms (in this case, Citation form-ECCO).

Data can also be entered into TraCS by scanning documents such as driver's licenses and vehicle documents with barcode readers (figure 3-7). Information obtained by barcode scanners can be reached through the "Common Information Manager" function as illustrated in figure 3-8.

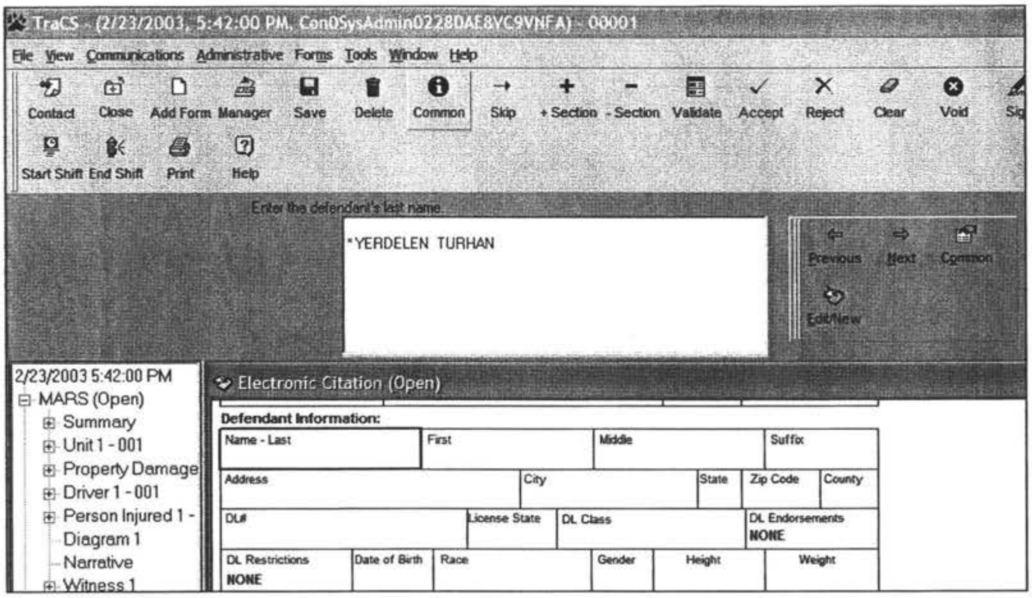


Figure 3-6. TraCS - Common information

Figure 3-7. Use of Image/Barcode scanner (Image: TraCS Demo CD).

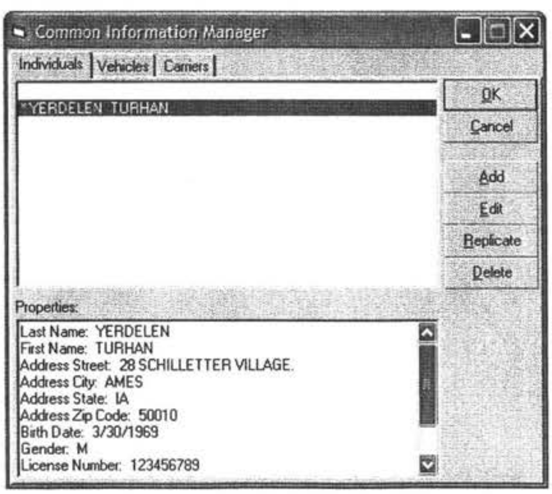


Figure 3-8. TraCS - Common Information Manager

3.2 Location

While paper forms describe crash location by referencing it to streets, the nearest city, milepost, definable intersection, bridge, or railroad, TraCS locates crashes through the Location Tool, an automated crash location system. The system is described (27):

> "The Incident Location Tool is a map-based utility that can be used to locate where an incident occurred. It was designed by the Iowa State University Center for Transportation Research and Education (CTRE) to be used as either an add-on interface to TraCS or a stand-alone application. Within a TraCS form, an officer can choose to launch the Incident Location Tool, navigate to the correct geographical area, and select the location where the incident occurred. The relevant location information (e.g., latitude, longitude, road name, etc.) is then automatically transferred to TraCS via an XML interface and populated onto the TraCS form."

The above-mentioned crash location procedures are illustrated in figures 3-9 through 3-13. Figure 3-9 shows how the Location Tool is accessed from the TraCS-MARS form. Once the crash location 'Literal Description' field is selected on the MARS form, the "Locate" icon appears on the data bar. Clicking on this icon opens the Location Tool.

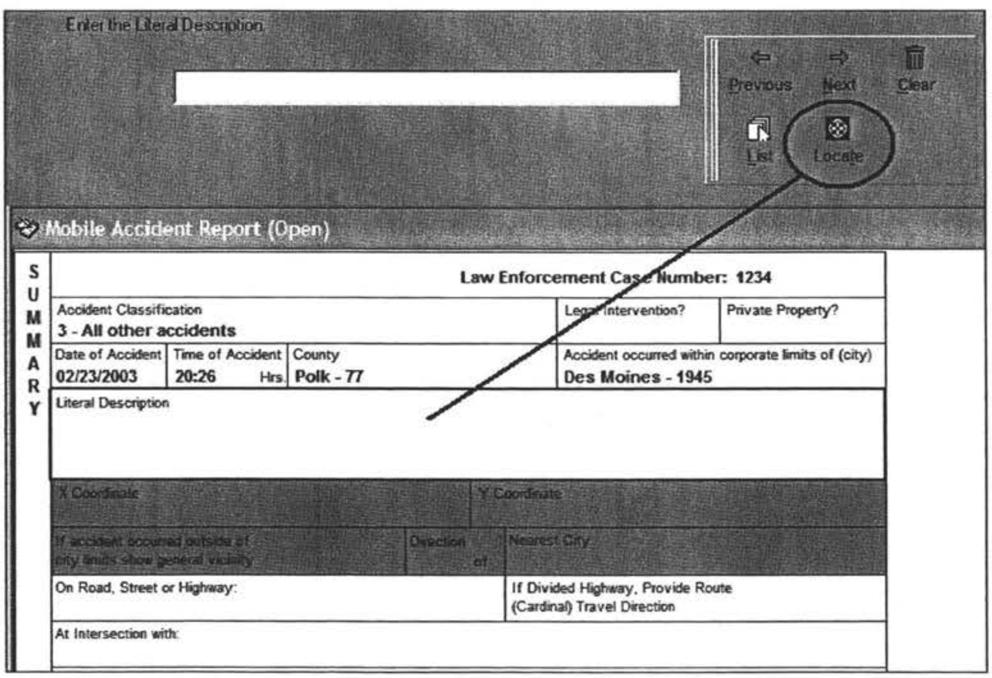


Figure 3-9. Communicating with Location Tool through MARS form.

Figure 3-10 displays the initial Location Tool interface. An officer finds the exact location of a crash by either zooming into the area (figure 3-11), or using location finder tools (figure 3-12), then locates the crash by clicking on the map where the crash occurred.

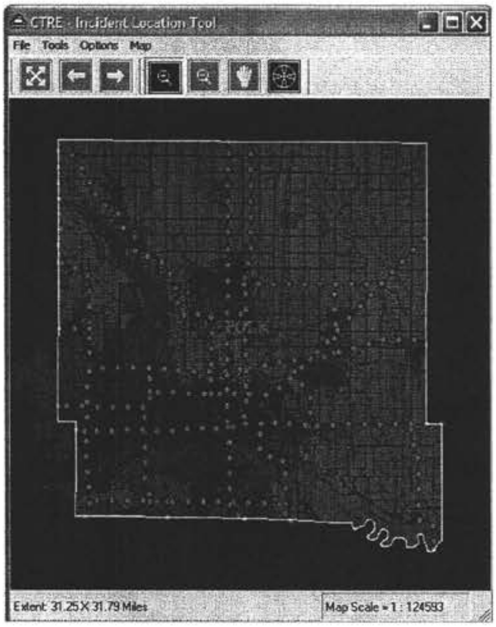


Figure 3-10. Location Tool Interface

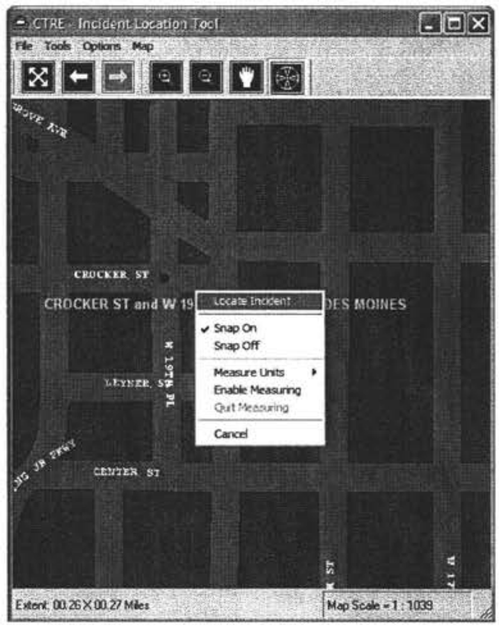


Figure 3-11. Locating a crash by zooming in the location.

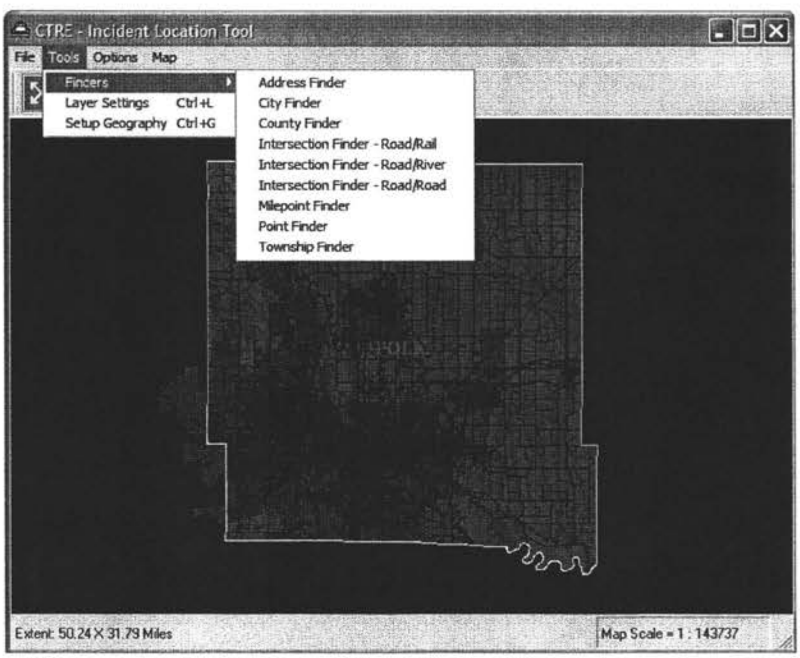


Figure 3-12. Location Tool - Location Finders.

Once the crash is located, the Location Tool software closes and the literal description and geographic coordinates populate the form (figure 3-13).

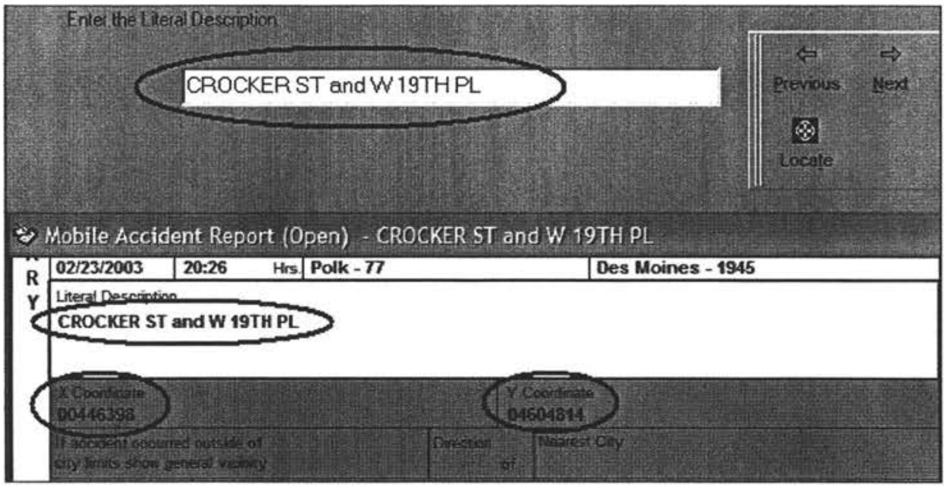


Figure 3-13. Populated Location information on the form.

3.3 Collision Diagramming

TraCS provides two options for users to create a collision diagram in the MARS form environment. First, a user can draw a collision diagram directly on the MARS form using the TraCS Diagram Tools and two other software packages, Microsoft Visio® 2000/2002 and Easy Street Draw. These programs can be launched from TraCS through an interface as illustrated in figure 3-14, and provide the user with a variety of templates and objects that are most likely to be at a crash scene. The user can drag and drop these templates and objects into the drawing environment (figures 3-15, 3-16, and 3-17), and then move, rotate or resize them as needed. The diagrams created in this way are finally directly populated onto a TraCS form when they are closed. For another option, the user can transfer a hand-drawn diagram into the form by utilizing a flatbed scanner or a barcode imager or to import a graphics file as a diagram through its image capture and import function (10).

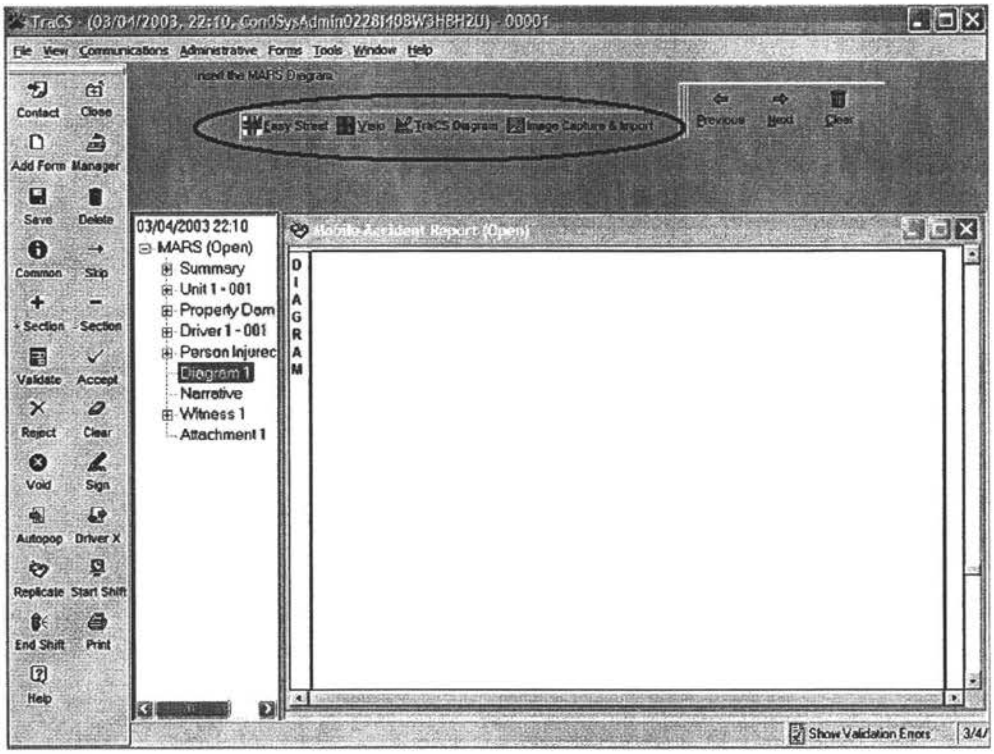


Figure 3-14. Collision Diagram interface in MARS.

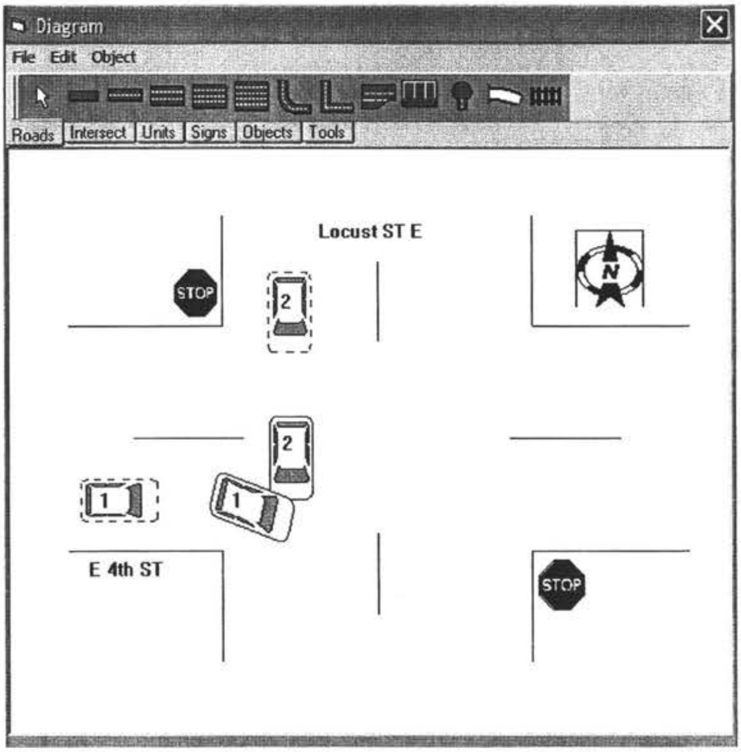


Figure 3-15. TraCS Diagramming Tool

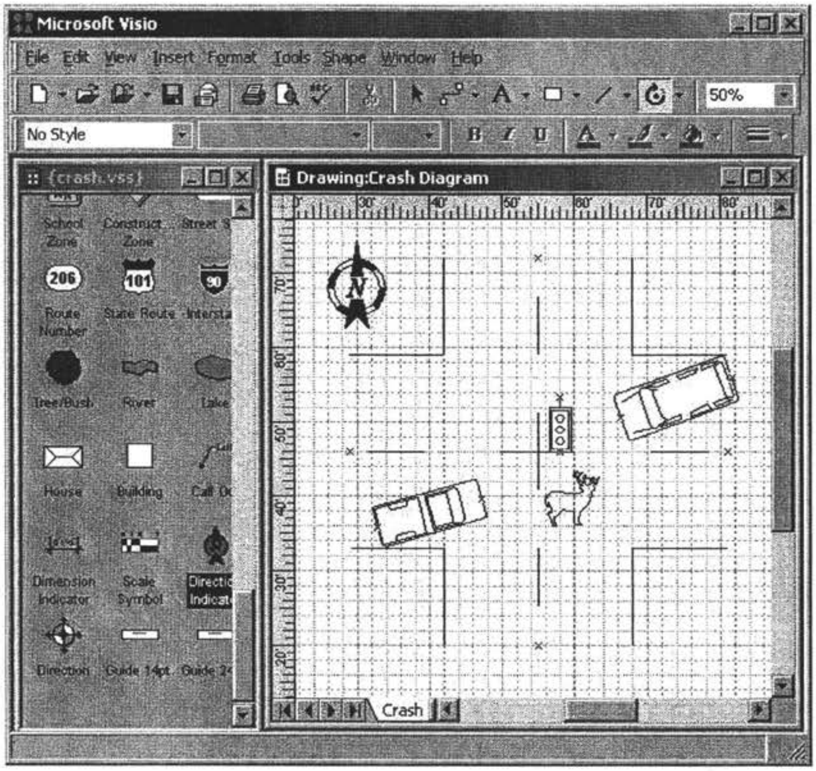


Figure 3-16. Diagramming using Microsoft Visio® (Source: TraCS Website)

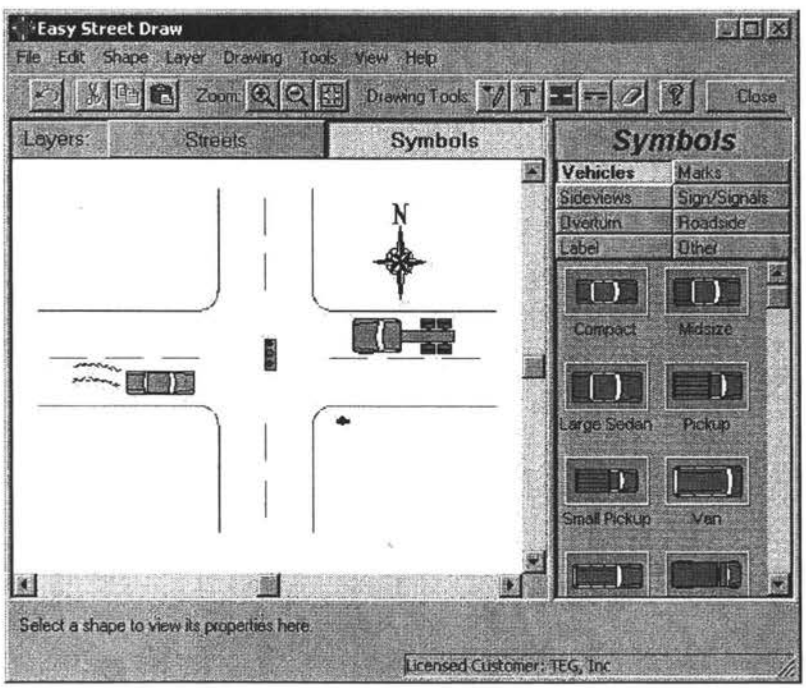


Figure 3-17. Easy Street Diagramming Tool. (Source: TraCS Website)

3.4 Narrative

Just like other manual data entry operations in TraCS, an officer uses the data bar to open the narrative editor. This procedure is also straightforward. Clicking on the 'Narrative' icon on the data bar opens a new window where the user types in the narrative. The text is then populated on the MARS form by pressing the 'Continue' button (figure 3-18). The narrative window is quite similar to Microsoft Notepad. It provides similar functions such as "Cut", "Copy", "Paste", and "Select All" functions as well as "Undo" and "Redo" actions. It also provides a Spell Check functionality, which allows a user to edit the text he or she typed before transferring it onto the MARS form.

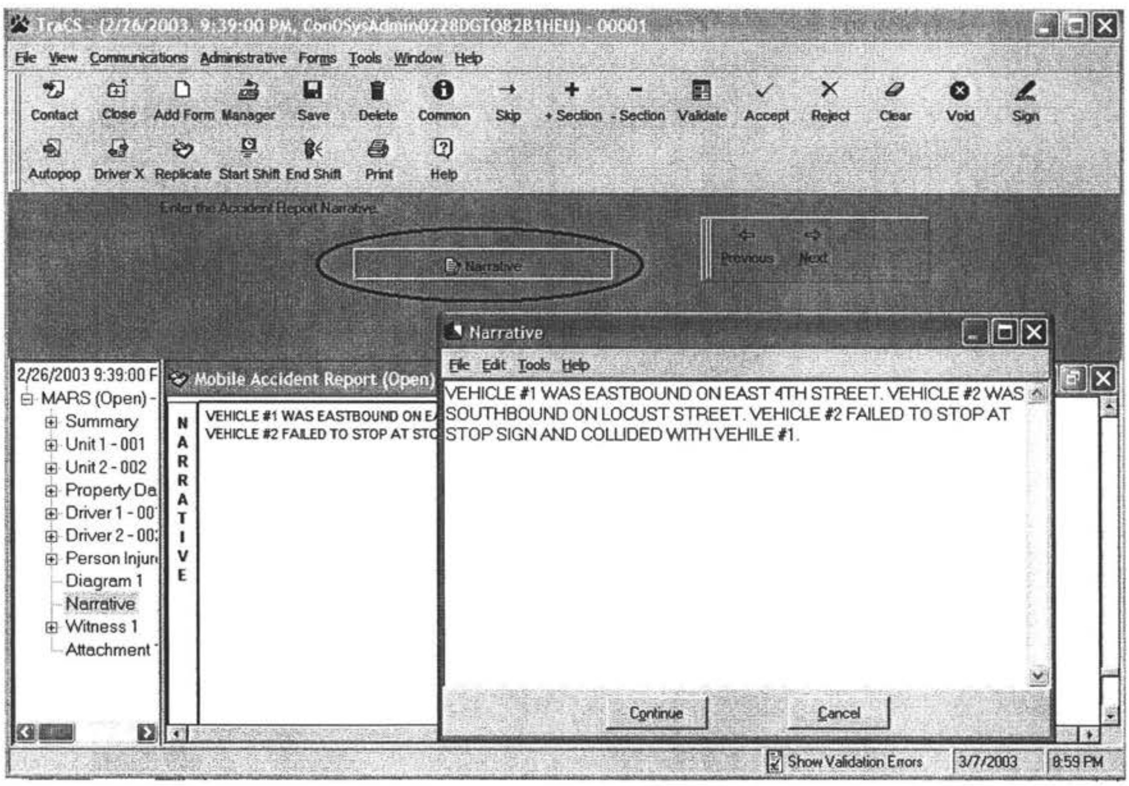


Figure 3-18. TraCS – Narrative entry interface

3.5 Validation

TraCS is equipped with a data validation functionality to ensure that the data entered into the electronic forms of TraCS are complete, consistent, and accurate. Once the MARS form is completed, the user runs the validation function by simply clicking the "validate" icon on the toolbar (figure 3-19).

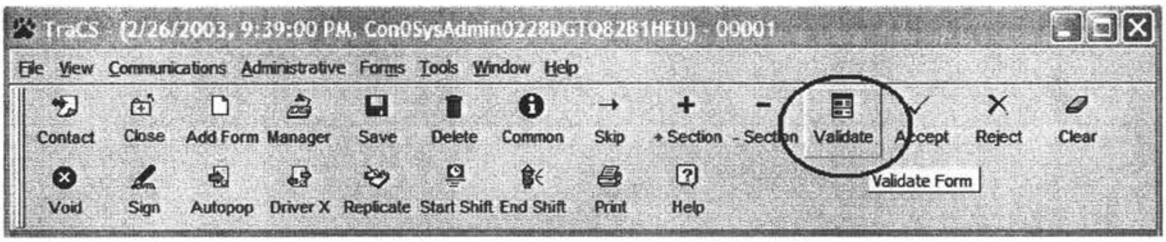


Figure 3-19. TraCS toolbar.

Initiating the batch validation process opens a new window listing validation errors. An example of the MARS Validation message window is presented in figure 3-20. In this example, in line 1, validations report that 'Surface Conditions' field was left blank as there must be an entry for that field. In line 2, there is a "Warning", indicating an inconsistent data entry. The information entered in the "First harmful event of crash" field was not listed in the 'Sequence of Events' section for any unit. In line 3, an inconsistent data entry between the 'date and time of the accident' and the 'light conditions' is reported.

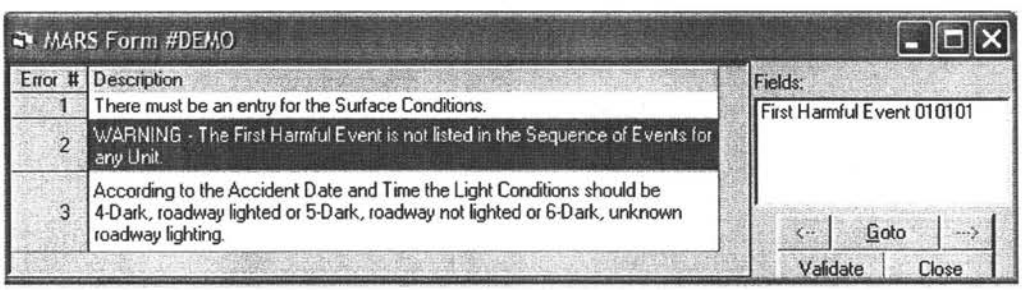


Figure 3-20. MARS validation error reporting window.

TraCS 6.5.2, the latest version as of June 2003, can validate a MARS report on 166 issues; of these, 72 messages are on 'erroneous' and 81 on 'required' data elements. 13 messages are 'warning' messages. (See Appendix A for the complete list).

CHAPTER 4 - METHODOLOGY

This chapter describes the methodology used to evaluate the efficiency of electronic collection of crash data for improved data quality and officer productivity, including measures of effectiveness and study approaches.

4.1 Measures of Effectiveness

In accordance with the objective of this research, the following characteristics are considered the best to measure the effectiveness of the system (TraCS):

- Data Accuracy - whether the system improves data accuracy problem
- Completeness - whether the system resolves or improves missing data problem
- Consistency - whether the system resolves or improves inconsistent data entry problem
- Legibility - whether the system resolves or improves legibility data problem
- Location Accuracy - whether the system resolves or improves location problems
- Speed - whether the system improves data collection time

4.2 Study Approach

Since this research intends to determine if the electronic data collection system of Iowa meets expectations, the studies selected for analysis are based on the potential benefits that can be expected from the electronic collection of crash data. Among several potential studies, three are considered to adequately measure the effectiveness of the system being currently used in Iowa. The studies performed are:

- Attribute quality assessment - whether electronic collection of crash data helps improve the quality of attributes (accuracy, completeness, consistency, legibility, etc.)
- Location Accuracy – whether the system improves accuracy of crash location
- Report Completion Time – whether the system helps save officer time at scene

4.2.1 Attribute Quality

This study seeks an answer to the question of to what degree could quality have been improved if all crash reports had been reported electronically. A reasonable way to get this answer is to enter paper reports into TraCS and detect attribute quality problems through TraCS's validation functionality, which ensures that forms are complete and the data entered are accurate. For this purpose, a simple random sampling of paper crash reports is made from 2001 records. In this study, only 2001 records are used because (i) Iowa implemented a new crash form in January 1, 2001 and current TraCS 6.5.2 MARS validations were restructured based on this new form, and (ii) 2002 data were not available during this study.

The recommended empirical value for minimum sample size for estimating the population parameters is close to 30 (28). Hence, initially 50 paper reports were selected using Avenue (internal coding language for ArcView GIS) script generating random numbers (this script was written by the Iowa DOT Office of Traffic and Safety), and were entered and validated. Errors were concentrated on a few data elements in the crash reports. This occurrence could be due to chance; hence, it was theorized that a larger sample size would be better for estimation. Therefore, another week was allotted for data entry and validation. The total number of reports entered at the end of the week was 151. The sample size thus utilized was also greater than 100, which is adequate for estimating population parameters (28). A comparison of the mean of missing data elements per crash report and their proportion to the sample population did not change significantly (less than 0.2 change in the mean) when the sample size was increased.

Moreover, the distribution of errors in the reports was similar to when only 50 samples were used. This was a characteristic of the dataset as only a few data elements within the report were most likely to be erroneous during data entry. In addition, out of the 151 reports entered, 109 were from 43 police departments, and 42 were from 30 county sheriff offices (table 4-1). The selected reports are from the first 9-month of 2001 and the agencies represent both small and large agencies throughout the state.

Table 4-1. Law Enforcement agencies from which sample reports were taken.

POLICE DEPARTMENTS			COUNTY SHERIFF'S OFFICE		
	Agency Name	*# of Cases*		*Agency Name*	*# of Cases*
1	Altoona	1	1	Benton	2
2	Ames	1	2	Boone	1
3	Anamosa	1	3	Bremer	1
4	Ankeny	2	4	Chickasaw	1
5	Armstrong	1	5	Crawford	1
6	Cedar Falls	2	6	Dallas	2
7	Clear Lake	1	7	Delaware	2
8	Clinton	6	8	Des Moines	1
9	Comanche	1	9	Fayette	2
10	Council Bluffs	7	10	Floyd	1
11	Creston	1	11	Franklin	1
12	Davenport	12	12	Ida	1
13	Decorah	2	13	Iowa	1
14	Denison	1	14	Jackson	1
15	Des Moines	26	15	Jones	2
16	Dubuque	1	16	Kossuth	2
17	Emmetsburg	1	17	Linn	1
18	Fairfield	2	18	Monona	1
19	Fort Dodge	5	19	Monroe	1
20	Fort Madison	1	20	Osceola	2
21	Grinnell	1	21	Palo Alto	1
22	Guthrie Center	1	22	Pocahontas	1
23	Hampton	1	23	Polk	4
24	Indianola	2	24	Pottawattamie	2
25	Iowa City	2	25	Tama	1
26	Manchester	1	26	Union	2
27	Manilla	1	27	Wapello	1
28	Maquoketa	1	28	Warren	1
29	Marshalltown	3	29	Winneshiek	1
30	Mason City	1	30	Worth	1
31	Mount Pleasant	1			
32	Muscatine	3			
33	New Hampton	1			
34	Osceola	1			
35	Oskaloosa	1			
36	Shenandoah	1			
37	Sioux City	4			
38	Spencer	1			
39	University Heights	1			
40	Waterloo	1			
41	Webster City	1			
42	West Des Moines	3			
43	Windsor Heights	1			

Due to an agreement made with the Iowa DOT, personal information on these reports was not copied into TraCS through the Mobile Accident Reporting System (MARS) component. Instead, false names, addresses, driver's license numbers, and license plates are used in order to avoid validation errors on these fields; for example, AAA and BBB was used to replace driver's name, 666AAA was used to replace unit's license plate, and 111222333 was used to replace driver's license number. In addition, some fields such as the citation information, narrative section, and diagram section were ignored since TraCS validations have no control over this information.

The attribute quality study aims to evaluate whether the electronic collection improved the quality of crash data in Iowa. For this purpose, three dimensions of "quality" were assessed: accuracy, completeness of reports, and legibility of reports.

4.2.1.1 Data accuracy

Accuracy of crash data is determined by the degree of correctness of the information. Incorrect data entry occur under two circumstances: (i) during collecting and reporting crash data at crash scene, and (ii) during re-keying paper reports at the local or DOT level.

At a crash scene, an officer may enter *erroneous* information for any of the data elements in the crash form or may enter information *inconsistent* with information in another data field. Inconsistent data entry assessment is based on the validations of 151 paper reports (sample used in the attribute quality study) in the TraCS environment while the assessment of erroneous data entry by investigating officers are based on the comparison of those reports to Iowa's database.

At any jurisdictional level, data errors may occur due to reentering paper reports into the databases. This assessment also required comparing the information on the original paper reports to those of the state's records.

4.2.1.2 Completeness

As in the data accuracy assessment, the completeness assessment is also based on the MARS validation messages. TraCS currently issues 81 validation messages for required data fields; each of these 151 paper reports was evaluated based on these validation messages.

4.2.1.3 Legibility

Legibility problems generally occur in two ways: (i) some data elements in the original paper reports are illegible due to various reasons such as poor handwriting, running ink due to weather conditions, etc. (ii) some parts of the report are unintelligible due to bad scanning of the original report at the DOT. The Iowa DOT currently does not keep original reports. Once paper crash reports arrived at the DOT, they are scanned and images are stored; after this process, original reports are disposed of. The legibility assessment of crash reports is made based on these two points over the randomly selected 151 paper crash reports.

4.2.2 Location Accuracy

This study also aims to evaluate the effectiveness of the Location Tool, which replaced an old link-node based location system. A brief explanation on the Location Tool was given in Chapter 3. This section gives brief information on the old location system and then explains the methodology used in the accuracy assessment of these two location systems.

Before January 1, 2000, Iowa used a link-node system to locate crashes. In this system, crashes were located at the DOT level, not at the scene or at a law enforcement office. Officers indicated only a literal description of the location on the crash report, including the names of highways or streets, distance to known locations or intersections, mile points, or other information. Iowa DOT locators performed the actual location process by referencing them to 'Reference' and 'Direction' nodes, and a distance to the reference node based on these literal descriptions. The Iowa "Accident Location Coding Manual" defines a reference node, as illustrated in figure 4-1, as "the node at which an accident occurred or the node from which the distance to the location of a link accident is measured, usually the nearest node", and a direction node as "the node adjacent to the reference node beyond the crash location" (29).

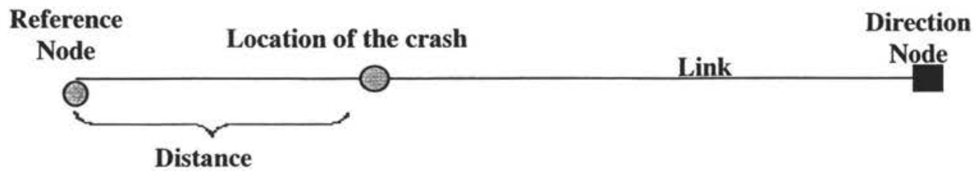


Figure 4-1. Link-Node based crash referencing

Deriving crash location in a GIS environment was accomplished by a "Straight-line Interpolation" process. In this process, an Avenue script locates crashes, and the script converts node references to projected coordinates and then places crashes on an imaginary straight line between these coordinates at a specified distance.

It is believed that the best way to determine to what degree the Location Tool has overcome the known location problems and improved the accuracy is to compare the results of these two location processes, location by link-node-based versus. GIS-based Location Tool. Logically, two problems may occur as a result of a location process: a crash cannot be located, or can be located but not at the correct location. Hereinafter, the terms "unlocated" and "mislocated" are used to refer to these problems, respectively.

First, an evaluation was made on "unlocated' crashes. A before and after study was considered the best way to compare the two location systems. For this purpose, 1991-1999 and 2000-2001 datasets were used to evaluate the link-node based location process and GIS-based location process, respectively. These datasets were analyzed using ArcView GIS software.

Second, an evaluation was made to determine the extent of "mislocated" crashes in both processes. It is possible that a crash could have been mislocated if an incorrect combination of reference and direction nodes was entered in the node-based process as shown in figure 4-2. A crash can only be mislocated using the Location Tool if an officer or locator picks a wrong point on the GIS map. Considering the magnitude of the numbers, 230,946 nodes and about 65,000 annual crashes, the detection of any mislocated crashes called for an automated process for each location system. For this purpose, reference-direction node pairs assigned for each crash (figure 4-3) were used to develop such a process.

There is only one way to evaluate the post-2000 crash locations, a comparison between all of the located crashes and the original location information on the crash reports, which is extremely time consuming and labor intensive. Hence, this evaluation was beyond the scope of this study.

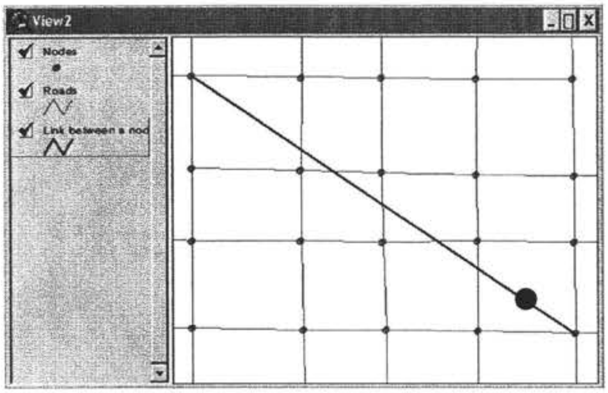
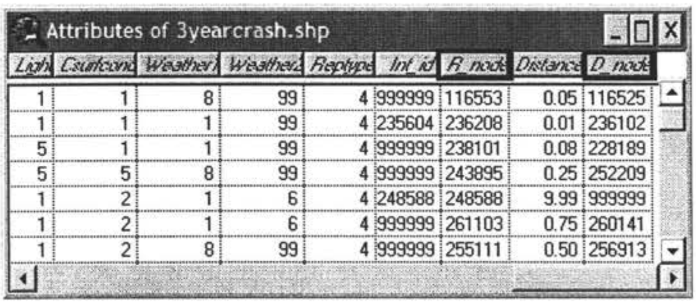


Figure 4-2. Illustration of an incorrect combination of reference and direction nodes.


Attributes of 3yearcrash.shp

Ligh	Csurfcond	Weather1	Weather2	Reptype	Int_id	R_node	Distance	D_node
1	1	8	99	4	999999	116553	0.05	116525
1	1	1	99	4	235604	236208	0.01	236102
5	1	1	99	4	999999	238101	0.08	228189
5	5	8	99	4	999999	243895	0.25	252209
1	2	1	6	4	248588	248588	9.99	999999
1	2	1	6	4	999999	261103	0.75	260141
1	2	8	99	4	999999	255111	0.50	256913

Figure 4-3. Crash database in part, showing node pairs assigned for each crash

Several approaches were considered for the automated process. Nevertheless, none of the approaches allowed detecting the exact number of mislocated crashes due to data specific limitations. The envisioned approaches are number of lines (roads) crossed, neighborhood, and distance.

The "number of lines (roads) crossed" approach tries to detect mislocated crashes based on the number of roads crossed by a link created between a pair of reference-direction nodes. Limitations for this approach are:

- 'state road' and 'node' shapefiles do not overlay. Much of the time, nodes are located away from the lines (roadway). This, as illustrated in figure 4-4, can cause a link created between the pairs of nodes to cross the line although it is correctly located.

- a crash link, as in figure 4-5, crossing the s-shaped road would have been assumed wrong, which is not the case.
- in some cases, as shown in figures 4-6 and 4-7, crash links do not cross any lines although they were mislocated.

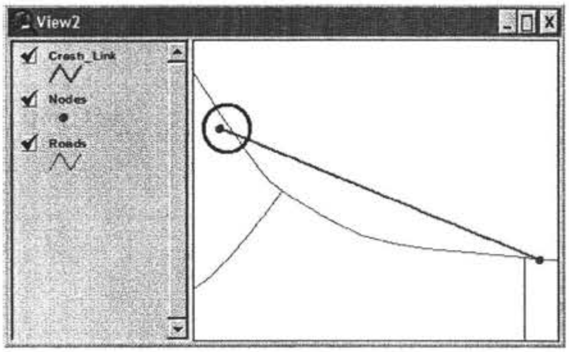


Figure 4-4. A crash link crosses a line.

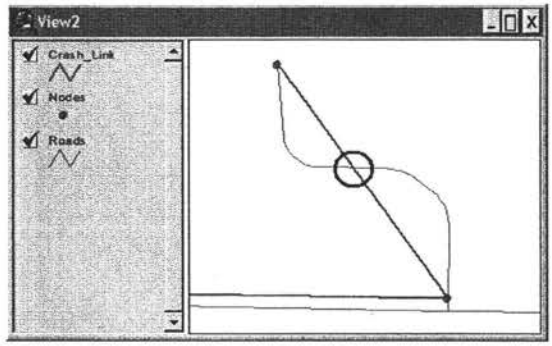


Figure 4-5. A crash link crosses a line.

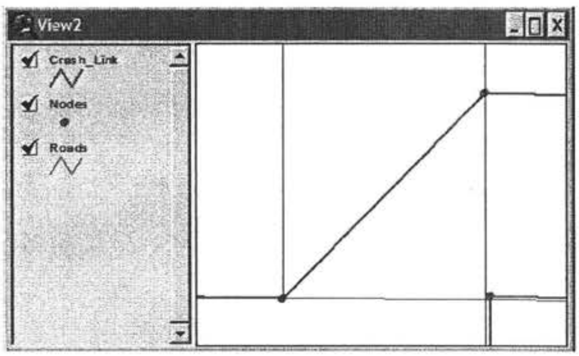


Figure 4-6. A crash link crossing no line

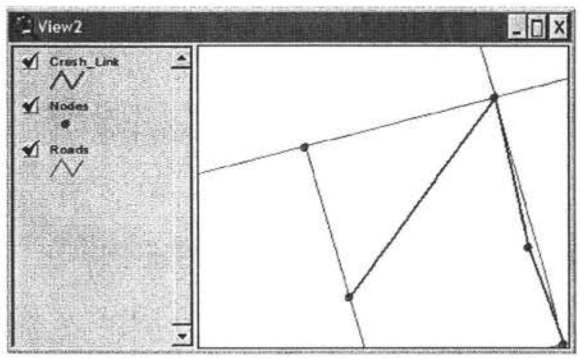


Figure 4-7. A crash link crossing no line.

The "neighborhood" approach is based on the relationship between nodes, which can be used to detect a wrong direction node. The process would take the reference node as the starting point and identify the neighboring node numbers as potential direction nodes. Then, a comparison is made between the direction node entered and the neighboring nodes. The result is twofold: (i) the direction node entered is among the neighboring nodes, hence, it is possible that the pair of reference-direction nodes entered is correct; or (ii) the direction node entered is not among the neighboring nodes, hence, the pair of reference-direction nodes entered is possibly incorrect.

This approach also has limitations. At some locations, no correlation can be established between the neighboring nodes. Figure 4-8 shows why the neighborhood approach cannot always detect mislocated crashes. In this real case, a small portion of highway 30 is selected. This line represents a link between the two nodes assigned to eight separate crashes (85217401 and 85216046). If a neighborhood approach had been used to detect actual reference-direction node pairs for each crash, node numbers 85217401 and 85216517 would have been selected and assigned for crashes 1 and 2. Likewise, 85216517-85216433 and 85216433-85216046 would have been selected and assigned for crashes 3-4 and 6-7-8, respectively. However, nodes 85216517 and 85216433 were skipped and node numbers 85217401 and 85216046 were selected as reference and direction nodes for all of these eight crashes. This is because the two nodes between the selected reference and direction nodes represented overpasses rather than regular intersections. Highway 30 passes under these bridges, which cannot be used as a reference or a direction node for any crash occurring on a route passing under them (29).

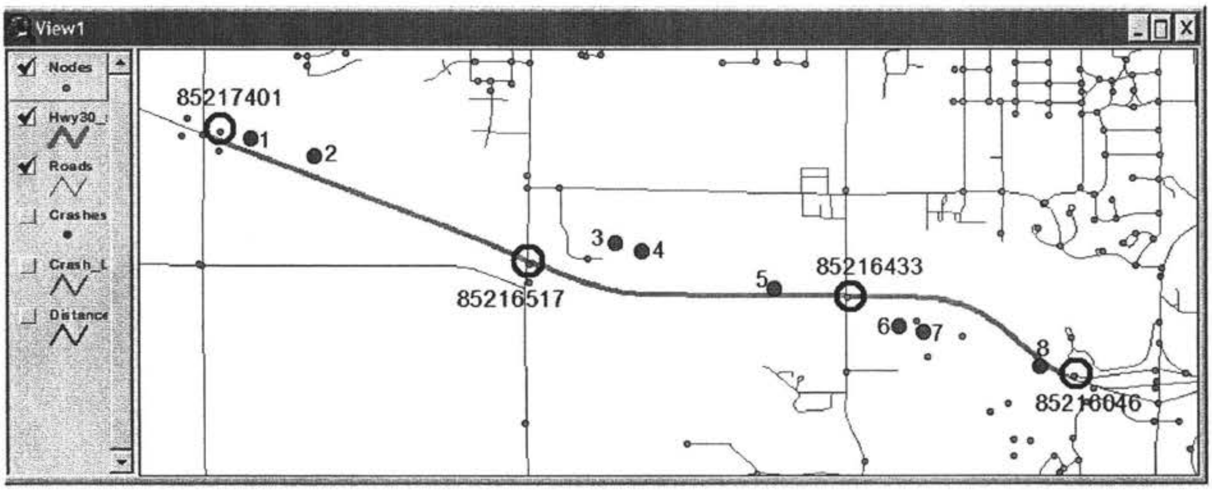


Figure 4-8. Neighborhood approach.

This study uses a "distance" approach to detect mislocated crashes. Considering that nodes in most urban areas are placed closely and the distances between them are usually less than a mile, the distance between the reference and direction node pairs assigned for crashes could indicate a potential mislocation. Taking this as starting point, an Avenue script was written by the Iowa DOT Office of Traffic and Safety that creates physical links between the node pairs, calculates their lengths, and creates a table including the lengths and road classes (interstate, US or state highways, county roads and city streets). Since the distance between nodes on primary roads vary, it is not possible to use a fixed distance; hence, mislocated crashes on primary roads were not identified.

The analysis of mislocated crashes is based on the spatial query of this newly created "shapefile" by length of the links. To assure the detection of the links representing mislocated crashes only, 1,5 and 2-mile link lengths for links on city streets and county roads, respectively, are considered safe to use in this spatial query. Any links having a length greater than 1.5 and 2 miles, depending on the road classes, are considered representing the mislocated crashes.

4.2.3 Report Completion Time

Another objective of this study is to measure the effectiveness of electronic collection of crash data based on report completion time. Before getting into the methodology, a brief discussion on the findings of previous studies might be helpful in understanding the rationale for choosing the strategy used in this study.

McKnight et al. (12), in Des Moines and West Des Moines in Iowa, collected data on the total time spent at the crash scene including the time spent collecting and reporting crash data. This study was based upon activity logs of agencies. The time police officers responded to the scene and the time officers left the scene was checked, and it was found that officers spent a mean time of 72 minutes for accidents reported using paper forms and 112 minutes for accidents reported using computer reports.

Hughes et al. (7), based on cooperating states' responses, reported a broad estimate of the time to complete a crash report form 1 hour for injury crashes and approximately 1.5 to 2 hours for fatal crashes.

Pfefer et al. (4), made an estimation of the amount of time spent on crash data collection "based on ride-along interviews with officers, and the experience of the project team, but not direct or indirect measurement". It was found that crash data collection took 22 to 52 minutes for single vehicle urban crashes (time increased depending on the severity, property damage only to fatal crashes), and 16 to 37 minutes for urban crashes. For multiple, crashes the time ranged from 26 to 62 minutes for rural and 19 to 44 minutes for urban crashes.

Noticeably, none of the report completion times in the above-mentioned studies was based on a direct measurement. Therefore, there is no certain evidence that times given in these studies reflect the actual time spent reporting crash data, especially on the electronic collection.

As suggested by the authors of the studies above, direct measurement of report completion time at a crash scene is an extremely difficult task to perform. This option was likewise not considered as a viable strategy for this thesis. Surveys and interviews were also not considered since they are usually based on officers' statements and estimations rather than measures. In some studies, officers were asked to note the time they spent collecting and reporting crash data and to return the results. Reportedly, this approach was also unsatisfactory due to a suspicion that officers did not remember or report the actual extent of time spent.

This research followed a different strategy than those of studies mentioned above. The objective was to measure the time spent solely on completing the crash report. The best environment for this was considered to be a lab environment, which is isolated from any distractions, interventions, and any other factors that might interrupt the reporting process such as adverse weather conditions, lighting conditions, or others. For this purpose, a hypothetical crash scenario was prepared to form the basis for this study. The same scenario is used for timing both paper and electronic (TraCS) reports. The idea behind this strategy was to compare the two reporting processes (paper-based versus electronic) based on the same crash data provided. This research seeks an answer to the question of how long it could take to complete a report if TraCS is used (if reported by paper form), under the same conditions.

As the majority of the crashes in Iowa occur between two vehicles (table 4-2), a two-vehicle crash scenario was chosen to best represent actual crash conditions and be used in this study.

Table 4-2. Motor vehicle crashes by number of vehicles involved

YEAR	# of Crashes	# of Vehicles Involved		
		1	2	2+
1991	71,272	20,245	46,904	4,123
1992	69,261	20,084	45,293	3,884
1993	73,608	20,603	48,494	4,511
1994	74,048	20,677	49,124	4,247
1995	76,240	22,384	49,541	4,315
1996	78,357	23,470	50,492	4,395
1997	71,513	21,501	45,876	4,135
1998	64,041	19,235	40,874	3,932
1999	64,484	19,342	41,191	3,951
2000	64,366	19,841	40,601	3,917

The study was performed in various police departments and county sheriff offices in Iowa, form which a total of 47 officers participated. Measurements were generally performed in offices. The majority of the agencies visited provided a desktop computer and a barcode reader. Before the timing process, a brief explanation on the scenario and the process was given to the officers. Based on the scenario, all data necessary to complete the reports were provided; hence, the measurements taken in this study solely represent the actual time spent completing the crash report and the citation form. Data collected in this study are listed in table 4-3. To make the conditions equal for the two reporting processes, TraCS users were asked not to use the Location Tool to locate crashes since the Location Tool is not used in paper-based reporting. Instead, they were asked to enter literal description of the crash location as in paper-based reporting processes.

Table 4-3. Data that were collected during "Report Completion Time" study

Data	**Description**
Agency	Agency name
Agency Type	0- Police Department, 1- County Sheriff's Office
Frequency	Frequency of reporting a crash by the officer timed.
Reporting type	0- Paper-based, 1- TraCS
Time to code the crash form	(Minutes)
Time to draw the collision diagram	(Minutes)
Total (coding + diagram)	(Minutes)
Time to complete the citation form	(Minutes)
Total time (crash form + citation)	(Minutes)

CHAPTER 5 - RESULTS

This chapter presents the findings from the studies performed to evaluate the effectiveness of electronic collection and reporting of crash data in Iowa. Analyses were made based on the comparisons between old paper-based and new electronic (TraCS) systems on three aspects: (i) attribute quality, (ii) location accuracy, and (iii) report completion time.

5.1 Results of Attribute Quality Study

Quality assessment of paper reports was made on completeness, data accuracy and legibility attributes. Completeness and data accuracy assessments were made based on the validations of 151 sample paper reports in TraCS. Results of the attribute quality study are as follows:

5.1.1 Completeness

TraCS - MARS validations found that 265 missing data elements in 107 (70.86 percent) of 151 crash reports. The most common missing data elements were from the "Sequence of Events" section of the crash report. In this section, as shown in figure 5-1, officers indicate the harmful events of a crash by selecting appropriate codes from a code list provided. Validations found that in 51 reports "most harmful event (by vehicle)", in 34 reports "first harmful event of crash", and in 26 reports, "first event", fields was not coded (missing), as 33.77, 22.52 and 17.22 percent, respectively.

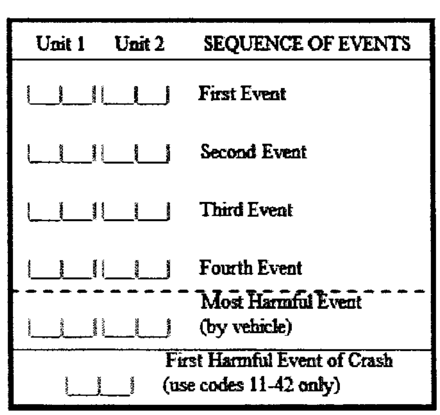
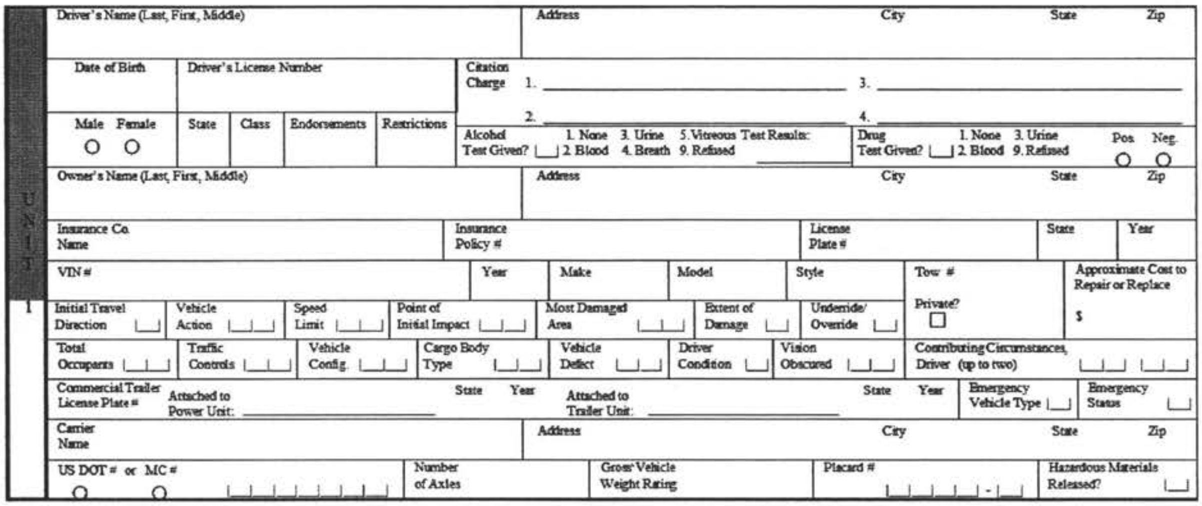

Unit 1 Unit 2 SEQUENCE OF EVENTS
First Event
Second Event
Third Event
Fourth Event
Most Harmful Event (by vehicle)
First Harmful Event of Crash (use codes 11-42 only)

Figure 5-1. Sequence of Events section of a paper crash form.

A second group of missing data elements was associated with the UNIT section of a crash report. In this section, officers enter information about unit(s) involving in the crash (figure 5-2). TraCS validations found the following data elements were missing: “Cargo body type” in 12 reports, “underride/override” in 12 reports, “vehicle year” in 12 reports, “approximate cost to repair or replace” in 11 reports, and “vehicle style” in 11 reports.



UNIT 1

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

Date of Birth | Driver's License Number | Citation Charge 1. 2. 3. 4.

Male Female | State | Class | Endorsements | Restrictions

Alcohol Test Given? 1. None 3. Urine 5. Vitreous Test Results: 2. Blood 4. Breath 9. Refused

Drug Test Given? 1. None 3. Urine 2. Blood 9. Refused | Pos. Neg.

Owner's Name (Last, First, Middle) | Address | City | State | Zip

Insurance Co. Name | Insurance Policy # | License Plate # | State | Year

VIN # | Year | Make | Model | Style | Tow # Private? | Approximate Cost to Repair or Replace $

Initial Travel Direction | Vehicle Action | Speed Limit | Point of Initial Impact | Most Damaged Area | Extent of Damage | Underride/ Override

Total Occupants | Traffic Controls | Vehicle Config. | Cargo Body Type | Vehicle Defect | Driver Condition | Vision Obscured | Contributing Circumstances, Driver (up to two)

Commercial Trailer License Plate # | Attached to Power Unit: | State | Year | Attached to Trailer Unit: | State | Year | Emergency Vehicle Type | Emergency Status

Carrier Name | Address | City | State | Zip

US DOT # or MC # | Number of Axles | Gross Vehicle Weight Rating | Placard # | Hazardous Materials Released?

Figure 5-2. Paper crash form - Unit section

Another common missing data element was the “contributing circumstances, driver”. This information was missing in 11 reports, representing 7.28 percent of 151 sample reports. As displayed in figure 5-3, 11 (7.8%) of 151 paper reports were missing the “contributing circumstances, driver” information. Considering that there are about 65,000 annual crashes in Iowa, 5,070 reports would not contain this information. Similarly, “driver condition” information would be missing in another 1,293 crash reports, “speed limit” information in 2,580 reports, “most harmful event (by vehicle)” in 21,950 reports, and so on. Some of these data can be derived from the narrative section of a crash report, but this would result in more DOT staff time.

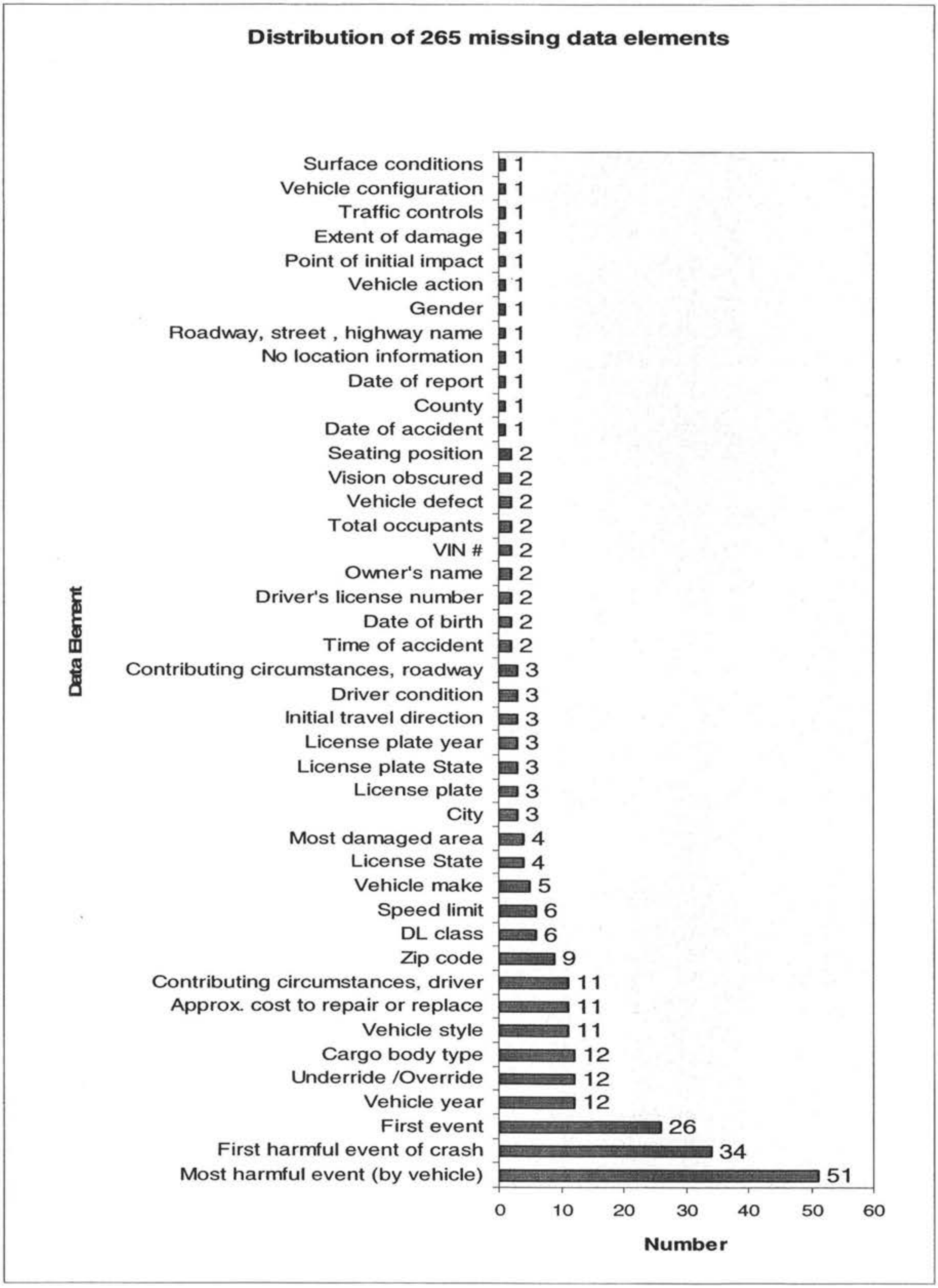


Figure 5-3. Missing data elements found through TraCS validations for 151 paper reports.

5.1.2 Data accuracy

This study analyzes errors stemming from (i) reporting erroneous data at crash scene, and (ii) re-keying paper reports at the DOT level.

The first type of errors occur when an officer enters *erroneous* information for any of the data elements in the crash form, or enters information that is *inconsistent* with information in another data field. In this study, "consistency" means agreement between the data elements entered by the investigating officer. MARS validation found 64 inconsistent entries in 49 paper reports (in 32.45 percent of 151 sample reports entered into TraCS). As displayed in table 5.1, in 13 reports (8.6%), "manner of crash/collision" and "number of unit" entries were found inconsistent based on the validation message *"The Manner of Crash/Collision is 2 through 7 so there must be more than one Unit involved in the accident."* (Refer to figure 5.4 for the codes). These 13 crashes were single vehicle crashes; no other vehicles were involved, but officers coded the manner of crash/collision field as "2- Head-on" in 9 reports, "5- Broadside" in 2 reports, "3- Rear-end" in 1 report, and "6- Sideswipe, same direction" in 1 report. This field should have been coded "1- Non-collision" as suggested by Iowa's accident reporting guide (30).

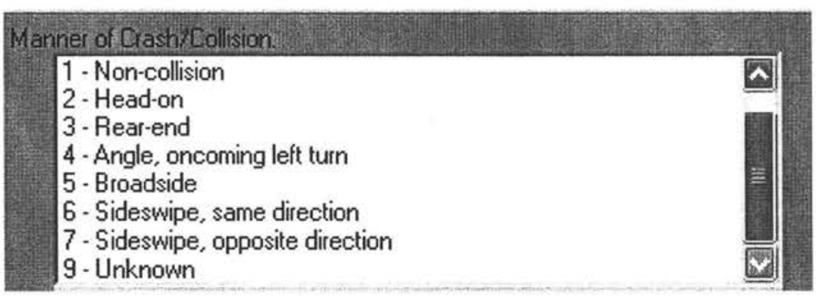


Figure 5-4. Options for coding 'Manner of Crash/Collision' (From TraCS MARS form)

Another common inconsistent entry occurred between the 'Approximate Cost to Repair or Replace' and the 'Extent of Damage' fields. In 10 reports (6.62% of reports), the 'Approximate Cost to Repair or Replace' field was left blank whereas the 'Extent of Damage' field was coded as '2- Minor damage', '3- Functional damage', '4- Disabling damage', and '5- Severe, vehicle totaled'". In fact, as suggested by the validation message, "Extent of Damage" field should have been coded as "1- None" or "9- Unknown".

Another type of validation message indicating inconsistency came with a title "Warnings". These warnings simply alert the users that the item(s) for which the warning was issued must be checked for errors. TraCS validations issue warnings on 13 cases. In this study, as can be found in table 5.1, only three types of these warnings were observed, (i) "First harmful event is not listed in the sequence of event for any unit", (ii) "Most harmful event is not listed in the sequence of events", and (iii) "Driver assigned to the persons injured section". In 14 reports, the first harmful event of crash field was coded something other than the ones listed as valid in the sequence of events' section for any unit reported; in 10 reports, most harmful event of crash field was coded differently than the ones coded in the sequence of events section; and in 5 reports, information about the injured driver was entered under the "persons injured" section, which should have been entered in the driver section. This means that officers coding this field other than "1- Non-collision" were not aware of this instruction or did not know it. Here, TraCS validation warns the officer of potential error by coding this field other that "1- Non-collision". This also suggests that electronic validation may be educative as well as corrective.

Table 5-1. Inconsistencies detected by MARS Validation (for 151 reports).

Inconsistencies	**# of reports**	**Percent**
Manner of crash/collision - Number of units	13	8.60
Approximate cost to repair or replace – Extent of damage	10	6.62
Vehicle action - Driver contributing circumstances	3	1.98
Driver conditions - Alcohol Test result/Drug test result	3	1.98
Accident date and time - Light conditions	2	1.32
Vehicle action - Traffic controls	1	0.66
Weather condition 1 - Weather condition 2	1	0.66
The Sequence of events - Property damage section	1	0.66
First harmful event of crash - Seating position	1	0.66
Warnings		
First Harmful Event is not listed in the Sequence of event for any Unit	14	9.27
Most Harmful Event is not listed in the Sequence of events	10	6.62
Driver assigned to the Persons Injured section	5	3.31

A second analysis was performed on the errors resulting from re-entering crash data from paper reports at the DOT level. During this research, 2001 crash records were not completely available to users. Hence, the comparison was performed on the available part of the State database. Of the 151 sample crash reports, 145 were used in this analysis.

The data fields compared in this analysis were related to the characteristics of the crashes and the units (including drivers and vehicles involved). Crash-related data fields included: date of accident, time of accident, county name, city name, location of first harmful event, light conditions, weather conditions, major contributing circumstances (environment and roadway), type of roadway junction or feature, and first harmful event. Unit-related data fields included: driver's date of birth, driver's gender, vehicle license plate state, vehicle license plate year, driver's license state, vehicle year, vehicle make, initial direction of travel, vehicle action, number of occupants, vehicle configuration, cargo body type, vehicle defect, driver's condition, vision obscured, and driver contributing circumstances 1 and 2.

The analysis showed that the data from the state's records and the original crash reports do not match under three conditions:

- *Condition 1*: Information in a data field from the original crash report is not included in the state records.
- *Condition 2*: Information in state records and original crash reports do not match for the same data fields.
- *Condition 3*: Information in a data field from the state records is not found in the original crash report.

Cases meeting *condition 3* were not taken into consideration in this study since all information about vehicles and drivers are obtained from vehicle registration and driver databases. Data entry computers at the DOT are connected to these databases. When a clerk is entering information and comes to the to the vehicle section, the only information they initially enter is the plate number. This automatically accesses the vehicle registration database, and information about the owner and other information about the vehicle from the database populates the manual data entry screen. The same occurs for the driver; the data entry clerk enters the driver's license number and all the information about that driver is brought over from the driver records database.

A comparison on crash related data fields found 13 cases meeting *Condition 1* and 39 cases meeting *Condition 2*. In other words, in 8.97% of the cases, the state records do not contain all the information from the original crash reports, and in 26.9% of the cases, information in the state records and the original crash reports do not match based on officer's accident reports. A major source of this type of error was found to be the time of the accident. As displayed in table 5.2, in 27 cases (18.6%), time of accidents reported on the crash forms were different from those of the state records, ranging from 1 minute to 12 hours. In 14 cases, the differences in time were minor, ranging from 1 to 10 minutes. In 2 cases, the differences ranged from 11 to 30 minutes and 3 of the cases ranged from 30 to 60 minutes. In 8 cases (5.51% of the cases), the differences were over an hour: 1:12 hours in 1 case, 2:25 hours in 1 case, 4:14 hours in 1 case, 8 hours in 1 case, and 12 hours in 4 cases. Minor differences in the time reported may be acceptable to some extent; however, higher differences in time may have a significant effect on "peak time" or "drinking and driving" crash analyses as well as the assessments of daylight conditions. A rough extrapolation suggests that in about 3,682 cases, differences between the actual and the state-reported time of the crash would be over an hour in Iowa (based on 65,000 annual crashes). General extrapolations on all cases meeting *Conditions 1* and *2* suggest that in 5,714 cases, the state records would not reflect some information that are in original crash reports, and in 17,485 cases, information in state records and original crash reports would not match.

Table 5-2. Number and percentage of errors on crash related information (for 145 crashes)

Data fields	**Condition 1**		**Condition 2**	
	#	**%**	**#**	**%**
City name	3	*2.07*	-	-
Major Contr. Circumstances: Environment	1	*0.69*	1	*0.69*
Major Contr. Circumstances: Roadway	1	*0.69*	1	*0.69*
County	-	-	1	*0.69*
Date (of the accident)	-	-	4	*2.85*
First Harmful Event of Crash	1	*0.69*	-	-
Manner of Crash/Collision	11	*0.69*	-	-
Surface Condition	1	*4.13*	-	-
Time (of the accident)	6	-	27	*18.6*
Type of Roadway Junction/Feature	-	-	4	*2.85*
Weather Conditions (1)	-	-	1	*0.69*
Weather Conditions (2)	-	*2.07*	-	-

Another comparison on the unit-related data fields found 99 records meeting *Condition 1*, and 265 records meeting *Condition 2*. In other words, in 36.8% of 269 records (number of units/drivers involved in 145 crashes), the state records did not contain information from the original crash reports, and in 98.5% of the records, information in the state records and the original crash reports do not match. Currently, the DOT allows the database to be populated with information from the vehicle registration and the driver records databases and does not change information to the information entered by the officer. In this case, this is a policy decision that the information on the accident database for the first 7 items in table 5.3 will be different from what the officers entered. Hence, these are not necessarily errors by data entry staff. What this analysis found for these items is the proof of the error type occurring due to incorrect data entry by officers. If there is any conflict between the state records and the information reported by officers, the state records should have the precedence over the officers'. The rationale is that the information provided by an officer on these items is from the documents issued by the state; hence, errors on these items must result from an officer's entry. However, in one of these 7 items, error results from the DOT's faulty programming. As can be seen in table 5.3, the most common unit (vehicle/driver) related data errors occur on the "vehicle license plate year" field. The year information for 11 (4.09%) units are not contained in the state records, and for 185 (68.7%) units, the records do not match. For all 185 records, the vehicle license plate year is recorded as "1997" in the state database regardless of what is reported in the original crash forms. As indicated by the DOT, this is a result of faulty programming of the system. The last general release of plates was 1997. When the clerk enters the plate number, the system is programmed to bring back the plate year when it should be bringing in the registration year. However, this error is tolerable since it is not an item typically used for data analysis - it only tells if they are current on the registrations.

Another common error associated with units/drivers is related to the "driver contributing circumstances" field. This information is not stated for 5 (1.85%) records in the state database although they are reported by investigating officers, and for 23 (8.55%) the records do not match.

The analysis also showed that at least for 10 different units (3.71% of 269 units), information indicating the causes of a crash, such as initial travel direction, vehicle action, vehicle defect, driver's condition, and vision obscured, are not stated in the state records, although they were reported. A rough extrapolation of the figures suggests that for about 4,638 units (based on 125,000 units involving crashes annually), the state records would not contain information on these fields despite the fact that they are reported.

Table 5-3. Number and percentage of errors on unit related information (for 269 units).

Data fields	Condition 1		Condition 2	
	#	%	#	%
Driver's Date of Birth	4	*1.48*	4	*1.48*
Driver's Gender	3	*1.11*	3	*1.11*
Vehicle License Plate State	1	*0.37*	1	*0.37*
Vehicle License Plate Year	11	*4.09*	185	*68.7*
Driver's License State	3	*1.11*	6	*2.23*
Vehicle Year	-	-	17	*6.32*
Vehicle Make	2	*0.74*	7	*2.6*
Initial Travel Direction	13	*4.83*	2	*0.74*
Vehicle Action	12	*4.46*	-	-
Occupants	-	-	8	*2.97*
Vehicle Configuration	-	-	6	*2.23*
Cargo Body Type	12	*4.46*	-	-
Vehicle Defect	12	*4.46*	-	-
Driver's Condition	10	*3.71*	-	-
Vision Obscured	11	*4.09*	3	*1.11*
Driver Contributing Circumstances 1-2	5	*1.85*	23	*8.55*

5.1.3 Legibility

Legibility analysis was performed on the same randomly selected 151 paper reports. It was found that illegibility occurs mostly on data elements that are in alpha-numerical characters such as Vehicle Identification Number (VIN), driver's license number and license plate number. In this study, 19 VINs, 5 license numbers and 8 license plate numbers (19.2%, 3.3%, and 5.3%, respectively) were found to be partly illegible. Another common legibility problem was with drivers' or owners' name; there were 12 reports where either the first or last name was illegible, which represents 7.9% of cases. Refer to table 5-4 for other illegible data elements found in this study.

Among the causes of illegibility of information on the reports, poor handwriting and similarities between some figures and letters play an important role. It was observed that confusion occurs between the on the following figures and letters: S – 5, G – 6, U – V, Z – 2, and B – 8.

In addition to poor handwriting and similarities between some letters and figures, scanning also affected the legibility. As paper crash reports arrive at the DOT, they are scanned and then originals are disposed of. Some scanned reports were so blurred that it was not possible to read a whole word or a number. Occasionally, scanning added characters and marks. This could have happened if multiple pages were placed on top of the first page in the scanning device, and the first page was slightly transparent.

Table 5-4. Illegible data elements found from 151 crash reports.

DATA ELEMENTS	Frequency	Percentage
VIN	29	19.2
Road, Street	3	2.0
Driver's/Owner's Name	12	7.9
Insurance Co. Name/#	3	2.0
Model	3	2.0
Style	1	0.7
City	2	1.3
State	1	0.7
License Plate	8	5.3
Address	5	3.3
Driver's License #	5	3.3
Narrative	6	4.0

5.2 Results of location accuracy study

This section presents the results of two separate analyses performed on unlocated and mislocated crashes for each location system (paper and electronic).

5.2.1 Unlocated crashes

As was indicated in Chapter 4, a "before & after" study was performed to compare the two location processes based on the number of unlocated crashes. An examination of crashes that were not located from 1991 to 1999 showed that crashes held "unlocated" status when (i) there was an error with the node numbers assigned, (ii) the location was known but no node number was available for that point, (iii) the location information was undecipherable, or (iv) no location information was provided at all. Each of these error types is addressed below.

An analysis of unlocated crashes in the old system showed that these crashes could not be located due to following reasons:

- Error in the reference node entered for a crash.
- Error in direction node entered for a crash.
- Errors in both nodes entered.

Over the 9-year period, 59,379 crashes were not located due to errors in reference, direction or both nodes in 34,334, 12,033 and 13,012 cases, respectively. Errors in node numbers may occur in two ways: (i) a node number assigned existed once, but not included in the database anymore, or (ii) the DOT locators inadvertently entered invalid node numbers. The distribution of unlocated crashes by year and error type is presented in table 5-5.

Table 5-5. Unlocated crashes by invalid node information (Iowa, 1991-1999)

YEAR	Invalid Reference Node	Invalid Direction Node	Both	Total
1991	2661	1637	1131	5429
1992	2439	1533	1267	5239
1993	3437	1543	1643	6623
1994	4072	1774	2085	7931
1995	4928	1652	1944	8524
1996	5901	1436	1724	9061
1997	4233	1088	1263	6584
1998	3210	687	953	4850
1999	3453	683	1002	5138
Grand Total	**34334**	**12033**	**13012**	**59379**

Another problem related to the "unlocated" status of crashes was the lack of node numbers for some locations. That is, although location information was included in a report, locating this crash was not possible if the location was not shown on the node map or there was no node number available for the location. In such a case, the locators coded the Congressional Township number followed by "9898". The "9898" code was used to flag the case so that it could be coded properly later when the node maps were updated. An analysis of the same 9-year crash data showed that 6,008 out of 59,379 unlocated crashes, 670 cases on average per year, were not located due to the lack of node numbers for the known crash locations.

An analysis for detecting undecipherable location data was not possible as it requires printing out 59,379 crash reports from the DOT crash database and checking the location information provided in these reports. Hence, the number of unlocated crashes due to indecipherable location information was ignored in this study.

Any reference node number ending with "0000", "0" and "9999" indicated that no location information was provided (29). Taking as starting point this knowledge, a query on the 9-year unlocated crash data found 19,550 cases having no location information, about 33 percent of all unlocated crashes.

In January 1, 2000 Iowa DOT started using Location Tool. An analysis of post-2000 crash data showed a significant decrease in the number of unlocated crashes. Among other efforts within the Iowa DOT, such as advanced edit checks and care given especially to fatal and severe injury crashes to ensure that they are located, the Location Tool was crucial for improved location accuracy.

In 2000, there were only 1,957 unlocated crashes representing about 3% of all crashes occurring. According to information given by the DOT Motor Vehicle Division, these crashes were not located because of insufficient location information. Due to limited use of the TraCS and the Location Tool at the law enforcement level in 2000, unlocated crash status continued to be a problem (figure 5-5).

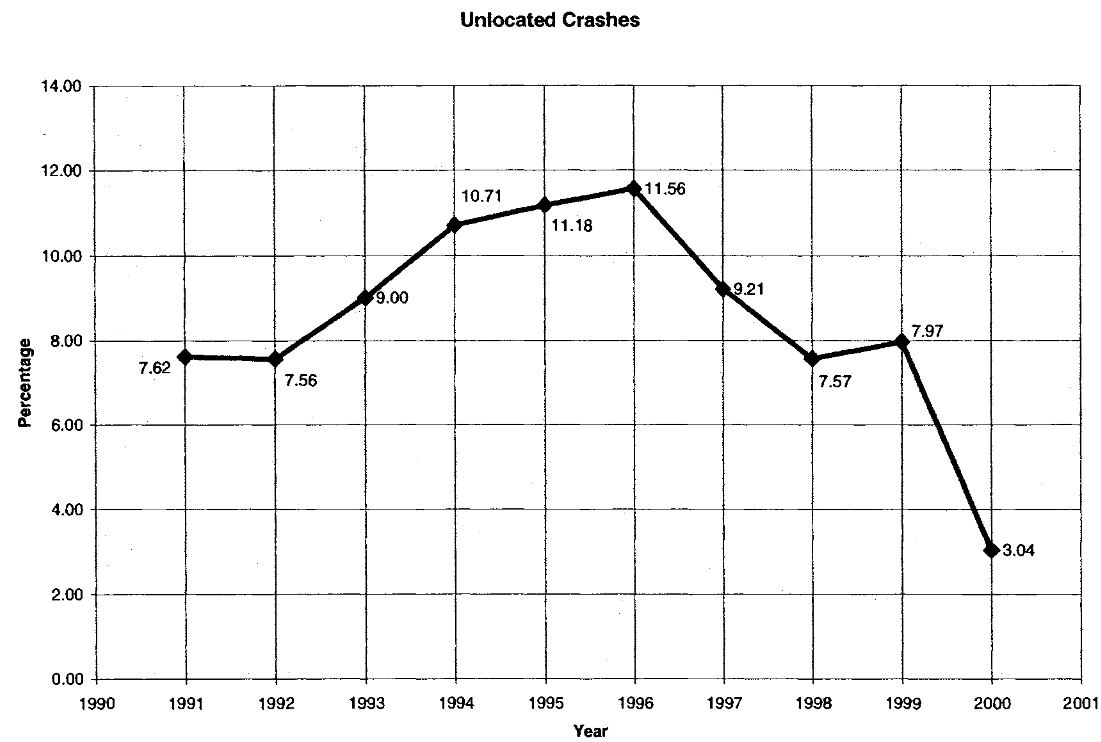


Figure 5-5. The trend of unlocated crashes in Iowa.

5.2.2 Mislocated crashes

This section addresses issues associated with the former node location system (straight-line interpolation process) and presents the results of mislocated crash analysis. As was discussed in section 4.4.2, there is no unique approach to detect all mislocated crashes in Iowa; hence, the analysis was conducted for demonstration purposes only. Therefore, only 3-year-crash data (1997-1999) were used in this analysis.

A major problem identified related to the straight-line interpolation process is that most crashes are located away from the roadway lines. This kind of error typically occurs on the curved roads. Figures 5-6 and 5-7 show crashes occurring at the same geographic area in 1999 and 2000. In these examples, Madison Road, Iowa 9, and US-52 were selected to illustrate the difference between two crash location processes. Figure 5-6 shows crashes located through straight-line process in 1999, whereas figure 5-7 shows crashes that were located using Location Tool in 2000.

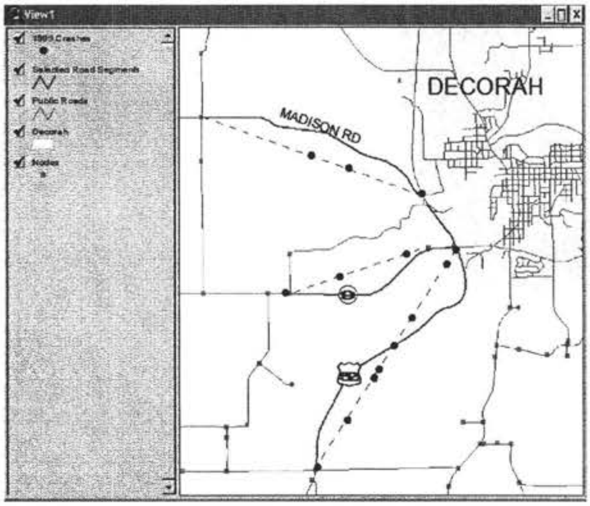


Figure 5-6. Crashes Located through straight-line interpolation process.

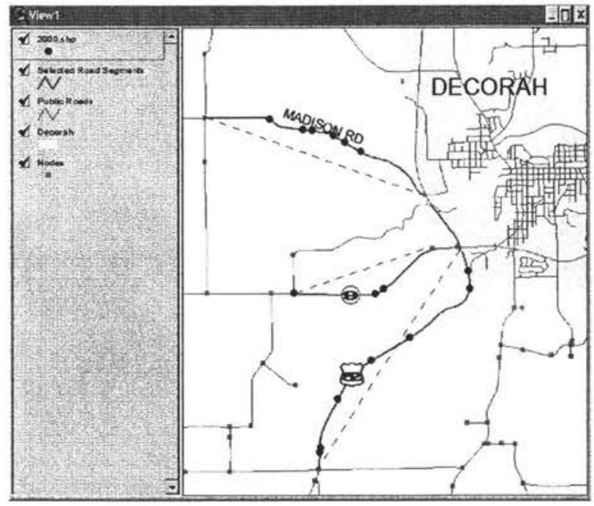


Figure 5-7. Crashes Located by using Location Tool.

In figure 5-6, most of the crashes on the selected routes were located away from the roadway lines. This is because the straight-line interpolation process locates the crashes on an imaginary straight line between the reference and direction nodes assigned for each of them. Figure 5-7 demonstrates how crashes were located at the same routes using the Location Tool. As can be seen, in 2000, all of the crashes were located exactly on the roadway. The dotted lines in both figures in fact do not exist; they were added to the map in order to illustrate the imaginary straight lines.

Another type of mislocation occurs due to the assignment of improper combination of reference and direction nodes. To identify these crashes, an Avenue script was written by the Iowa DOT Office of Traffic and Safety. The code created physical links between the node pairs assigned for each crash and calculated the lengths of these links, that is, the distance between the reference and direction node.

Two separate queries were performed, one for crashes occurring on city streets and another on county roads. For the detection of mislocated crashes on city streets, a 1.5-mile link length was considered to represent most of mislocated crashes on the grounds that nodes were closely placed in urban areas. On county roads, nodes were generally placed farther apart as comparing to city streets. Hence, a 2-mile link length was considered long enough to detect links representing mislocated crashes on county roads. A spatial query in ArcView GIS found 170 links on city streets and another query found 690 links on county roads, representing 170 and 690 crashes, respectively. A combination of these spatial queries is shown in figure 5-8. Figures 5-9 and 5-10 show the same links in Des Moines area and the city of Ames, respectively.

This simple query indicates that a total of 860 crashes were mislocated in 1997, 1998, and 1999. However, a closer look at the links created on the map showed that there were still many crash links representing incorrect combination of nodes, but not selected because they were less than 1.5 and 2 miles (figure 5-11). A manual selection made only in the Des Moines area, as shown in figure 5-12, found 156 such links. This is close to the number of links found as a result of the query for the statewide city streets and county roads. Considering that links representing Interstate and primary road crashes were ignored in this study, it can be suggested that the number of mislocated crashes in fact could be higher than it is found in this analysis.

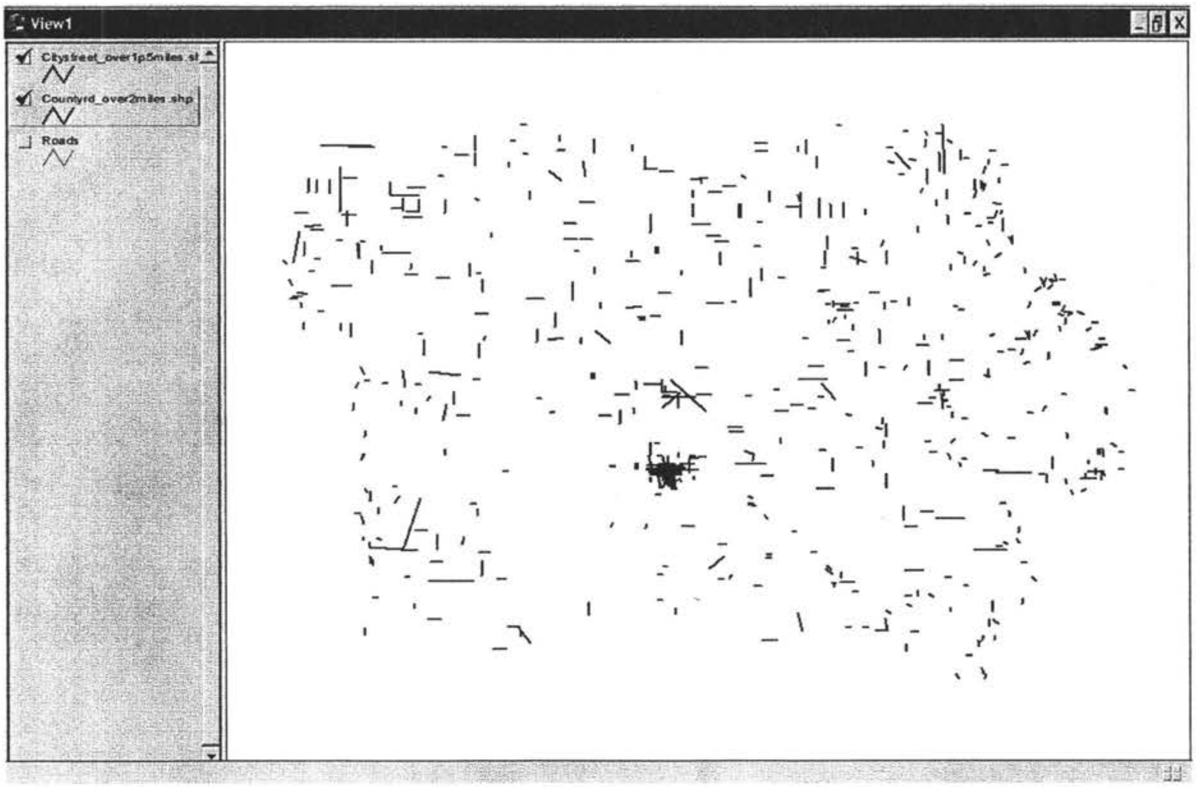


Figure 5-8. Links longer than 1.5 and 2 miles on city streets and county roads, respectively.

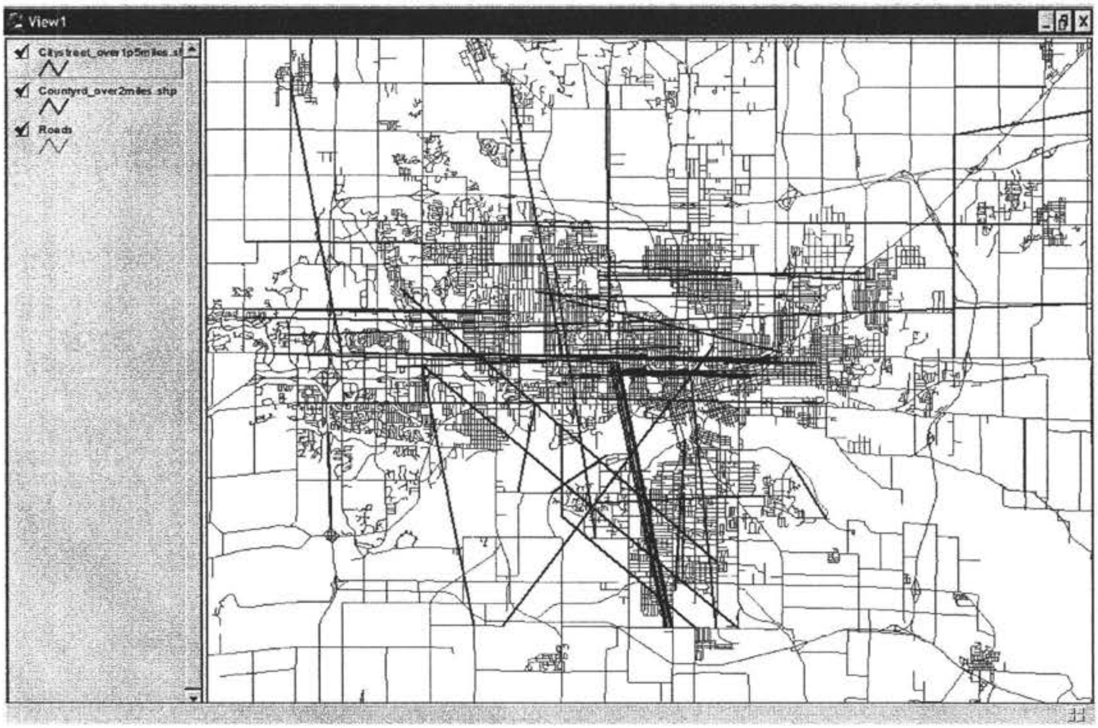


Figure 5-9. Links longer than 1.5 and 2 miles in Des Moines area.

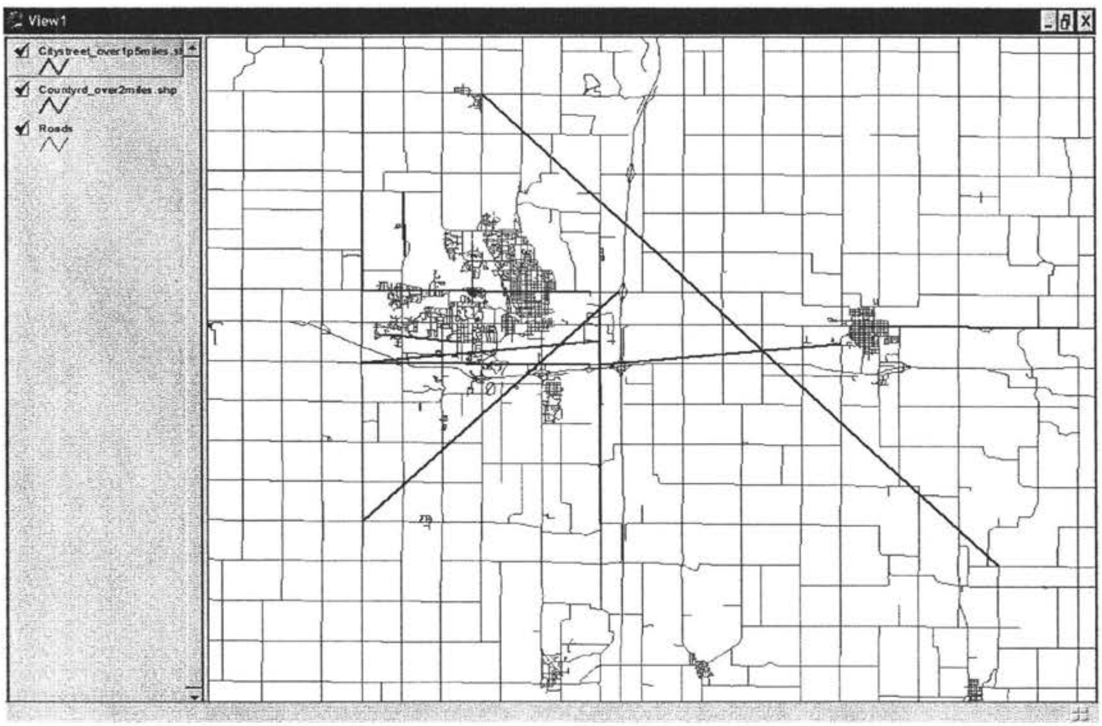


Figure 5-10. Links longer than 1.5 and 2 miles in the city of Ames and surroundings.

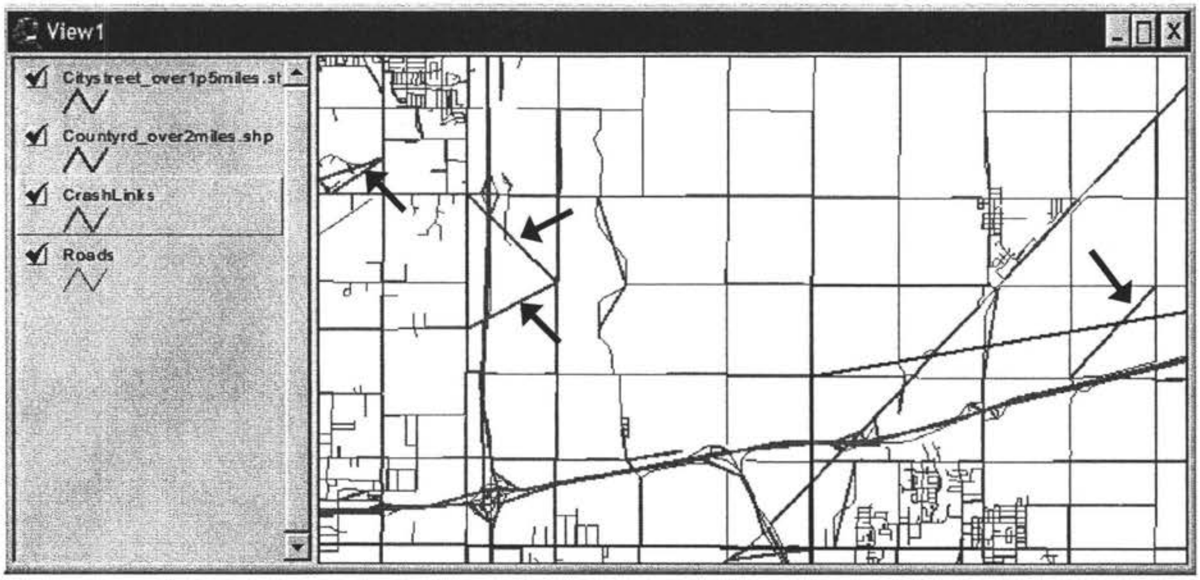


Figure 5-11. Some of the links < 1.5 miles representing unselected "mislocated" crashes.

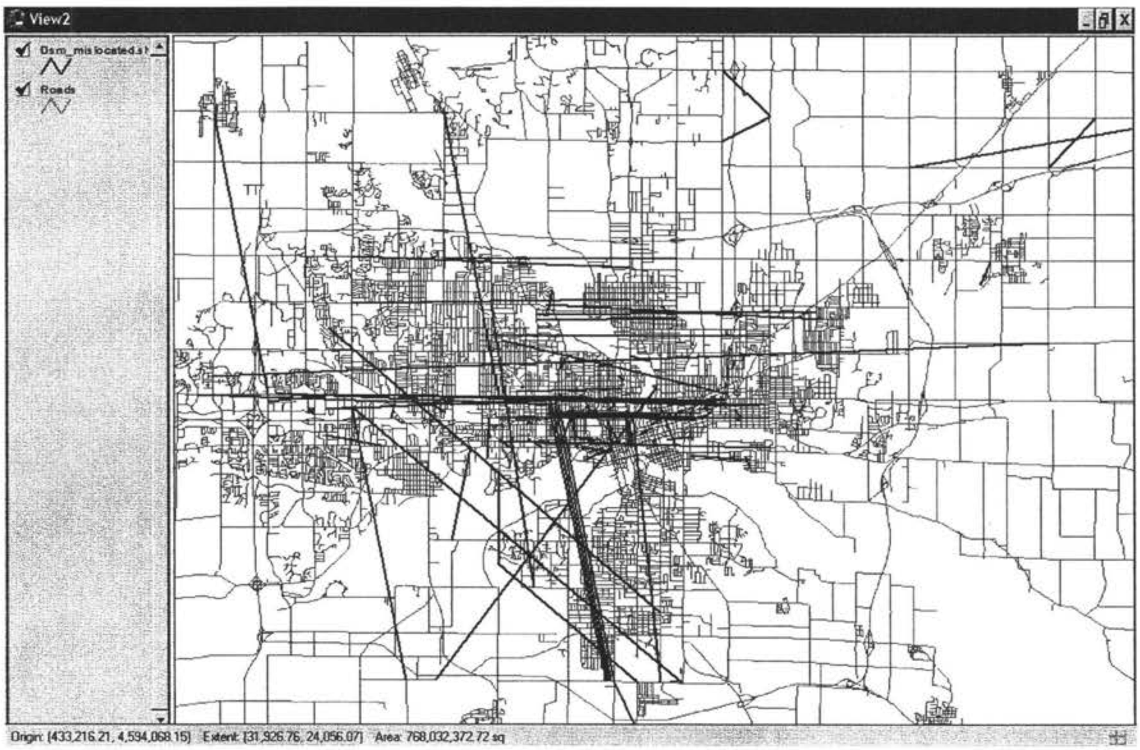


Figure 5-12. Manually selected links representing mislocated crashes in Des Monies area.

Detection of mislocated crashes for 2000 data was not possible since this procedure had already been done and necessary corrections made by Iowa DOT personnel. Therefore, it was not possible to analyze the current database for those crashes. As indicated by Iowa DOT, the locators, while locating crashes in Location Tool, key other crash information into the APS program (a program used to enter crash reports into the state database). During the edit checks, it was seen that county numbers entered into the APS program and those of derived from the Location Tool did not match in 495 cases. The source of this problem is not known yet. It could be the Location Tool or the data entry people at the DOT, or it could be a processing problem.

5.3 Results of Report Completion Time Study

Based on the hypothetical crash scenario, a total of 47 reports were completed and timed (20 paper, 27 TraCS) at ten law enforcement agencies in Iowa. These agencies included police departments, sheriff offices and Iowa State University DPS. During the study, the following measures were noted: time to complete the crash form, time to complete a citation form, and total time to complete a crash form plus a citation form.

5.3.1 Time to complete the crash report

An analysis of crash reporting time was made based on three measures: (i) time to code the data elements including the narrative section, (ii) time to draw the collision diagram, and (iii) total time spent completing a crash form.

An analysis of the time spent filling out a crash report, excluding the collision diagram, found a mean of 12 minutes for paper reports and 10:18 minutes for electronic reports. Measures for the coding process ranged from 8:30 minutes to 14:10 minutes for paper and from 6:10 minutes to 15:20 minutes for electronic reports. The difference in means was significant at $\alpha = 0.05$ in favor of electronic reporting.

On the other hand, an analysis of the time spent drawing the collision diagram found a mean of 1:55 minutes for paper and 3:38 minutes for electronic reports. Measures for the collision diagram ranged were from 1:05 minutes to 4:10 minutes for paper and from 1:37 minute to 7:30 minutes for electronic reports. The difference in means was significant at $\alpha=0.05$, in favor of paper-based reporting. Removing outliers did not significantly change the results.

A third analysis of the total time spent completing the crash form (coding and diagramming) found a mean of 13:55 minutes for paper-based and 13:57 minutes for electronic reporting process, ranging from 9:35 minutes to 16:35 minutes and 9:35 minutes to 22:30 minutes, respectively. An analysis of the measures with outliers removed resulted in minor changes in favor of the electronic reporting process. A mean of 13:41 minutes was found for paper-based and 13 minutes for electronic reporting.

In conclusion, the electronic process saved 1:42 minutes in coding the report while the paper-based process saved 1:43 minutes in drawing the collision diagram, resulting in the same average report completion time. However, it should be noted that the location process was not performed in this study. Hence, adding the time it takes to locate a crash using the Location Tool would increase the overall report completion time for TraCS users.

5.3.2 Time to complete the citation form

During the study, officers were also asked to complete a citation form. For the paper process, the mean time to complete a citation was 2:57 minutes for paper and 3:02 minutes for electronic process, ranging from 2:10 minutes to 4:35 minutes and from 50 seconds to 5:35 minutes, respectively. The difference in means was not significant at $\alpha=0.05$. Removing outliers did not significantly change the results.

5.3.3 Total time to complete the crash form and the citation form

Because the crash report and citation completion times were nearly equal, the total time to complete both reports was also nearly equal. The addition of the two totals resulted in 16:52 minutes (16:33 minutes without outliers) for paper-based, and 16:59 minutes (16:58 minutes without outliers) for the electronic reporting process. The results of the "report completion time" study are given in tables 5-6 through 5-9.

Table 5-6. Mean times (minutes) to complete the crash form and the citation.

REPORT TYPE	Coding	Diagram	Crash Report (Coding+Diagram)	Citation	Report+ Citation
Paper	12'00"	1'55"	13'55"	2'57"	16'52"
TraCS	10'18"	3'38"	13'57"	3'02"	16'59"

Table 5-7. Mean times (minutes) to complete the crash form and the citation. (Outliers excluded).

REPORT TYPE	Coding	Diagram	Crash Report (Coding+Diagram)	Citation	Report+ Citation
Paper	11'53"	1'47"	13'41"	2'51"	16'33"
TraCS	09'43"	3'16"	13'00"	2'57"	15'58"

Table 5-8. Ranges (Minutes)

REPORT TYPE	Coding		Diagram		Crash Report (Coding+Diagram)		Citation		Report+ Citation	
	Min	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*
Paper	8'30"	14'10"	1'05"	4'10"	9'35"	18'20"	2'10"	4'35"	12'25"	22'35"
TraCS	6'10"	15'20"	1'37"	7'30"	8'10"	22'30"	0'50"	5'00"	9'35"	25'30"

Table 5-9. Ranges without outliers (Minutes)

REPORT TYPE	Coding		Diagram		Crash Report (Coding+Diagram)		Citation		Report+ Citation	
	Min	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
Paper	8'30"	13'50"	1'05"	3'00"	9'35"	16'35"	2'10"	4'00"	12'25"	19'55"
TraCS	6'10"	13'00"	1'37"	5'26"	8'10"	16'50"	0'50"	5'00"	09'35"	21'50"

5.3.4 Regression analysis

Because of the significant ranges observed in this study, a regression analysis was performed to determine whether a relationship existed between officers' crash reporting experience (frequency of crash reporting) and time to complete a report. The simple linear regression analysis that was performed using SPSS software resulted in an R^2 square value of 0.018. This value indicates that the independent variable "Frequency of crash reporting" explains only 1.8% of the dependent variable "Time to complete a crash report".

A scatter plot of these two variables, as illustrated in figure 5-13, also suggests that there is almost no relationship between the variables.

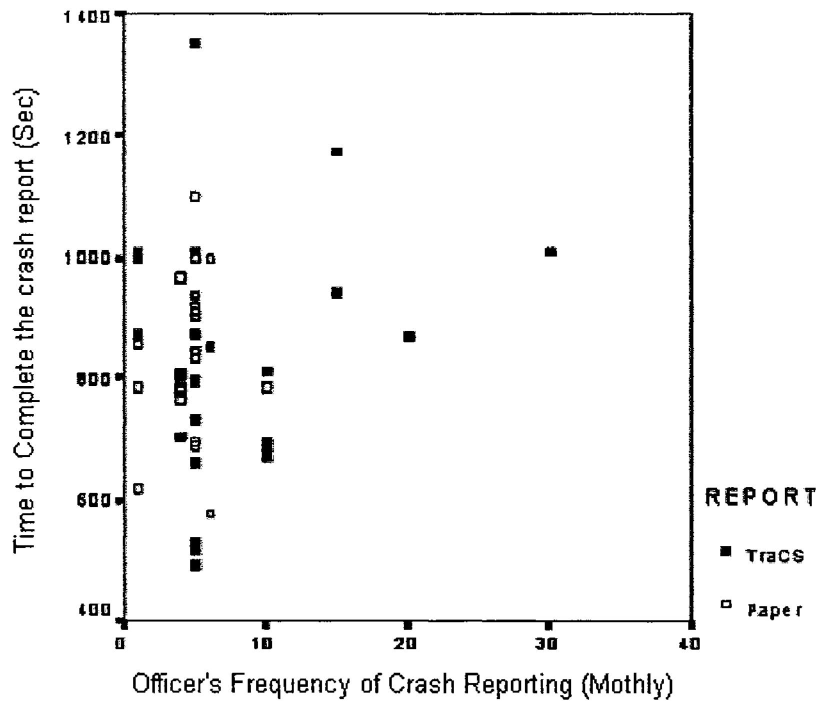


Figure 5-13. SPSS Scatter plot for 'Frequency' and 'Time' variables.

5.4 Discussion: Factors affecting the speed of reporting

During the study, it was observed that four factors affected the speed of the reporting process. These factors include:

- User defaults
- Scanning issues
- Computer and typing skills
- Care given to work

All fields in TraCS forms may be defaulted by users. Defaults make for quicker data entry in the TraCS system by prompting required information to be entered in relevant fields. Defaulting certain fields such as accident city, accident county, date of accident, date of report, officer's signature, and courthouse information potentially decreases the time to complete a form. In this study, one officer completed the electronic crash and citation forms on a computer configured with his defaults. The officer completed coding the crash form in 6:10 minutes and the citation form in 50 seconds, the fastest completion in this study. Considering that the mean time for coding is 10:18 minutes and for the citation 3:02 minutes, the results are evidently significant. However, the officer's computer skills and electronic reporting experience also played an important role in getting these results.

During the study, it was indicated by the officers that about 30% of the time driver's licenses and vehicle documents are missing, and most of the out-of-state licenses cannot be scanned due to format requirements. In this case, officers enter driver and vehicle information manually.

The preferred method of capturing signatures is signing directly on the screen of pen-based computers or on a signature pad for desktop application. However, as was mentioned earlier, this study was mostly performed on desktop computers in offices, and about 1/3 of the cases barcode scanners were used to capture signatures. During this slow and clumsy process, some officers captured the signature immediately whereas others had some difficulties in doing so. Officers oftentimes moved the scanner back and forth, tried to give an angle to the document, or attempted to re-scan until the barcode is read. Also, some minor delays were encountered capturing signatures in the electronic citation form. As illustrated in figures 5-14 through 5-16, failure to adjust the angle and distance caused capturing too large, too small, or partly-scanned signature images. Hence, officers had to re-scan signatures several times until they captured them with a reasonable size and appearance (figure 5-17). In addition, officers often times forgot to press the "Barcode Scanner" button before attempting to capture a signature, which caused an extra delay.

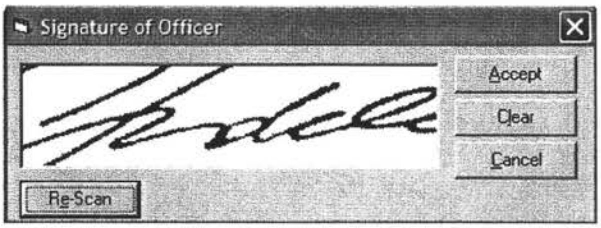


Figure 5-14. Improper scanning-1

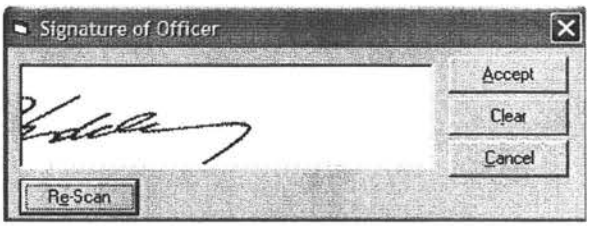


Figure 5-15. Improper scanning-2

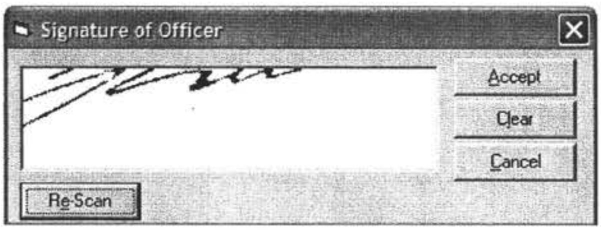


Figure 5-16. Improper scanning-3

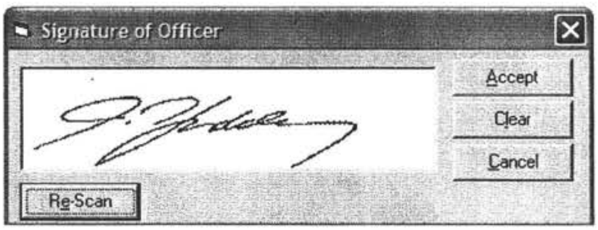


Figure 5-17. Ideal scanning

It was also observed that officers with better computer and typing skills completed the electronic crash form earlier than others.

Some officers carefully checked their entries for any mistakes they might have. Similarly, some officers preferred to use an accident template, a straight edge or a ruler to draw the collision diagram in paper-based reporting, extending the time to draw the diagram. Attempts to resize and relocate objects, texts and lines in diagrams in the TraCS environment also increased the time required to draw the diagram.

5.5 Cost assessment

Cost assessment of TraCS is based on the discussions made with TraCS team members and information provided through the National Model Project Report (31). Discussions made in this section include the implementation costs and the savings that can be expected from using TraCS.

The National Model Project Report indicates that developing independent software costs $6 million dollars based on New York and Wisconsin estimates. Development of each electronic form (e.g. MARS, Citation, Driver/Vehicle Inspection Report, Incident Report, etc.) costs about $1-$1.2 million. Implementation costs of a typical fee-based electronic data collection system include software licensing, maintenance, configuration, and other support fees. Reportedly, these services cost about $850-$4000 per user (including a $100 annual maintenance fee).

TraCS can be used both in office and in the field. For an Iowa agency desiring to use TraCS at office level, there is no cost if the agency uses its own desktop computers. For field use, according to TraCS Grant Application document, there is a $7,500 estimated cost for in-vehicle computer equipment, including computer and keyboard, printer, barcode scanner, adapters and special mounting equipment such as cradles, keyboard holders, pedestals and stand, and holders for printers and barcode readers. For other states' agencies, in addition to above items, there is also a need to customize the TraCS environment to meet their individualized data entry and reporting requirements. For this purpose, the TraCS is supported by a Software Development Kit (SDK) and a free training is offered to agencies that choose to train staff and develop their own forms (modules).

CHAPTER 6 - CONCLUSIONS

6.1 Conclusions

The stated objective of this thesis was to evaluate the effectiveness of Iowa's electronic crash data collection system (TraCS) and to document if the system meets expectations such as better quality crash data, reduced data collection time in the field, and other suggested benefits. For this purpose, three studies were performed:

- attribute quality (data accuracy, completeness, consistency, and legibility)
- location accuracy (analysis of 'unlocated' and 'mislocated' crashes)
- time to complete a crash report.

Results of the attribute quality study suggest that substantial improvements to the quality of crash data can be achieved through use of technology in crash data collection. TraCS validations detected a number of attribute quality problems such as missing information (incompleteness) and incorrect and inconsistent data entries in paper reports.

A comparison of the state records to the original paper crash reports found that accuracy of crash data are significantly affected by officers' erroneous data entry in the field as well as reentering paper reports into state database. One of the problems observed was that some of the information in the original paper report and in the state database did not match. This mismatch problem occurs in two ways: (i) correct data in paper crash report are keyed wrongly in the state database, or (ii) officers enter driver and/or registration related information erroneously. TraCS eliminates the first type of mismatch problem since reports are transferred to the state database without user intervention, and the second type of mismatch through scanning that type of information. The barcode scanning capability of TraCS helps agencies provide correct data on drivers and vehicles. Iowa's current electronic crash form contains 16 data fields for driver information, 9 fields for owner information, and 8 fields for vehicle information. All available information can be transferred to these data fields in the crash form by scanning driver's licenses and vehicle registration documents. In conclusion, the accuracy analysis suggests if all crashes in Iowa were reported using TraCS, thousands of pieces of crash and unit related information would have been preserved as they were reported.

The completeness analysis showed that paper crash reports have a significant missing data problem. From an engineering point of view, some of the missing data elements found by TraCS validations (such as vehicle make, vehicle style, model, address city, zip code, VIN#, driver's license class, driver's license state, license plate number, license plate year, license plate state, owner's name, date of report, total occupants, underride/override, approximate cost to repair or replace, and most damage area) are tolerable as they are not generally used in crash analyses. However, other missing data elements (such as date of accident, time of accident, driver's date of birth, contributing circumstances for environment and roadway, contributing circumstances for driver, vision obscured, driver condition, vehicle action, speed limit, first event, first harmful event of crash, and most harmful event of crash) are required to determine causes of accidents. These findings show that TraCS validations help improve the quality of crash data by detecting and warning investigating officers of the absence of these critical data elements. Similarly, TraCS has a positive contribution to the quality of crash data by detecting inconsistencies between data elements such as "time of accident" and "light conditions", "manner of crash/collision" and "number of units".

Based on the findings from the attribute quality study, it can be concluded that TraCS provides more complete, accurate, consistent and legible crash data as well as a professional appearance with intelligible diagrams and narratives.

The Location Tool integrated with TraCS achieved a substantial success in locating crashes by reducing the number of unlocated crashes as well as locating crashes at their exact locations. While the extent of "mislocation" problems for crashes located with the Location Tool is not known, it is safe to suggest that this problem is much less likely to occur if the Location Tool is used. A crash, using the Location Tool, can only be mislocated if the user picks a wrong spot on the smart map screen, as opposed to more sources of error in the former location process (e.g. errors in node numbers, missing nodes, incorrect combination of nodes, undecipherable location information, etc.). Locating crashes at the crash scene may slightly increase the time to complete a crash report; however, it saves significant time and administrative work in the office. Statewide data may then be made available to users in timely fashion.

The "report completion time" study showed that TraCS saves time coding crash data, but loses approximately the same amount of time while drawing a collision diagram. However, this delay can be reduced if TraCS users store templates of roads and intersections under their specific user files, and use them when they draw a collision diagram in TraCS diagram tool, Visio or Easy Street Draw. TraCS users lose some time during the validation and editing process of the reports. However, even longer delay may occur in paper reports if an officer makes a vital error. In this case, an officer may decide to discard the whole report and start over. Improvement of computer and typing skills is crucial in lessening the time to complete crash reports.

Although the testing shows the time it takes to complete a report electronically and on paper is nearly the same, it is important to look at the system processes. In a paper-based system, the data is written by an officer, it is reentered into a database at the local agency, and reentered again at the state level for entry into a state database. At each of these entry points there are resource expenditures and also possible data quality degradation. Therefore, from a system point of view, the electronic process saves time and improves accuracy for database even if it does not save time for officers in the field.

In addition to the improvements in the timeliness and quality of crash data as well as and the location accuracy, TraCS is also beneficial for agencies desiring to implement an electronic crash data collection system. Agencies choosing TraCS can save millions of dollars by avoiding the development of independent TraCS-type software or by eliminating licensing and maintenance costs of fee-based software since they are provided free of charge for Iowa and other state agencies. In addition to software-related costs, TraCS also eliminates the costs associated with transferring and processing paper reports. To that effect, savings include shipping charges, scanning costs and most importantly, the labor used to process paper reports.

6.2 Recommendations

Knowing that the primary purpose of electronic collection of crash data is to improve the quality of data, during the course of this research, several points pertaining to TraCS validations were noted and the followings are recommended:

- Validating incomplete location information
- Giving “warnings” for several other data fields
- Eliminating ambiguous error messages

6.2.1 Validating incomplete location information

TraCS does not validate 55 data fields in Iowa’s electronic crash form (MARS) and Iowa DOT does not consider validating these fields for following reasons:

- The need for each possible validation is reviewed based on its necessity, therefore only validations that are seen as necessary or that resolve problems experienced with incomplete or incorrect information are added to a report.
- It is not desirable or practical to include excessive validations, as they can affect the performance of the software and also serve as a source of frustration that makes the software less user friendly.
- It is not desirable to require something that users are unable to provide and set-up a situation where the officer has to fabricate information because the validation routine requires it.
- Requiring officers to enter something in a field that only occasionally has information requires unnecessary data entry steps on each and every report. (e.g. “work zone related”, “placard number”, “hazardous materials released” information).
- The use of some information is for local agency benefit and a local agency policy to determine its use. The state is not inclined to require information it does not use. (e.g. “the time officer notified”, “time officer arrived at scene”, “the report given to all drivers”, “technical investigation number“, “other investigating agency”, “tow number’ fields)
- Some information is not available for everyone or every case. (e.g. not everyone has a middle name, suffix, phone, insurance company, policy number or insurance company phone number; likewise, not every case has a second, third, fourth event).

However, a validation on the location information should be considered. As illustrated in figure 6-1, TraCS does not detect incomplete location information. In the highlighted field “on road, street or highway” it is indicated that the crash occurred on 1st Avenue in Des Moines, Polk County. However, the exact location of the crash is not known since no supportive information in other location-related field or fields, such as “At intersection with”, “Distance”, Direction” and “Definable intersection, bridge, or railroad crossing”, is given. Validations could be used to issue a “warning” alerting the officer for the incompleteness of the information entered. Although it is indicated that location information is not heavily validated to allow flexibility and it would be difficult to envision every possible way that may be appropriate to enter the location, it is believed that these missing attributes can be important for agencies, which do not use the Location Tool and still need sufficient information to locate the crashes.

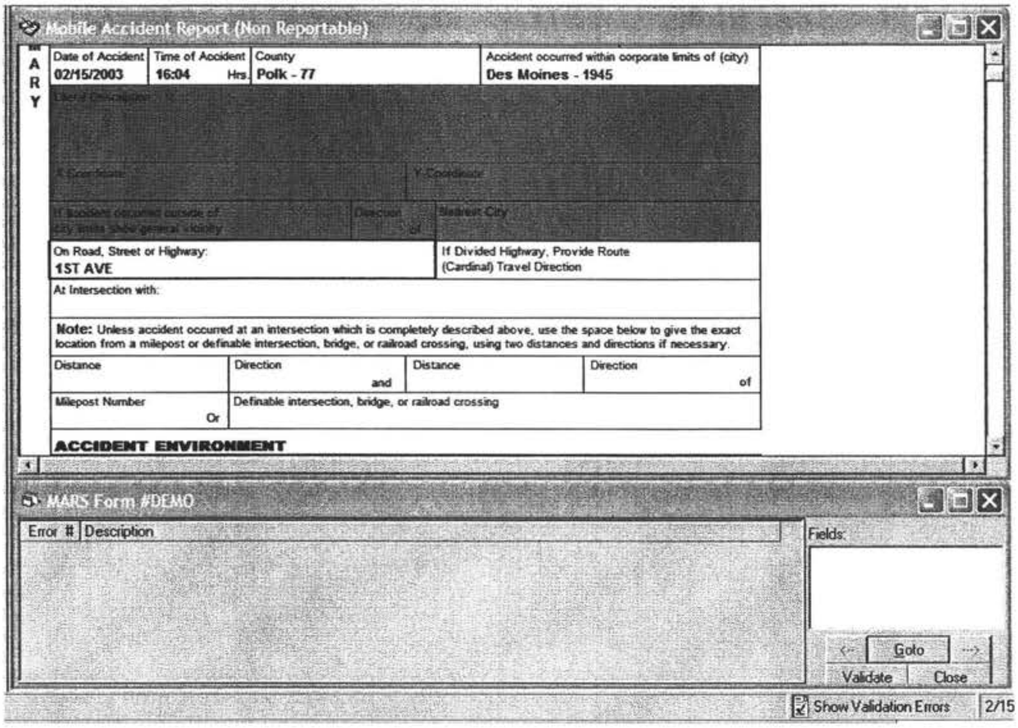


Figure 6-1. MARS Report Form and Validation Error Message

6.2.2 Giving "warnings" for several other data fields

In the "Sequence of Events" section (figure 6-2), an officer enters "Overturn/Rollover" or "Jack-knifed" in the "First Event" field. Normally, these events cannot be the first event for a crash as maneuvers by the driver prior to the events listed cause the crash to happen (which could include losing control, run-off the road, evasive action, animal or object in roadway, equipment failure, etc.). A validation warning on these kinds of entries would be useful in the analyses of the crashes.

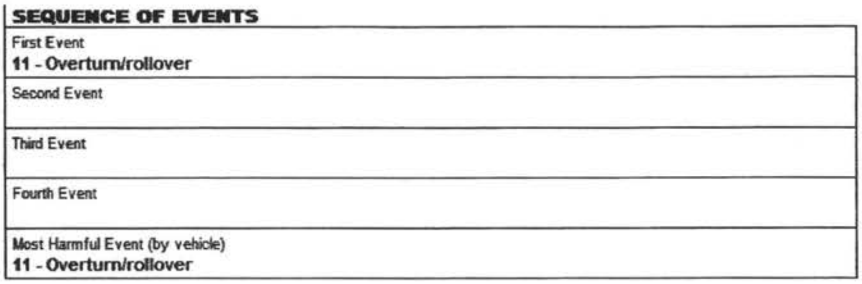


Figure 6-2. TraCS - MARS Form - Sequence of Events

Another warning may be issued when the "Extent of Damage" field is coded "1-None" and the "Approximate cost to repair or replace" field is coded with a value greater than $0.00. This situation is illustrated in figure 6-3. As can be seen, there is $5,000 in damage; however, the "Extent of damage" field is coded "1-None". In this case, TraCS validation should have issued an error message warning the officer that the "Extent of Damage field should be coded other than '1-NONE'".

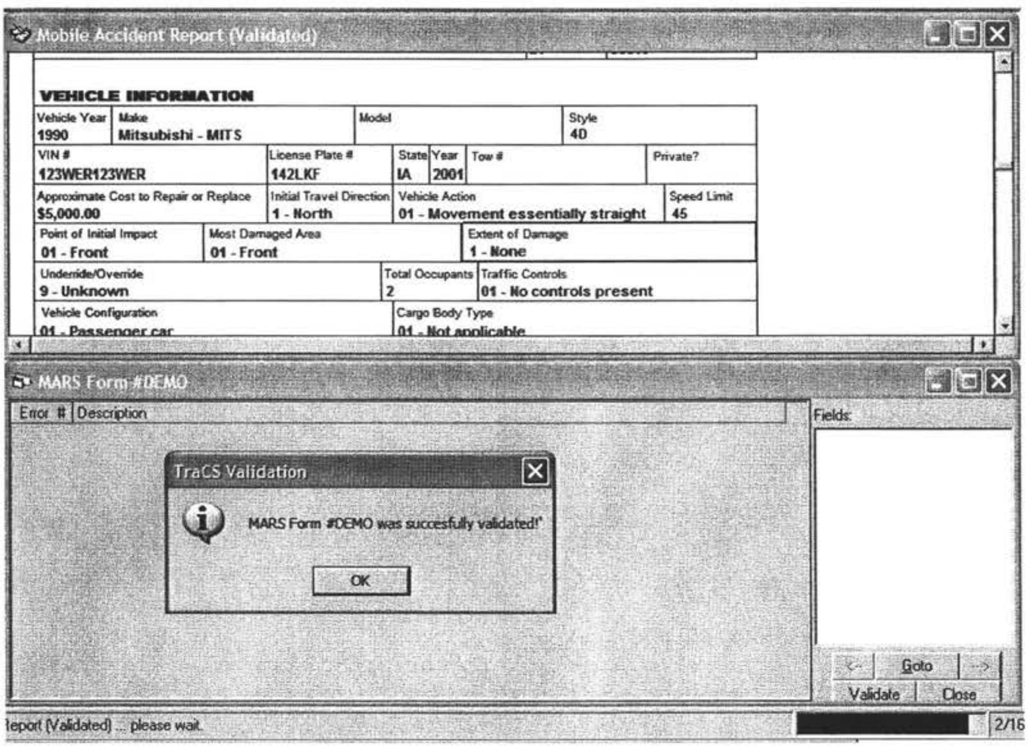


Figure 6-3. MARS Report Form and Validation Error Message

6.2.3 Eliminating ambiguous error messages

In the case of missing 'time of accident' information, as shown in figure 6-4, MARS validation gives the following error messages:

- There must be an entry for the "time of accident"
- According to the date and time of the accident the light conditions should be '4-Dark, roadway lighted' or '5-Dark, roadway not lighted' or '6-Dark, unknown roadway lighting'.

The first validation message is correct whereas the second is not. Since there is no time specified, an advice on such light conditions is not suitable. Hence, this second message should appear only if there is a conflict between the "Light Conditions" and the "Time of Accident" entered.

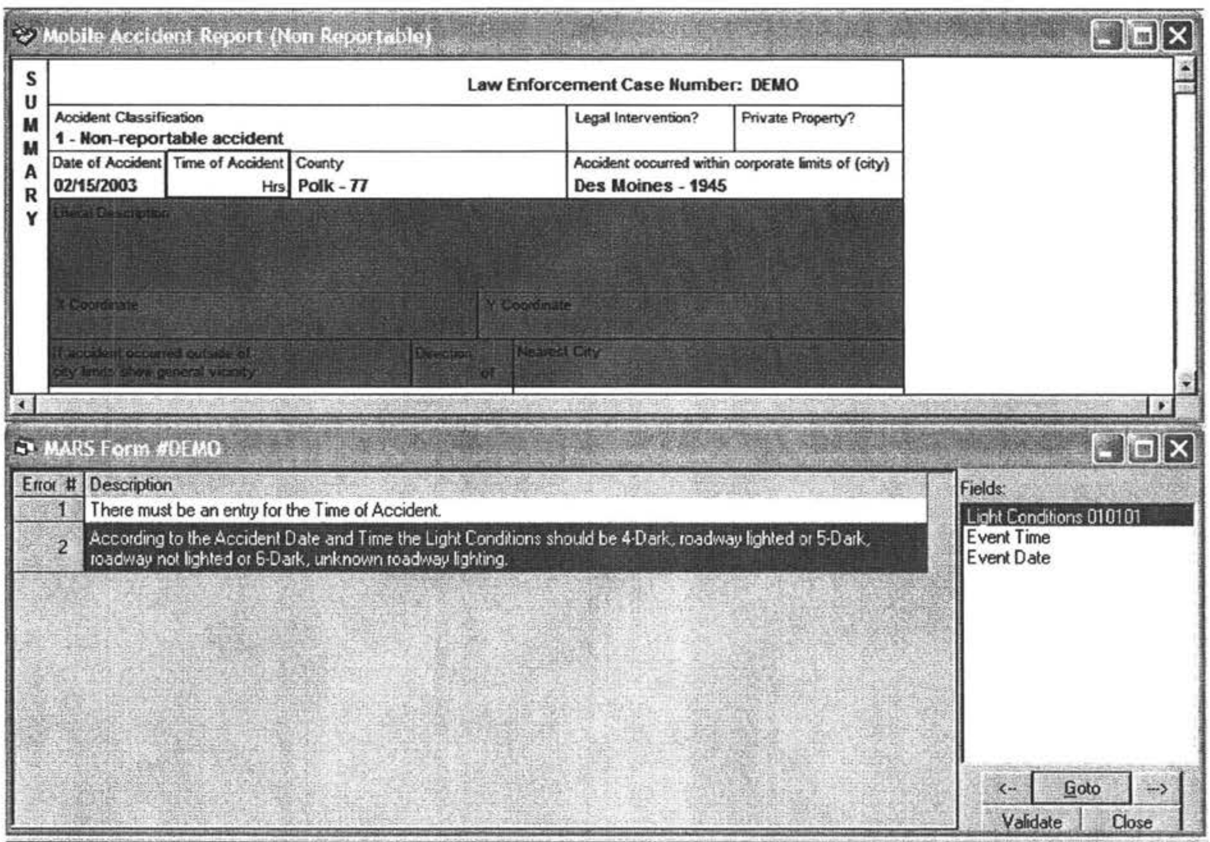


Figure 6-4. MARS Report Form and Validation Error Message

6.3 Future Research

As a continuation of this research, an analysis of attribute quality can be done on the TraCS reports as well. In this thesis, TraCS (MARS) reports were not analyzed; instead, TraCS was used to analyze paper reports for attribute problems.

A second area where additional research could be performed pertains to the analysis of "unlocated" and "mislocated" crashes that are processed by MARS and the Location Tool. The process of detecting unlocated crashes is straightforward: (i) identify the unlocated crashes from the crash database, and (ii) check for the location information in the original reports. For detecting mislocated crashes, two separate analyses are required: (i) an analysis on the crashes which are located by the DOT locators, and (ii) another on the crashes located by the officers in the field. The distinction between these two is that there is only one way to detect mislocated crashes that are located by the officers, which is comparing the narrative and collision diagrams to the Location Tool generated literal description. For the crashes located by the DOT, the method is different. This process requires obtaining the location information from the original reports and compare it to the Location Tool generated location information (literal description).

A third area where additional work could be performed is in the report completion time. In this research, timing was performed mostly on computers that were located in the offices and not configured for each officer tested. An analysis can be done using fully configured computers containing diagram templates, ID's, signatures and other personal information of officers. This should improve the time to complete a report. Another analysis could be made on time required to validate reports.

APPENDIX A. TraCS v.6.5.2. MARS Validation Messages

Validation Error Messages for 'Required fields'

1. "There must be an entry for the Law Enforcement Case Number."
2. "There must be an entry for the Accident Classification."
3. "There must be an entry for the Date of Accident."
4. "There must be an entry for the Time of Accident."
5. "There must be an entry for the Accident County."
6. "There must be an entry for either the Accident City or the Nearest City."
7. "There must be an entry for the Location of First Harmful Event."
8. "There must be an entry for the Manner of Crash/Collision."
9. "There must be an entry for the Light Conditions."
10. "There must be an entry for the Weather Conditions."
11. "There must be an entry for the Surface Conditions."
12. "There must be an entry for the Environment Contributing Circumstances."
13. "There must be an entry for the Roadway Contributing Circumstances."
14. "There must be an entry for the Type of Roadway Junction/Feature."
15. "There must be an entry for the Workzone Location."
16. "There must be an entry for the Workzone Type."
17. "There must be an entry for the Workzone Worker's Present field."
18. "There must be an entry for the First Harmful Event of Crash."
19. "There must be an entry for the Date of Report."
20. "There must be an entry for the Is All Information Known/Applicable field."
21. "There must be an entry for the Driver's Last Name."
22. "There must be an entry for the Driver's Street Address."
23. "There must be an entry for the Driver's Address City."
24. "There must be an entry for the Driver's Address State."
25. "There must be an entry for the Driver's Address Zip Code."
26. "There must be an entry for the Driver's Date of Birth."

27. "There must be an entry for the Driver's License Number."

28. "There must be an entry for the Driver's License State."

29. "There must be an entry for either the Owner's Last Name or the Owner Company Name."

30. "There must be an entry for the Owner's Street Address."

31. "There must be an entry for the Owner's Address City."

32. "There must be an entry for the Owner's Address State."

33. "There must be an entry for the Owner's Address Zip Code."

34. "There must be an entry for the Vehicle Year."

35. "There must be an entry for the Vehicle Make."

36. "There must be an entry for Vehicle Style."

37. "There must be an entry for the Initial Travel Direction."

38. "There must be an entry for the Vehicle Action."

39. "There must be an entry for the Speed Limit."

40. "There must be an entry for the Point of Initial Impact."

41. "There must be an entry for the Most Damaged Area."

42. "There must be an entry for the Extent of Damage."

43. "There must be an entry for Underride/Override."

44. "There must be an entry for Total Occupants."

45. "There must be an entry for Traffic Controls."

46. "There must be an entry for Vehicle Configuration."

47. "There must be an entry for the Cargo Body Type."

48. "There must be an entry for Vehicle Defect."

49. "There must be an entry for the Driver Condition."

50. "There must be an entry for Vision Obscured."

51. "There must be an entry for the Driver Contributing Circumstances."

52. "There must be an entry for the Emergency Vehicle Type."

53. "There must be an entry for the Emergency Status."

54. "There must be an entry for the First Event of the Sequence of Events."

55. "There must be an entry for the Is CMV? field."

56. "There must be an entry for the Carrier Name."

57. "There must be an entry for the Carrier's Street Address."

58. "There must be an entry for the Carrier's Address City."

59. "There must be an entry for the Carrier's Address State."

60. "There must be an entry for the Carrier's Address Zip Code."

61. "There must be an entry for either the US DOT# or the MC #."

62. "There must be an entry for the Number of Axles."

63. "There must be an entry for the Gross Vehicle Weight Rating."

64. "There must be an entry for the Most Harmful Event of the Sequence of Events."

65. "There must be an entry for the Driver Unit Number."

66. "There must be an entry for the Injured Seating Position."

67. "There must be an entry for the Injured Injury Status."

68. "There must be an entry for the Injured Unit Number."

69. "There must be an entry for the Injured Occupant Protection."

70. "There must be an entry for Injured Airbag Deployment."

71. "There must be an entry for the Injured Airbag Switch Status."

72. "There must be an entry for Injured Ejection."

73. "There must be an entry for the Injured Ejection Path."

74. "There must be an entry for Injured Trapped."

75. "There must be an entry for the Non-Motorist Type."

76. "There must be an entry for the Non-Motorist Location."

77. "There must be an entry for the Non-Motorist Action."

78. "There must be an entry for the Non-Motorist Condition."

79. "There must be an entry for Non-Motorist Safety Equipment."

80. "There must be an entry for the Non-Motorist Contributing Circumstances."

81. "There must be an entry for the Non-Motorist Unit Number of Vehicle Striking."

Validation Error Messages for 'Erroneous Data'

1. "If the Accident Classification is '2-Short form accident' then there can be only one Unit."
2. "Since the status of the MARS form is Non Reportable, the Accident Classification must be '1-Non-reportable accident'. Change the Non Reportable status by selecting the Toggle Non Reportable option from the File menu."
3. "Since the Accident Classification is '1-Non-reportable accident', the status of the MARS form must be Non Reportable. Change the Non Reportable status by selecting the Toggle Non Reportable option from the File menu."
4. "Since there is either $1000 or more worth of property damage as a result of this accident or there is at least one injury or fatality, this accident cannot be marked Non-reportable."
5. "Since there is less than $1000 worth of property damage as a result of this accident and no injuries or fatalities, this accident must be marked Non-reportable."
6. "The Date of Accident cannot be greater than today's date."
7. "The accident must be located. Either the Location Tool must be used to locate the accident or the On Road, Street or Highway field must be populated."
8. "The Literal Description field should only be populated if the Location Tool was used to locate the accident. Either clear the field or locate the accident using the Location Tool."
9. "The Manner of Crash/Collision is 2 through 7 so there must be more than one Unit invloved in the accident."
10. "According to the Accident Date and Time the Light Conditions should be 4-Dark, roadway lighted or 5-Dark, roadway not lighted or 6 - Dark, unknown roadway lighting."
11. "According to the Accident Date and Time the Light Conditions should be 1- Daylight."
12. "One of the Weather Conditions is '01-Clear' so the other Weather Condition must be Blank, '09-Severe winds', '10-Blowing sand, soil, dirt, snow', '88-Other' or '99-Unknown'."
13. "Surface Conditions cannot be '9-Unknown' if Weather Conditions contain '06-Rain', '07-Sleet, hail, freezing rain', or '08-Snow'."
14. "If Weather Conditions contain '06-Rain' or '07-Sleet, hail, freezing rain' then Surface Conditions cannot be '1-Dry'."
15. "If Weather Conditions contain '01-Clear' and Surface Conditions is '1-Dry' then Environment Contributing Circumstances cannot be '02-Weather condition'."
16. "The First Harmful Event of Crash is 23-Parked motor vehicle so at least one Unit must have a Vehicle Action of 12-Legally Parked or 13-Illegally Parked/unattended."

17. "The First Harmful Event of Crash is '20-Non-motorist' so at least one Injured Person must have a Seating Position of '15-Pedestrian', '16-Pedalcyclist, or '17-Pedalcyclist, passenger'."

18. "The First Harmful Event of Crash is '24-Railway vehicle/train' so the Vehicle Configuration for at least one Unit must be '22-Train'."

19. "The Date of Report cannot be greater than today's date."

20. "The Driver's Date of Birth cannot be greater than today's date"

21. "Drivers cannot be assigned to the Person Injured section. Delete the Person Injured section(s) containing Drivers. Information on Injured Drivers should be entered in the Driver section."

22. "If an American state, the first 5 characters of the Driver's Address Zip Code must be numeric, last 4 numeric or spaces, and the first 3 a valid state range."

23. "If a Canadian state, the Driver's Address Zip Code should be either CANADA or A9A9A9, where A = alpha and 9 = numeric."

24. "If a Mexican state, the Driver's Address Zip Code should be MEXICO."

25. "The Driver's License State is 'IA' so Driver's License Number must be nine digits long with no dashes or spaces; the first three digits must be numeric or 'NDL'; the last four digits must be numeric."

26. "The Driver's License State is 'IA' so License Class must be entered."

27. "The Owner Company Name has been entered so the Owner's Last, First, Middle, and Suffix Names must be blank."

28. "If a Canadian state, the Owner's Address Zip Code should be either CANADA or A9A9A9, where A = alpha and 9 = numeric."

29. "If an American state, the first 5 characters of the Owner's Address Zip Code must be numeric, last 4 numeric or spaces, and the first 3 a valid state range."

30. "If a Mexican state, the Owner's Address Zip Code should be MEXICO."

31. "The Vehicle Year of the Unit is more than 1 year greater than the Date of the Accident."

32. "The same Vehicle cannot be assigned to more than one Unit. Remove the Vehicle from the incorrect Unit by going to the Vehicle Year field in that Unit and choosing the blank line in the list. Next, move off of the field and answer 'Yes' to the Data Sharing Message Box. Lastly, move back to the Vehicle Year field and select the correct Vehicle from the list or click on the Edit/New button to add a new Vehicle."

33. "The same Vehicle Identification Number cannot be used in more than one Unit. Ensure that the correct Vehicles are assigned to the correct Units."

34. "The same Vehicle License Plate Number cannot be used in more than one Unit. Ensure that the correct Vehicles are assigned to the correct Units."

35. "The VIN Number should be alphanumeric and must not contain any spaces or dashes."

36. "There must be an entry for the Approximate Cost to Repair or Replace."

37. "Since the Approximate Cost to Repair or Replace is blank or 0, the Extent of Damage must be '1-None' or '9-Unknown'."

38. "If the Vehicle Action is '12-Legally Parked' then Driver Contributing Circumstances must contain '28-No improper action'."

39. "If the Vehicle Action is '11-Stopped for stop sign/signal' then Traffic Controls cannot be '01-No controls present', '06-No Passing Zone (marked)' or '99-Unknown'."

40. "If Traffic Controls is '01-No controls present' then Driver Contributing Circumstances cannot contain '01-Ran traffic signal' or '02-Ran stop sign'."

41. "The Vehicle Configuration is 14-Motorcycle, or 15-Moped so the Total Occupants must be less than 4."

42. "The Driver Condition is '1-Apparently Normal' so the Alcohol Test Results must be 'Blank' or Zero and the Drug Test Results must be 'Blank' or 'N - Negative'."

43. "If Vision Obscured is '01-Not obscured' then Driver Contributing Circumstances cannot contain '26-Vision obstructed'."

44. "Vision Obscured is '12-Blowing snow' so Weather Conditions must contain '07-Sleet, hail, freezing rain', '08-Snow', '09-Severe winds' or '10-Blowing sand, soil, dirt, snow'."

45. "The Emergency Status cannot be '3 - Not Applicable' if the Emergency Vehicle Type is 2 through 7 or 9"

46. "If the Sequence of Events for any Unit contains '38-Poles (utility, light, etc.)', '39-Sign post', or '40-Mailbox' then there must be a non blank Property Damage section."

47. "Company Name are blank, the Sequence of Events for this Unit should include '52-Hit and run'."

48. "If a Canadian state, the Carrier's Zip Code should be either CANADA or A9A9A9, where A = alpha and 9 = numeric."

49. "If an American state, the first 5 characters of the Carrier's Zip Code must be numeric, last 4 numeric or spaces, and the first 3 a valid state range."

50. "If a Mexican state, the Carrier's Zip Code should be MEXICO."

51. "The Number of Axles must be more than one."

52. "The Gross Vehicle Weight Rating must be greater than '10000'."

53. "The Vehicle Involvement field must not be blank if the Is CMV? field is Yes."

54. "If Vehicle Involvement has '5-None of the above' selected, then no other items for Vehicle Involvement can be selected."

55. "If an American state, the first 5 characters of the Property Owner's Zip Code must be numeric, last 4 numeric or spaces, and the first 3 a valid state range."

56. "If a Mexican state, the Property Owner's Zip Code should be MEXICO."

57. "If a Canadian state, the Property Owner's Zip Code should be either CANADA or A9A9A9, where A = alpha and 9 = numeric."

58. "There are more Units than there are Driver Sections. There must be a corresponding Driver Section for each Unit even if the Driver of the Unit is unknown. In the case that the Driver is unknown, add a Driver Section for the Unit and leave the fields blank."

59. "There are more Driver Sections than there are Units. There should be one Driver Section for each Unit."

60. "The Driver for Unit 001 does not match the Driver in Driver Section 001."

61. "Since the Driver Name in Unit 001 is blank, the corresponding Driver Name in Driver Section 001 should also be blank."

62. "The Injured Person's Date of Birth cannot be greater than today's date"

63. "If an American state, the first 5 characters of the Injured Person's Zip Code must be numeric, last 4 numeric or spaces, and the first 3 a valid state range."

64. "If a Mexican state, the Injured Person's Zip Code should be MEXICO."

65. "If a Canadian state, the Injured Person's Zip Code should be either CANADA or A9A9A9, where A = alpha and 9 = numeric."

66. "The Unit Number on one of the Person Injured Sections does not correspond to an existing Unit. Enter 0 if the Unit Number is unknown."

67. "The Unit Number of Vehicle Striking on one of the Person Injured Sections does not correspond to an existing Unit. Enter 0 if the Unit Number is unknown."

68. "If an American state, the first 5 characters of the Witness Zip Code must be numeric, last 4 numeric or spaces, and the first 3 a valid state range."

69. "If a Mexican state, the Witness Zip Code should be MEXICO."

70. "If a Canadian state, the Witness Zip Code should be either CANADA or A9A9A9, where A = alpha and 9 = numeric."

71. "Either a First Name or a Last Name of the Witness must be entered."

72. "Either a full Witness Address or Daytime or Evening Phone Number must be entered."

Validation 'Warning' Messages

1. "WARNING – One or more of the road segments selected in the Location Tool falls outside of the county selected in the County field."
2. "WARNING - The First Harmful Event is not listed in the Sequence of Events for any Unit."
3. "WARNING - The T.I.# is filled in but a Other Technical Investigating Agency has not been selected. If the Other Technical Investigating Agency is not an Iowa agency or is not in the list provided, clear the T.I.# field and enter the information in the narrative."
4. "WARNING - The Driver's Date of Birth indicates that the driver is less than 14 years old."
5. "WARNING - The Driver's Date of Birth indicates that the driver is more than 100 years old."
6. "WARNING – The same Driver's License Number has been used for more than one Driver. Ensure that the correct Driver's License Numbers are assigned to the correct Drivers."
7. "WARNING - The Most Harmful Event is not listed in the Sequence of Events."
8. "WARNING - Since the Driver Last Name is blank and the Owner Last Name and Owner
9. "WARNING – You have selected an Injury Status of '1 - Fatal' for this driver. Please confirm that the driver was fatally injured."
10. "WARNING – The Airbag Deployment for the Driver is '1-Deployed front of person', '2-. Deployed side of person', or '3-Deployed both front/side' so the Airbag Switch Status should not be '2-Switch in OFF position'."
11. "WARNING - The Injured Person's Date of Birth indicates that the person is more than 100 years old."
12. "WARNING - You have selected an Injury Status of '1 - Fatal' for this injured person. Please confirm that the injured person was fatally injured."
13. "WARNING - The Airbag Deployment for the Person Injured is '1-Deployed front of person', '2-Deployed side of person', or '3-Deployed both front/side' so the Airbag Switch Status should not be '2-Switch in OFF position'."

APPENDIX B. Crash Scenario Used in "Report Completion Time" Study.

Form 433003 January 2001

MAIL REPORTS TO:
Iowa Department of Transportation
Office of Driver Services
Park Fair Mall, 100 Euclid Avenue
P.O. Box 9204
Des Moines, Iowa 50306-9204

Iowa Department of Transportation
INVESTIGATING OFFICERS REPORT OF MOTOR VEHICLE ACCIDENT

Law Enforcement Case Number: **TEST**

Legal Intervention? ☐ Private Property? ☐

LOCATION

Date of Accident	Time of Accident	County	Accident occurred within corporate limits of (city)
02/26/03	19:12 Hrs.	Polk - 77	Des Moines - 1945

Location Literal Description: E 4TH ST and LOCUST ST E

If accident occurred outside of city limits show general vicinity: "N/A" of nearest city "N/A"

On Road, Street, or Highway: "N/A" At Intersection with: "N/A"

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

X-Coordinate: 00448936
Y-Coordinate: 04604368

Distance "N/A" Direction "N/A" and Distance "N/A" Direction "N/A" of

Milepost Number "N/A" Or Definable intersection, bridge, or railroad crossing "N/A"

If Divided Highway, Provide Route (Cardinal) Travel Direction "N/A"

UNIT 001

Driver's Name - Last	DRIVER
First	IMA
Middle	TEST
Suffix	
Address	1 DOT DATA PROCESSING
City	AMES
State	IA
Zip	50010
Date of Birth	02/28/1954
Driver's License Number	999999996
Gender	Female
State	IA
Class	C
Endorsements	NONE
Restrictions	NONE
Alcohol Test Given?	1 - None
Test Results	
Drug Test Given?	1 - None
Test Results	
Citation Charge Code 1 / Citation Charge 1	
Citation Charge Code 2 / Citation Charge 2	
Citation Charge Code 3 / Citation Charge 3	
Citation Charge Code 4 / Citation Charge 4	
Owner's Name - Last	ANDREWS
First	DON
Middle	W
Suffix	
Owner Company Name	
Address	789 10TH
City	WAUKEE
State	IA
Zip	50367
Insurance Co. Name	AAAAAAAAAA
Insurance Policy #	1234
License Plate #	EGL1
State	IA
Year	2002
VIN No.	2G2FS22G422999998
Year	2002
Make	Pontiac - PONT
Model	2F67
Style	CV
Tow #	
Approximate Cost to Repair or Replace	$5,000.00
Private?	☐
Initial Travel Direction	2
Vehicle Action	01
Speed Limit	45
Point of Initial Impact	08
Most Damaged Area	08
Extent of Damage	4
Underride/Override	1
Total Occupants	1
Traffic Controls	01
Vehicle Config.	01
Cargo Body Type	01
Vehicle Defect	01
Driver Condition	1
Vision Obscured	12
Contributing Circumstances, Driver (up to two)	28
Sequence of Events: First Event	06
Second Event	21
Third Event	
Fourth Event	
Most Harmful Event (by vehicle)	21
Commercial Trailer License Plate #	
Attached to Power Unit / State / Year	
Attached to Trailer Unit / State / Year	
Emergency Vehicle Type	1
Emergency Status	3
Carrier Name / Address / City / State / Zip	
US DOT # or MC #	
Number of Axles	
Gross Vehicle Weight Rating	
Placard #	
Hazardous Materials Released?	

UNIT 002

Driver's Name - Last	MISTER
First	TEST
Middle	RECORD
Suffix	
Address	800 LINCOLNWAY
City	AMES
State	IA
Zip	50010
Date of Birth	04/01/1962
Driver's License Number	999999997
Gender	Male
State	IA
Class	C
Endorsements	NONE
Restrictions	B
Alcohol Test Given?	1 - None
Test Results	
Drug Test Given?	1 - None
Test Results	
Citation Charge Code 1 / Citation Charge 1	FAIL TO OBEY STOP SIGN
Citation Charge Code 2 / Citation Charge 2	
Citation Charge Code 3 / Citation Charge 3	
Citation Charge Code 4 / Citation Charge 4	
Owner's Name - Last	FREMONT
First	YOUNG
Middle	
Suffix	
Owner Company Name	
Address	734 FARRAGUT RD
City	DES MONIES
State	IA
Zip	50305
Insurance Co. Name	BBBBBBBBB
Insurance Policy #	12345
License Plate #	638NDO
State	IA
Year	2003
VIN No.	1FABP42X12F100001
Year	2002
Make	Ford - FORD
Model	P42
Style	2D
Tow #	
Approximate Cost to Repair or Replace	$5,000.00
Private?	☐
Initial Travel Direction	3
Vehicle Action	01
Speed Limit	45
Point of Initial Impact	01
Most Damaged Area	01
Extent of Damage	3
Underride/Override	1
Total Occupants	1
Traffic Controls	04
Vehicle Config.	01
Cargo Body Type	01
Vehicle Defect	01
Driver Condition	1
Vision Obscured	12
Contributing Circumstances, Driver (up to two)	02
Sequence of Events: First Event	21
Second Event	
Third Event	
Fourth Event	
Most Harmful Event (by vehicle)	21
Commercial Trailer License Plate #	
Attached to Power Unit / State / Year	
Attached to Trailer Unit / State / Year	
Emergency Vehicle Type	1
Emergency Status	3
Carrier Name / Address / City / State / Zip	
US DOT # or MC #	
Number of Axles	
Gross Vehicle Weight Rating	
Placard #	
Hazardous Materials Released?	

ACCIDENT ENVIRONMENT				ROADWAY CHARACTERISTICS Major Contributing Circumstances:		WORKZONE RELATED? No	SEQUENCE OF EVENTS
Location of First Harmful Event	1	Weather Conditions (up to two)	08	Environment	2	Location	First Harmful Event of Crash (use codes 11-42 only) 21
Manner of Crash/Collision	5			Roadway	02	Type	
Light Conditions	2	Surface Conditions	4	Type of Roadway Junction/Feature	01	Workers Present?	

DRIVER

Unit No.	Name - Last	First	Phone
001	DRIVER	IMA	

Sex	Seating Position	Injury Status	Occupant Protection	Airbag Deployment	Airbag Switch Status	Ejection	Ejection Path	Trapped
Female	01	3	2	1	9	1	1	1

Transported to:	Transported by:
REFUSED	

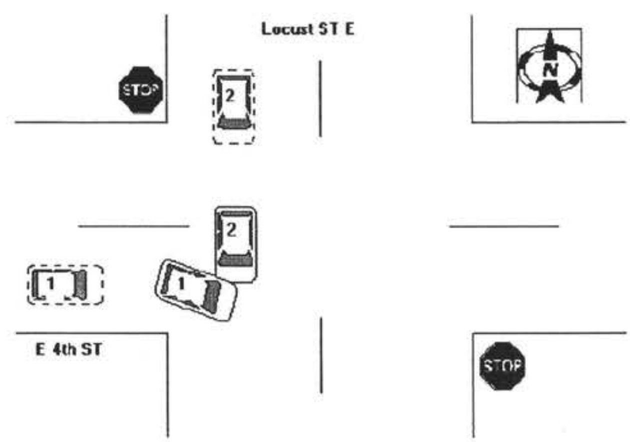
DRIVER

Unit No.	Name - Last	First	Phone
002	MISTER	TEST	

Sex	Seating Position	Injury Status	Occupant Protection	Airbag Deployment	Airbag Switch Status	Ejection	Ejection Path	Trapped
Male	01	4	2	1	3	1	1	1

Transported to:	Transported by:
REFUSED	

DIAGRAM



NARRATIVE

Describe what happened (refer to vehicles by number)

VEHICLE #1 WAS EASTBOUND ON EAST 4TH STREET. VEHICLE #2 WAS SOUTHBOUND ON LOCUST STREET. VEHICLE #2 FAILED TO STOP AT STOP SIGN AND COLLIDED WITH VEHILE #1

Officer	Badge No.	Time Officer Notified of Accident	Time Officer Arrived At Scene
Admin System	00001	19:20 Hrs.	19:30 Hrs.

Name of Agency	Date of Report	Investigation made at scene?	T.I. #
Des Moines Police Department	02/26/2003	Yes	

Report Reviewed By:	Date Reviewed	Report Given to All Drivers?	Other Technical Investigation Agency
		Yes	

Not to scale.

APPENDIX C. Iowa Crash Form 433003

Form 433003
01-01

MAIL REPORTS TO:
Iowa Department of Transportation
Office of Driver Services
Park Fair Mall, 100 Euclid Avenue
P.O. Box 9204
Des Moines, Iowa 50306-9204

PLEASE TYPE OR PRINT

Iowa Department of Transportation
INVESTIGATING OFFICER'S REPORT OF MOTOR VEHICLE ACCIDENT

Sheet ___ of ___
Law Enforcement Case Numbers:
Legal Intervention? ☐ Private Property? ☐

LOCATION

Date of Accident | Time of Accident Hrs. | County | Accident occurred within corporate limits of (city)

If accident occurred outside of city limits show general vicinity ___ miles N NE E SE S SW W NW of nearest city

On Road, Street, or Highway: ___ At Intersection with: ___

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

Feet or Miles N NE E SE S SW W NW and Feet or Miles N NE E SE S SW W NW of

Milepost Number Or Definable intersection, bridge, or railroad crossing

County: ___ Route: ___
X-Coordinate ___
Y-Coordinate ___

If Divided Highway, Provide Route (Cardinal) Travel Direction
NB SB EB WB

UNIT 1

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

Date of Birth | Driver's License Number | Citation Charge 1. ___ 2. ___ 3. ___ 4. ___

Male Female | State | Class | Endorsements | Restrictions

Alcohol Test Given? 1. None 2. Blood 3. Urine 4. Breath 8. Vitreous 9. Refused Test Results:

Drug Test Given? 1 None 2. Blood 3. Urine 9. Refused Pos. Neg

Owner's Name (Last, First, Middle) | Address | City | State | Zip

Insurance Co. Name | Insurance Policy # | License Plate # | State | Year

VIN # | Year | Make | Model | Style | Tow # | Private? ☐ | Approximate Cost to Repair or Replace $

Initial Travel Direction | Vehicle Action | Speed Limit | Point of Initial Impact | Most Damaged Area | Extent of Damage | Underride/ Override

Total Occupants | Traffic Controls | Vehicle Config. | Cargo Body Type | Vehicle Defect | Driver Condition | Vision Obscured | Contributing Circumstances, Driver (up to two)

Commercial Trailer License Plate # | Attached to Power Unit: | State | Year | Attached to Trailer Unit: | State | Year | Emergency Vehicle Type | Emergency Status

Carrier Name | Address | City | State | Zip

US DOT # or MC # | Number of Axles | Gross Vehicle Weight Rating | Placard # | Hazardous Materials Released?

UNIT 2

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

Date of Birth | Driver's License Number | Citation Charge 1. ___ 2. ___ 3. ___ 4. ___

Male Female | State | Class | Endorsements | Restrictions

Alcohol Test Given? 1. None 2. Blood 3. Urine 4. Breath 8. Vitreous 9. Refused Test Results:

Drug Test Given? 1 None 2. Blood 3. Urine 9. Refused Pos. Neg

Owner's Name (Last, First, Middle) | Address | City | State | Zip

Insurance Co. Name | Insurance Policy # | License Plate # | State | Year

VIN # | Year | Make | Model | Style | Tow # | Private? ☐ | Approximate Cost to Repair or Replace $

Initial Travel Direction | Vehicle Action | Speed Limit | Point of Initial Impact | Most Damaged Area | Extent of Damage | Underride/ Override

Total Occupants | Traffic Controls | Vehicle Config | Cargo Body Type | Vehicle Defect | Driver Condition | Vision Obscured | Contributing Circumstances, Driver (up to two)

Commercial Trailer License Plate # | Attached to Power Unit: | State | Year | Attached to Trailer Unit: | State | Year | Emergency Vehicle Type | Emergency Status

Carrier Name | Address | City | State | Zip

US DOT # or MC # | Number of Axles | Gross Vehicle Weight Rating | Placard # | Hazardous Materials Released?

If Property other than vehicles damaged explain | Object Damaged | Estimate of Damage $

Owner's Full Name (Last, First, Middle) | Was owner or tenant notified? 1 – Yes 9 - Unknown 2 – No

Street or RFD | City, State, & Zip Code

SEQUENCE OF EVENTS (Unit 1, Unit 2)
- First Event
- Second Event
- Third Event
- Fourth Event
- Most Harmful Event (by vehicle)
- First Harmful Event of Crash (use codes 11-42 only)

ACCIDENT ENVIRONMENT
- Location of First Harmful Event
- Weather Conditions (up to two)
- Manner of Crash/Collision
- Light Conditions
- Surface Conditions

ROADWAY CHARACTERISTICS
Major Contributing Circumstances:
- Environment
- Roadway
- Type of Roadway Junction/Feature

WORKZONE RELATED? Yes No
- Location
- Type
- Workers Present?

VOID

NON-MOTORIST

Type |__| Location |__|

Action |__| Condition |__|

Safety Equipment |__|

Contributing Circumstances |__|__|

Unit No. of Vehicle Striking |__|

Motorcycle Seating Position
01 - Motorcycle Driver
04 - Motorcycle Passenger
88 - Other (explain in narrative)

SEATING POSITION

01	02	03
04	05	06
07	08	09

10 - Sleeper Section
11 - Enclosed Cargo Area
12 - Unenclosed Cargo Area
13 - Trailing Unit
14 - Exterior
15 - Pedestrian
16 - Pedalcyclist
17 - Pedalcyclist, passenger
88 - Other (explain in narrative)
99 - Unknown

Sex | Unit No. | Seating Position | Injury Status | Occupant Protection | Airbag Deployment | Airbag Switch Status | Ejection | Ejection Path | Trapped

DRIVERS

DRIVER OF UNIT 1 — Phone — Transported to: — Transported by:

DRIVER OF UNIT 2 — Phone — Transported to: — Transported by:

PERSONS INJURED

Name 1. — Date of Birth
Address — Transported to: — Transported by:

Name 2 — Date of Birth
Address — Transported to: — Transported by:

Name 3 — Date of Birth
Address — Transported to: — Transported by:

Name 4. — Date of Birth
Address — Transported to: — Transported by:

DIAGRAM

DIAGRAM WHAT HAPPENED: *Instruction*

Number each vehicle and show direction of travel by arrow:

Use solid line to show path before accident.:

Use dotted line to show path after accident.:

Show pedestrian by.:

Show railroad by.:

Show utility poles by.:

Show motorcycles by.:

Show animal by.:

INDICATE NORTH

NARRATIVE

Describe what happened (refer to vehicles by number)

WITNESSES

Name (Last, First)	Street or RFD	City	State	Zip	Phone

Signature of Officer — Badge No. — Time Officer Notified of Accident ___ Hrs. — Time Officer Arrived At Scene ___ Hrs.

Name of Agency — Date of Report — Investigation made at scene? Y N — Supplemental Information Will Follow? Y N — T.I. #

Report Reviewed by — Date Reviewed — Report Given to All Drivers? Y N — Other Technical Investigating Agency

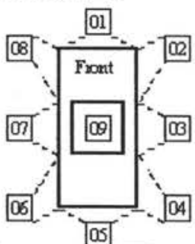
APPENDIX D. Iowa Crash Report Code Sheet

Driver/Vehicle Characteristics

Initial Travel Direction
(prior to coded Vehicle Action)
1 - North
2 - East
3 - South
4 - West
9 - Unknown

Vehicle Action
01 - Movement essentially straight
02 - Turning left
03 - Turning right
04 - Making U-turn
05 - Overtaking/passing
06 - Changing lanes
07 - Entering traffic lane (merging)
08 - Leaving traffic lane
09 - Backing
10 - Slowing/stopping
11 - Stopped for stop sign/signal
12 - Legally Parked
13 - Illegally Parked/Unattended
88 - Other (explain in narrative)
99 - Unknown

Point of Initial Impact
Most Damaged Area



10 Under-Carriage 99 Unknown

Extent of Damage
1 - None
2 - Minor damage
3 - Functional damage
4 - Disabling damage
5 - Severe, vehicle totaled
9 - Unknown

Underride/Override
1 - None
2 - Underride, compartment intrusion
3 - Underride, no compartment intrusion
4 - Underride, compartment intrusion unknown
5 - Override, moving vehicle
6 - Override, parked/stationary vehicle
9 - Unknown

Traffic Controls
01 - No controls present
02 - Traffic signals
03 - Flashing traffic control signal
04 - Stop signs
05 - Yield signs
06 - No Passing Zone (marked)
07 - Warning sign
08 - School zone signs
09 - Railway crossing device
10 - Traffic director
11 - Workzone signs
88 - Other control (explain in narrative)
99 - Unknown

Vehicle Configuration
01 - Passenger car
02 - Four-tire light truck (pick-up, panel)
03 - Van or mini-van
04 - Sport utility vehicle
05 - Single-unit truck (2-axle, 6-tire)
06 - Single-unit truck (>= 3 axles)
07 - Truck/trailer
08 - Truck tractor (bobtail)
09 - Tractor/semi-trailer
10 - Tractor/doubles
11 - Tractor/triples
12 - Other heavy truck (cannot classify)
13 - Motor home/recreational vehicle
14 - Motorcycle
15 - Moped/All-Terrain Vehicle
16 - School bus (seats > 15)
17 - Small school bus (seats 9 - 15)
18 - Other bus (seats > 15)
19 - Other small bus (seats 9 - 15)
20 - Farm vehicle/equipment
21 - Maintenance/construction vehicle
22 - Train
88 - Other (explain in narrative)
99 - Unknown

Cargo Body Type
01 - Not applicable

Truck Cargo Type:
02 - Van/enclosed box
03 - Dump truck (grain, gravel)
04 - Cargo tank
05 - Flatbed
06 - Concrete mixer
07 - Auto transporter
08 - Garbage/refuse
09 - Other truck cargo type (explain in narrative)

Trailer type:
10 - Small utility (one axle)
11 - Large utility (2+ axles)
12 - Boat
13 - Camper
14 - Large mobile home
15 - Oversize load
16 - Towed vehicle
17 - Pole
18 - Other trailer type (explain in narrative)
99 - Unknown

Vehicle Defect
01 - None
02 - Brakes
03 - Steering
04 - Blowout
05 - Other tire defect (explain in narrative)
06 - Wipers
07 - Trailer hitch
08 - Exhaust
09 - Headlights
10 - Tail lights
11 - Turn signal
12 - Suspension
88 - Other (explain in narrative)
99 - Unknown

Driver Condition
1 - Apparently normal
2 - Physical impairment
3 - Emotional (e.g., depressed, angry, disturbed)
4 - Illness
5 - Asleep, fainted, fatigued, etc.
6 - Under the influence of alcohol/drugs/medications
8 - Other (explain in narrative)
9 - Unknown

Vision Obscured
01 - Not obscured
02 - Trees/crops
03 - Buildings
04 - Embankment
05 - Sign/billboard
06 - Hillcrest
07 - Parked vehicles
08 - Moving vehicles
09 - Person/object in or on vehicle
10 - Blinded by sun or headlights
11 - Frosted windows/windshield
12 - Blowing snow
13 - Fog/smoke/dust
88 - Other (explain in narrative)
99 - Unknown

Contributing Circumstances, Driver (up to two)
01 - Ran traffic signal
02 - Ran stop sign
03 - Exceeded authorized speed
04 - Driving too fast for conditions
05 - Made improper turn
06 - Traveling wrong way or on wrong side of road
07 - Crossed centerline
08 - Lost Control
09 - Followed too close
10 - Swerved to avoid: vehicle, object, non-motorist, or animal in roadway
11 - Over correcting/over steering
12 - Operating vehicle in an erratic, reckless, careless, negligent, or aggressive manner

Failed to yield right-of-way:
13 - From stop sign
14 - From yield sign
15 - Making left turn
16 - Making right turn on red signal
17 - From driveway
18 - From parked position
19 - To pedestrian
20 - At uncontrolled intersection
21 - Other (explain in narrative)

Inattentive/distracted by:
22 - Passenger
23 - Use of phone or other device
24 - Fallen object
25 - Fatigued/asleep

Other (explain in narrative):
26 - Vision obstructed
27 - Other improper action
28 - No improper action

99 - Unknown

Emergency Vehicles

Emergency Vehicle Type
1 - Not applicable
2 - Police
3 - Fire
4 - Ambulance
5 - Towing
6 - Military
7 - Maintenance
9 - Unknown

Emergency Status
1 - Yes, in emergency
2 - No, not in emergency
3 - Not Applicable
9 - Unknown

Hazardous Materials Released? (Cargo Only)

1 - Yes
2 - No
3 - Not applicable
9 - Unknown

Iowa Department of Transportation

INVESTIGATING OFFICER'S REPORT OF MOTOR VEHICLE ACCIDENT CODE SHEET

Form 433014
01-01

Workzone Related?

Location
1 - Before work zone warning sign
2 - Between advance warning sign and work area
3 - Within transition area for lane shift
4 - Within or adjacent to work activity
5 - Between end of work area and "End Work Zone" sign
8 - Other work zone area (explain in narrative)
9 - Unknown

Type
1 - Lane closure
2 - Lane shift/crossover (head-to-head traffic)
3 - Work on shoulder or median
4 - Intermittent or moving work
8 - Other type of work zone (explain in narrative)
9 - Unknown

Workers Present?
1 - Yes
2 - No
9 - Unknown

Accident Environment

Location of First Harmful Event
1 - On Roadway
2 - Shoulder
3 - Median
4 - Roadside
5 - Gore
6 - Outside trafficway
9 - Unknown

Manner of Crash/Collision
1 - Non-collision
2 - Head-on
3 - Rear-end
4 - Angle, oncoming left turn
5 - Broadside
6 - Sideswipe, same direction
7 - Sideswipe, opposite direction
9 - Unknown

Light Conditions
1 - Daylight
2 - Dusk
3 - Dawn
4 - Dark, roadway lighted
5 - Dark, roadway not lighted
6 - Dark, unknown roadway lighting
9 - Unknown

Weather Conditions (up to two)
01 - Clear
02 - Partly cloudy
03 - Cloudy
04 - Fog, smoke
05 - Mist
06 - Rain
07 - Sleet, hail, freezing rain
08 - Snow
09 - Severe winds
10 - Blowing sand, soil, dirt, snow
88 - Other (explain in narrative)
99 - Unknown

Surface Conditions
1 - Dry
2 - Wet
3 - Ice
4 - Snow
5 - Slush
6 - Sand, mud, dirt, oil, gravel
7 - Water (standing, moving)
8 - Other (explain in narrative)
9 - Unknown

Roadway Characteristics

Contributing Circumstances, Environment
1 - None apparent
2 - Weather conditions
3 - Physical obstruction
4 - Pedestrian action
5 - Glare
6 - Animal in roadway
7 - Previous accident
8 - Other (explain in narrative)
9 - Unknown

Contributing Circumstances, Roadway
01 - None apparent
02 - Road surface condition
03 - Debris
04 - Ruts, holes, bumps
05 - Work Zone (construction, maintenance, utility)
06 - Worn, travel-polished surface
07 - Obstruction in roadway
08 - Traffic control device inoperative, missing, obscured
09 - Shoulders (none, low, soft, high)
10 - Non-highway work
11 - Non-contact vehicle
99 - Unknown

Type of Roadway Junction/Feature
Non-intersection:
01 - No special feature
02 - Bridge/overpass/underpass
03 - Railroad crossing
04 - Business drive
05 - Farm/residential drive
06 - Alley intersection
07 - Crossover in median
08 - Other non-intersection (explain in narrative)
Intersection:
11 - Four-way intersection
12 - T - intersection
13 - Y - intersection
14 - Five-leg or more
15 - Offset four-way intersection
16 - Intersection with ramp
17 - On-ramp merge area
18 - Off-ramp diverge area
19 - On-ramp
20 - Off-ramp
21 - With bike/pedestrian path
22 - Other intersection (explain in narrative)
99 - Unknown

Harmful Events

Sequence of Events
Most Harmful Event
First Harmful Event
Pre-crash events:
01 - Ran off road, right
02 - Ran off road, straight
03 - Ran off road, left
04 - Crossed centerline/median
05 - Animal or object in roadway
06 - Evasive action (swerve, panic braking, etc.)
07 - Downhill runaway
08 - Cargo/equipment loss or shift
09 - Equipment failure (tires, brakes, etc.)
10 - Separation of units
Non-collision events:
11 - Overturn/rollover
12 - Jackknife
13 - Other non-collision (explain in narrative)
Collision with:
20 - Non-motorist (see non-motorist type)
21 - Vehicle in traffic
22 - Vehicle in/from other roadway
23 - Parked motor vehicle
24 - Railway vehicle/train
25 - Animal
26 - Other non-fixed object (explain in narrative)
Collision with fixed object:
30 - Bridge/bridge rail/overpass
31 - Underpass/structure support
32 - Culvert
33 - Ditch/embankment
34 - Curb/island/raised median
35 - Guardrail
36 - Concrete barrier (median or right side)
37 - Tree
38 - Poles (utility, light, etc.)
39 - Sign post
40 - Mailbox
41 - Impact attenuator
42 - Other fixed object (explain in narrative)
Misc. events:
50 - Fire/explosion
51 - Immersion
52 - Hit and run
99 - Unknown

Injury/Protective Devices

Injury Status
1 - Fatal
2 - Incapacitating
3 - Non-incapacitating
4 - Possible
5 - Uninjured
9 - Unknown

Occupant Protection
1 - None used
2 - Shoulder and lap belt used
3 - Lap belt only used
4 - Shoulder belt only used
5 - Child safety seat used
6 - Helmet used
8 - Other (explain in narrative)
9 - Unknown

Airbag Deployment
1 - Deployed front of person
2 - Deployed side of person
3 - Deployed both front/side
4 - Other deployment (explain in narrative)
5 - Not deployed
6 - Not applicable
9 - Unknown

Airbag Switch Status
1 - Switch in ON position
2 - Switch in OFF position
3 - No ON/OFF switch present
9 - Unknown

Ejection
1 - Not ejected
2 - Partially ejected
3 - Totally ejected
4 - Not applicable (motorcycle, bicycle, etc.)
9 - Unknown

Ejection Path
1 - Not ejected/not applicable
2 - Through front windshield
3 - Through side window/door
4 - Through roof
5 - Through back window/tailgate
9 - Unknown

Trapped
1 - Not trapped
2 - Freed by non-mechanical means
3 - Extricated by mechanical means
9 - Unknown

Non-Motorist

Type
1 - Pedestrian
2 - Pedalcyclist (bicycle, tricycle, unicycle, pedal car)
3 - Skater
8 - Other (explain in narrative)
9 - Unknown

Location (prior to impact)
1 - Marked crosswalk at intersection
2 - At intersection, no crosswalk
3 - Non-intersection crosswalk
4 - Driveway access crosswalk
8 - Other non-intersection (explain in narrative)
9 - Unknown

Action
1 - Entering or crossing roadway
2 - Walking, running, jogging, playing, cycling
3 - Working
4 - Pushing vehicle
5 - Approaching or leaving vehicle
6 - Playing or working on vehicle
7 - Standing
8 - Other (explain in narrative)
9 - Unknown

Condition
1 - Apparently normal
2 - Physical impairment
3 - Emotional (e.g., depressed, angry, disturbed)
4 - Illness
5 - Asleep, fainted, fatigued, etc.
6 - Under the influence of alcohol/drugs/medications
8 - Other (explain in narrative)
9 - Unknown

Safety Equipment
1 - Helmet
2 - Reflective clothing
3 - Lighting
4 - None
8 - Other (explain in narrative)
9 - Unknown

Contributing Circumstances
01 - Improper crossing
02 - Darting
03 - Lying or sitting in roadway
04 - Failure to yield right of way
05 - Not visible (dark clothing)
06 - Inattentive (talking, eating, etc.)
07 - Failure to obey traffic signs, signals, or officer
08 - Wrong side of road
88 - Other (explain in narrative)
99 - Unknown

Not to scale.

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