Evaluation of Emerging Technologies for Traffic Crash Reporting

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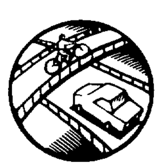

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16. Abstract

An evaluation was performed of the effect of emerging technologies on traffic accident reporting. The technologies evaluated were standard laptop and pen-based portable computers, Global Positioning Systems (GPS), Geographic Information Systems (GIS), computer-based accident diagramming, and various forms of computer-based data entry (e.g., optical character recognition vs. keyboard entry). Data on the use of traditional paper forms were also collected so that comparisons could be made between the use of computers and paper forms. Technologies were evaluated for their effect on accuracy and completeness of data, speed of data entry, practicality (e.g., ease of learning, ease of use), and sturdiness of equipment. Costs of hardware and software used are also provided. The report describes the implementation of these technologies at four sites: (1) Des Moines and West Des Moines, IA; (2) Trenton, NJ; (3) Thurston County, WA; and (4) Dane County, WI. The report provides the results of analyses of the effects of the technologies, describes problems encountered in implementing and using them, and includes recommendations for future implementation.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

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

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

(Revised September 1993)

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BACKGROUND

ACCIDENT DATA PROBLEM

A traffic accident records system is a necessity for a cost-effective safety program at any level of government — local, State, or Federal. The more complete the system, the more potential exists for the application of scarce resources to those accident countermeasures that will be most effective in reducing accidents at the lowest cost.

A traffic records system plays several roles in the highway safety effort. First, it provides information to support the identification and selection of countermeasure activities that will impact specific problems. It is an essential tool for engineering improvements, law enforcement programs, and operations. It provides the data to determine the locations and times for the implementation of selective enforcement programs. It identifies those locations where safety construction improvements will be most beneficial and provides the basis for evaluating and prioritizing the work to be done.

A traffic accident records system is also vital to the State's management of the highway safety Federal safety grant program. It represents the information base and provides the technological framework for identifying safety problems, developing corrective measures, and evaluating actions taken. State highway safety offices depend on this information base to set priorities for allocating Federal grant funds to the various safety programs supported.

Finally, a State traffic accident records system forms the main source for national databases so that assessment of the highway safety problem can be accomplished on a national level. The National Highway Traffic Safety Administration's (NHTSA's) National Center for Statistics and Analysis depends on State data for its two major databases: the Fatal Accident Reporting System (FARS) and the General Estimating System (GES). The Federal Highway Administration (FHWA) also looks to State data systems as the best source of information for identification of safety problems, design and evaluation of accident countermeasures, and development and evaluation of safety programs. For example, these data are absolutely essential for FHWA to identify truck safety problems for administration of its Motor Carrier Safety program and to identify safety problems that should be addressed by the highway construction program.

Traffic accident records files contain a record for each police-investigated and reported accident that occurs within the State. They contain data that describe accident incidents; identify the drivers, vehicles, and roadways involved; and describe the results of the incident on the persons and vehicles involved. Their primary purpose is to serve the operational requirements related to the collection and maintenance of data on traffic accidents within the State. Accident files also serve as the heart or central focus of the integrated traffic records system, that is, they provide a main thread in the interlinking of files within the system and in traffic safety analyses conducted from the data within these files; it is the principal source of data for traffic safety analyses.

While the State traffic accident records systems have grown to meet the demands created by the highway safety program, many deficiencies exist that prevent optimum performance of the systems. State data analysis functions are still hampered by a lack of adequate and reliable accident-related data. Problems with the data include its accuracy, completeness, and the timeliness with which the data make their way into the State traffic accident records system. In many cases, these problems have led to the creation of duplicate systems at the State and local levels. These redundant systems represent a waste of valuable and limited resources.

Uniform, complete, and accurate accident reporting can tell us not only how many accidents we have, but what kind of accidents they are; where and when they occur; the physical circumstances and the people, and the injuries, death, and damage they involve; what emergency services and enforcement agencies responded; and what judicial actions resulted, to mention only the most obvious possibilities. Current paper-based accident report forms as designed by the States are intended to provide objective data for accident analyses and comparisons without being too great a burden to the officers tasked with completing them.

The task of recording information and completing an accident report is often not an easy one. Officers may be called upon to get help for injured persons and may, in some cases, need to assist in their care. Officers must secure the accident scene in an attempt to prevent further accidents and/or injuries. If there is indication of drug or alcohol use, the officer must make arrangements for tests to be made as soon as possible. Officers must obtain information concerning the operator(s) and vehicle(s) involved in the accident. Often this involves dealing with individuals who may be emotionally upset or physically injured. Officers must attempt to get information from injured persons before they are removed from the scene. If this is not possible, officers may need to go to the hospital to collect all required information. In addition to collecting this information, the officer must search for any individuals who may have witnessed the accident.

The officer must check for marks on the vehicle and/or roadway that may indicate what happened in the accident. Environmental conditions, e.g., bad weather, which might have been associated with the accident must be observed. The officer must check the driver's path to identify any obstructions of view and compare this to the actual perception of the accident as stated by the operator(s). Traffic controls are checked to see that they are in operation.

Factors that may have contributed to the accident, such as darkness, inclement weather, and impaired drivers, may make it difficult to gather the information necessary for the report. Often, police officers may be called away from the scene of an accident before the report can be completed. Despite these difficulties, police officers must make certain that information is recorded as completely and accurately as possible, due to the possibility, especially in a severe accident, that the information in the report may eventually be considered evidence for legal proceedings.

Attemps at improving the quality of data collected must take into account the fact that recording accident data is only part of an officer's duties at an accident location, and that dealing with accidents is only part of the officer's duties. Therefore, it is desirable, if not absolutely necessary, to find ways to improve the quality of data without adding to the work involved in recording those data. The use of emerging technologies, such as mobile computers, Global Positioning Systems (GPS), Geographic Information Systems (GIS), printers, and magnetic stripe and barcode readers, has been suggested as a way to improve the quality of traffic accident data, which actually has the potential for making the police officer's job easier. Still, any attempt to improve upon the process through the use of emerging technologies must acknowledge the fact that the typical police cruiser is already overburdened with equipment, so there is very little space left over for computers, GPS receivers, etc. Any such systems also need to be easy to learn and use, because the time available for training is limited and the potential for errors, in such a distracting environment, is high.

HISTORY OF THE EVALUATION OF EMERGING TECHNOLOGIES FOR TRAFFIC CRASH REPORTING PROJECT

The Federal Highway Administration (FHWA), as one of the end users of the data collected from accident reports, has a keen interest in seeing that data are collected in as complete and accurate a manner as possible, and that the data will be entered into the State traffic accident record system in as timely a fashion as possible. The FHWA is also in an ideal position to act as a central agency to aid in the funding of projects aimed at improving the process of reporting traffic accident data, and to act as a clearing house for information on such projects. It is for these reasons that they initiated this project.

The objectives of this study were to:

- Help to coordinate field tests that demonstrate how newly developed technologies could be applied to the collection of highway accident data.
- Gather data from the use of such technologies for the evaluation of their effects on various aspects of the State accident reporting process.
- Evaluate and report the effects of the technologies on the accident reporting process, including such items as data accuracy, time to complete forms, and user acceptance, as well as issues encountered in the implementation of technologies.

The study was developed to determine if these technologies could be effectively used to decrease the demand on the investigating officer while improving the accuracy of the data and the time it took to collect that information.

TECHNOLOGIES CONSIDERED FOR STUDY

This section describes the types of new technology that are potentially applicable to traffic accident reporting and that were considered for inclusion in this study:

- Portable computers.
- Pen-type computers.
- Global Positioning Systems (GPS).
- Geographic Information Systems (GIS).
- Encoded driver's license and vehicle registration documents.

Portable Computers

Portable computers, including those categorized as laptop, notebook, or palmtop computers, were considered for this study because they represent an off-the-shelf solution to the problem of providing computers to police officers for use in police cruisers. Portable computers can also be easily removed from police vehicles for use in the station or anywhere else that an officer might want to work. They can take advantage of software and hardware that have already been created for them. Another reason for studying off-the-shelf laptops within this study is that (theoretically) once a given type of computer was selected, the same type could be provided to all sites participating in the study and the results would apply directly to anyone else who purchased the same type of computer.

Advantages that could be expected from the use of computers by officers include eliminating redundant effort caused by the current need for the data to be entered (by others) into a database from information on the original accident report. The data entered might also be more accurate when this redundant effort is eliminated, because it would eliminate those errors created during the extra data entry step, as well as those errors created when data entry staff misinterpret the data as recorded by the officer.

Further improvements in data accuracy could be expected from the guidance provided by the reporting software during data entry, i.e., where data is entered by making a choice from a list of options, officers are guided into making an entry that is acceptable. For example, when there is only one acceptable name for a given road that may commonly be known by multiple names, having the officer identify the road name from a list will guarantee that the name preferred by the State accident records system is used. If codes are used for a given data element, the software can be made to provide an English language description of each code so that officers can check to make sure that the code number they are entering stands for what they think it does.

One way in which the accident reporting software can help improve data accuracy and completeness is by automating the process of checking the form for errors and missed data elements. Such a process would notify the officer of any required data elements that have been skipped, as well as comparing data entered into different cells for consistency. For example, if lighting conditions are given as bright sunlight and the time is given as 1:00 a.m., the automated check would notify the officer completing the report of the inconsistency so that it could be fixed prior to submitting the report. By identifying these errors early, they can be corrected by the person in the best position to know the correct information and at a time when that information is still fresh in his or her mind.

Pen-Type Computers

Pen-type computers are portable units that allow users to interact with the computer by means of a pen-like device by touching it to the computer screen. They offer the same benefits available from the standard portable computer, plus two additional advantages associated with using a pen. The first is that the pen provides an intuitive pointing device that users may find easier to use than a mouse, trackball, or TrackPoint-type device (a small button embedded in the keyboard that is pushed in different directions to control the movement of the cursor). The second is the ability of users to handwrite characters on the screen that character recognition software can then turn into computer-recognizable characters. Use of optical character recognition in this way has the potential benefit of allowing officers who are not familiar with the computer keyboard to use handwritten characters instead. It also allows the computer to be smaller by eliminating the keyboard.

Global Positioning System (GPS)

The Global Positioning System (GPS) was developed by the U.S. Department of Defense as an aid to navigation. It consists of a set of 24 satellites that orbit the earth and transmit signals that can be received on the ground. Information from those satellites can be used to determine the location of the GPS receiver with a high degree of accuracy. In order to determine a location, the GPS receiver must have information from at least 3 of the 24 satellites. To get an accurate location, the receiver should be in contact with at least four satellites. The more satellites that the receiver is in contact with, the more accurately the location can be determined. With a GPS receiver using satellite signals alone, locations can be determined with an accuracy of about 30.5 m.

The accuracy of GPS can be increased by using what is known as "differential correction." With differential correction, a second GPS receiver is installed at a known location. That receiver can help compensate for errors in the satellite signals by calculating the difference between the location that is supplied to it by the satellites and the location that it knows to be correct. In the case of "real-time" differential correction, that difference is then transmitted to the GPS receiver in the field for use in correcting its own location. "Post-processing" differential correction is a method that involves correcting readings taken in the field at an earlier time by using information on what the error was at that time. Figures on the accuracy of differentially corrected GPS vary. If signals are collected over a long enough period of time, differentially corrected GPS readings have the potential to provide locations accurate to within a centimeter. According to conservative estimates, differentially corrected GPS readings should be accurate to about 5 m in general use.

The signal used for real-time differential correction can come from three sources: (1) the U.S. Coast Guard transmits a differential corrections signal from some locations in the United States, (2) an agency or individual could build its own differential corrections transmitter, and (3) companies transmit signals that can be used for differential corrections. Access to these signals is sold on a subscription basis. Real-time differential correction requires a separate receiver to obtain the correction signal.

In March 1996, the Federal Government announced plans to change the Global Positioning System to allow uncorrected GPS systems to achieve the accuracy now available only from differentially corrected signals. At that time, it was said that implementation of this change was still a few years away. If and when that change takes place, it would greatly simplify the process of using GPS to record accurate locations by eliminating the need for differential correction.

Advantages of using GPS receivers include the fact that they are capable of providing accurate locations and that those locations can be recorded with very little effort from the user as long as the hardware and software is in place and functioning properly. The accuracy of GPS can be affected by obstructions such as tall buildings, tree cover, and tunnels that interfere with the signals received from the orbiting satellites. One aspect of GPS technology that does *not* lend itself to accident reporting as it currently stands is that it provides location information in the form of degrees of latitude and longitude, and States are currently not set up to use latitude and longitude values for identifying accident locations. Another disadvantage of GPS is that it can only be used at the location; once the officer has left the accident scene, it is not possible to use the GPS later to determine where he or she *was*.

Geographic Information Systems (GIS)

A Geographic Information System (GIS) is a computerized system for recording and using data that are related to geographic locations. A GIS can include a map of an area as well as any kind of information that can be referenced to a location in that area. Examples of such information include zip codes, population densities, or locations of utility poles. A GIS used for accident reporting would include information on the road network with a way to identify all points on that road network in a form usable by interested State agencies. It would probably include a map of the area that could be used by the officer to indicate the accident location and/or to verify that the location is correct. It would also probably include road names and other features (e.g., utility poles, bridges, etc.) to aid in the identification of locations on the map.

A primary benefit of using a GIS for accident location is that a location in a GIS is, by definition, tied to some useful piece of information concerning that location. Generally, the GIS would contain information on the road system in a format (e.g., link-node designations) that is useful to the State accident records system. This would guarantee a certain amount of accuracy and usability not provided by GPS-derived latitude and longitude coordinates alone. The GPS coordinates alone, while being accurate, aren't necessarily usable by themselves; some effort needs to be made to convert them to a description of a location on a road. When GPS coordinates are superimposed on a map or GIS database, they won't necessarily appear on a road. This may be due to a lack of accuracy of the GPS reading (perhaps due to nearby buildings). Or it could be due to a lack of accuracy in assigning latitudes and logitudes to locations within the GIS. When the GPS-derived reading does not fall on a roadway within the GIS, and where there are two or more roads in the vicinity of that GPS-derived location, it may be difficult or impossible to determine on which road the crash occurred. Identifying accident locations by indicating the location on a map in a GIS helps make certain that the indicated crash location will be on a road and on the correct road.

Another advantage of using a GIS is that it provides an indication of the crash location (in the form of a spot on a map and/or an English language description) that is easily understood. This makes it relatively easy to verify that the location is accurate. In comparison, it is difficult to verify the accuracy of latitude and longitude coordinates by looking at them. And, unlike GPS, users can use the GIS after leaving the accident location.

Ultimately, the GIS could also provide information that would make it a labor-saving device for the police officer by completing parts of the accident form from a central database. This database could contain such information as what material the road is made of (e.g., concrete, asphalt), the terrain (e.g., curves, hills), roadway configuration (e.g., number of lanes, presence of median strip), and who is responsible for the road (e.g., State, county, private).

Encoded Driver's License and Vehicle Registration Documents

Bar code, magnetic stripe, laser, and integrated circuit chip (ICC) technologies provide the ability to pre-code standard information from the driver's licensing and vehicle registration areas to avoid or reduce manual and redundant entries. At the time this study began, the only system that was being used widely enough to warrant examination was the driver's license with a magnetic stripe. The magnetic stripe driver's license could be used in the preparation of police reports (accident reports, citations, etc.). A magnetic stripe reader could retrieve all the driver data and pass it to a computer both quickly and accurately, as long as the information encoded on the magnetic stripe was up to date and readable.

At the time this project began, it was determined that the States of California and Virginia had issued enough magnetic stripe licenses to warrant their inclusion in this study. However, of the proposals received from State and local jurisdictions wishing to take part in this study, none involved the study of the use of magnetic stripe licenses. Lacking a site at which to study this technology, it was dropped from inclusion in the project.

METHODOLOGY

This section describes the methodology used to evaluate the effect of emerging technologies on the traffic accident reporting process. Issues discussed here include:

- Site selection.
- Participating officers.
- Accident reporting software.
- Technologies selected for study.
- Measures of effectiveness.
- Studies performed.
- Description of systems used.

SITE SELECTION

A request for proposals was sent out from Federal Highway Administration Regional offices for State and regional agencies interested in participating in the study as part of a cooperative agreement. It was hoped that use of the cooperative agreement would allow participating agencies to implement the technologies in such a way that the needs of the study design could be met while allowing maximum flexibility to participating agencies in terms of how the technologies would be implemented. Use of the cooperative agreement also had the effect of decentralizing control over implementation of the technologies, which, in turn, made it more difficult to conduct a controlled evaluation of the technologies.

Four sites were selected for participation in the study: Iowa, New Jersey, Washington, and Wisconsin.

Iowa

The Developing and Emerging Technologies (DET) sites in Iowa (the cities of Des Moines and West Des Moines) are located in Polk County. Polk County has a population of 345,890. Des Moines and West Des Moines have populations of 193,189 and 31,702, respectively.

Participating officers were from the Des Moines and West Des Moines police departments. The City of Des Moines' police department has a total of 350 police officers. The City of West Des Moines has 48 officers. Originally, eight officers from Des Moines and four from West Des Moines were to take part in this project. However, officials in Des Moines decided to conduct a separate study rather than take part in the study as designed and carried out by the other three sites and West Des Moines. The Des Moines study did not involve all eight of their officers. Some of the results from Iowa are based on data from all 12 officers, while other results are from a subset of Iowa officers. Experience reporting accidents as a police officer ranged from 6 to 19 years and averaged 15.31 years for those officers who completed a questionnaire that asked that question.

The data collection period in Iowa ran from the the first week of November 1995 until the last week of April 1996.

New Jersey

In New Jersey, participating officers were from the City of Trenton Police Traffic Unit. Trenton, New Jersey's capital is in the western edge of the State, near the Pennsylvania border. Trenton has a population of 88,675 and is located in Mercer County, which has a population of 329,430.

The Trenton Police Department has 377 officers. A total of 10 officers took part in the study. This includes two officers who had to drop out and were replaced. The majority of data comes from the eight officers who were participating at the end of the data-gathering period. Experience reporting accidents as a police officer ranged from 1 to 23 years and averaged 13.65 years.

The data collection period in New Jersey ran from the third week in October until the last week in December 1995.

Washington

The Washington State Patrol (WSP) in Thurston County participated in the DET project. Thurston County (1883 km^2), with a population of 187,238, includes the City of Olympia (population 33,729), the capital of Washington. Thurston County is located in the western third of the State, approximately midway between the Canadian and Oregon borders. Interstate 5 runs North-South through the county.

In Washington, participating officers were from the Washington State Patrol. The WSP has 24 officers in Thurston County. A total of 16 officers participated in the project. Their years of experience reporting accidents as a police officer ranged from 4.5 to 21 years and averaged 11.10 years.

Data gathering in Washington took place from the first week in June 1995 through the first week in January 1996.

Wisconsin

In Wisconsin, participating officers were from the Dane County Sheriff's Department. Dane County (3121 km^2), with a population of 390,254, includes the City of Madison (the State capital), which has a population of 190,766.

The Dane County Sheriff's Department has 350 officers. A total of 11 officers took part during the entire course of data gathering, though only 8 took part at any one time. Years of experience reporting accidents as a police officer ranged from 3 to 23 years and averaged 13.72 years.

Data gathering in Wisconsin took place from the first week in October through the last week of December 1995.

ACCIDENT REPORTING SOFTWARE

The accident reporting software used in this study was created by American Management Systems, Inc. (AMS) of Fairfax, Virginia. The program used in New Jersey, Washington, and Wisconsin was based on the Mobile Accident Reporting System (MARS) component of the Officer Information Manager (OIM) program developed by AMS for Iowa and already in use there. The purpose of the software *in this study* was to provide a program that could be used for evaluating the technologies under study (computers, GIS, GPS, etc.). It was not the intention of this project to evaluate the software itself. The abilities of the program were necessarily limited, due to time and funding limitations imposed by the project.

The software runs under the Windows for Pen Computing environment. This is essentially a version of the well-known Microsoft Windows environment modified to run on pen-based computers. Data from the OIM program are saved in a series of Microsoft Access tables.

A more detailed description of the OIM/MARS program is provided in Appendix A.

TECHNOLOGIES SELECTED FOR STUDY

Of those technologies that were deemed worthy of study in this project, the following were selected, based upon the desires of the selected sites and the abilities of the sites to implement them:

Computers

Standard Laptop Computer - a standard IBM-compatible laptop computer with color monitor. There were two models used in this study: the IBM 355CS, used in New Jersey, and the IBM 360CE, used in Washington.

Pen-Capable Laptop Computer - similar to the standard, only with a pen-type pointing device. Two types of this computer were used: the Compaq Concerto, used in Iowa, and the IBM 360P, used in New Jersey, Washington, and Wisconsin.

Pen-Capable Computer With Detachable Keyboard - smaller than a laptop, with a keyboard that can be detached so that the section containing the CPU and monitor can be held in one hand and used with just the pen. The computer used in this study was the Fujitsu Stylistic, used only in Wisconsin.

A more detailed description of the computers that were used is found later in Appendix C, Description of Systems Used.

GPS Technology

Iowa, Washington, and Wisconsin were interested in using GPS technology for locating accidents. All States elected to use differentially corrected GPS. The exact equipment used and the source of the differential corrections signal differed from site to site and will be discussed below.

GIS Technology

Washington and Wisconsin were interested in using a GIS for locating accidents. In both sites, the system consisted of software that would display a map of the area. Officers could zoom into certain areas of the map and find the spot where the accident was located. They then used a pointing device to indicate that spot and the GIS recorded that location in the accident record database. More detailed descriptions of the Washington and Wisconsin GIS programs appear in Appendix C.

GPS and GIS Combined

In both Washington and Wisconsin, a system was set up whereby officers who had a GPS reading prior to starting the GIS software would have the location preselected in the GIS upon starting it. This facilitated zooming into the accident location (assuming the GPS reading was accurate). Once zoomed in, officers could change the location indicated by the GPS, if they saw fit. This could be done if, for example, the GPS reading placed the location off the road or at the wrong spot on the road. Unfortunately, there were very few cases during the data-gathering period in which officers used both GIS and GPS together. Therefore, it was not possible to report anything meaningful about the accuracy of such a system based on officers using it in this way.

Paper Forms

In order to determine the effects of emerging technologies on accident reporting, it was beneficial to compare the performance of these technologies with the current system of recording traffic accident data, i.e., using paper forms. A sample of accident reports entered on paper were collected at each site for the purpose of comparing paper reports and computer-generated reports in terms of accuracy, completeness, and time to complete reports.

Collision Diagrams

The collision diagram was not originally considered to be an aspect of the computerized reporting process to be studied. However, the fact that the accident reporting software included two methods of creating the diagram made it possible to compare them. These were:

- The *Electronic Ink* diagram, in which the officer draws the diagram on the screen using the pen, much the same way that one would draw a diagram on paper.

- The *Drag and Drop* diagram, in which the officer constructs a diagram from pre-programmed objects by selecting the objects, moving, resizing, and otherwise manipulating them. The Drag and Drop diagram used an off-the-shelf diagramming software package called Visio Express®.

OPERATING ENVIRONMENT

Except for the use of these technologies, officers participating in this study conducted their business as they normally would. Once officers arrived at the scene, they would start the computer if it was not already running. Generally, computers were configured to start Windows automatically. In some cases, the computers might be in "sleep mode," which is a portable computer feature that allows the computer to shut down some functions and remain running at reduced power levels. In this case, it was possible to resume using the computer in the state in which it had been left when it was put into sleep mode, i.e., it was not necessary to restart the computer, reenter Windows, or restart the accident reporting software.

Once the reporting software was started, officers would log into the database and start a new accident record. Officers would begin data entry by entering information on drivers and vehicles involved in the accident. Officers would then be able to enter other information and to start the GPS and/or GIS software.

Generally, officers equipped with GPS tried to start the GPS software early in the process in order to allow the maximum time for obtaining locks on satellites. It was possible to continue entering accident data while the GPS worked in the background at obtaining locks. It was originally intended that officers would leave the GPS running throughout their shift so that it was only necessary to get a lock on satellites once. This turned out to be difficult for various reasons that will be discussed later. The nature of GPS was such that the reading must be taken at the scene. In some cases, officers were called away from the scene before they could get a reading and, in some cases, they stayed longer at the scene solely for the purpose of obtaining a reading.

The GIS software was slightly different in Washington and Wisconsin. In both implementations, officers would indicate the accident location by selecting the general area in which the accident occurred. They would then zoom into the accident location and locate the accident by clicking on the map at a spot that they felt best indicated the accident location. The detail on the maps was restricted to roads, i.e., it was not possible to include details such as utility poles to aid in the identification of the accident location. In some cases, officers would zoom into an area only to realize that it didn't include the accident location. In this case, it was necessary to zoom out a level or two and try again. Once a minimal amount of driver and vehicle information had been entered, it was possible to begin using the GIS software.

DISTRIBUTION OF TECHNOLOGIES

Technologies To Be Used at Each Site

Table 1 shows which technologies and computers were used at each site.

Table 1. Distribution of technologies across sites.

Technology	Iowa	New Jersey	Washington	Wisconsin
Standard Laptop	None	IBM 355CS	IBM 360CE	None
Pen Laptop	Compaq Concerto	IBM 360P	IBM 360P	IBM 360P
Pen computer with detachable keyboard	None	None	None	Fujitsu Stylistic
GPS	Yes	No	Yes	Yes
GIS	No	No	Yes	Yes
Drag & Drop Diagram	Yes	Yes	Yes	No

Distribution Within Site

In order to eliminate, as much as possible, user effects, seasonal effects, learning effects, and/or order effects upon the evaluation of the technologies, schedules were created for the distribution of technologies at each site. All officers were to be given an opportunity to use each of the computers being tested at their site and each of the location-finding technologies. In New Jersey, only computers were being evaluated. Over the first month of a 2-month data-gathering period, half of the officers used one computer and the other half used the other computer. In the second month, they switched. In Iowa, only one computer was used. All officers used that computer with the GPS for the duration of the data-gathering period. In Washington and Wisconsin, the schedules were more complex and involved the trading of computers, GPS equipment, and GIS software on a periodic basis. Distribution schedules for Washington and Wisconsin are included in this report in Appendix B.

MEASURES OF EFFECTIVENESS

The evaluation plan called for the technologies under study to be evaluated for differences in performance with respect to the following characteristics:

- *Accuracy* - How free are the data from errors caused by either entering incorrect information or by mis-entering information?

- *Completeness* - How many fields are missed that should have been entered?

- *Speed* - How long does it take to complete the report? How long does it take to enter individual data elements?

- *Practicality* - How easy is it to learn and to use the technology? To what extent does the technology interfere with other actions?

- *Sturdiness* - How well does the technology hold up under use in the field conditions?

- *Costs* - What are all the costs involved in implementing the technology?

STUDIES PERFORMED

The combination of technologies and measures of effectiveness lead to a number of smaller studies within the overall study. Each of these studies involved the comparison of technologies with respect to the measures of effectiveness. The following studies were performed:

- Studies of Accuracy and Completeness
    - Study of GIS/GPS Accuracy
    - Study of the Accuracy and Completeness of Paper Forms vs. Computerized Forms

- Studies of Data Entry Speed
  - Time to Complete Report
  - Data Entry Time Per Data Element
  - Learning Effect

- Study of Practicality

- Study of Sturdiness

- Study of Costs

Studies of Accuracy and Completeness

Study of GIS/GPS Accuracy

This study was intended to determine the accuracy of locations recorded using GPS and GIS technology under actual field accident reporting conditions. The accuracy of GPS technology has been determined in the past. However, these findings come primarily from use of GPS equipment by well-trained users who are focusing on the task of using GPS equipment. Police officers at accident scenes have much to deal with without concerning themselves with using GPS equipment to gather location readings. It should not be assumed that officers who are given this equipment can use it to provide readings of the accuracy known to be possible under "laboratory" conditions. Similarly, a GIS can be created that can provide accident location data that are accurate and highly useful when used by highly trained personnel under ideal conditions. It is tempting to believe that this technology can be put into the hands of the police officer at the accident scene and equal accuracy can be realized. This cannot, however, be assumed.

"Disagreement" as a Measure of Accuracy - To find out how accurate a system was, the natural inclination would have been to determine the "true location" of the accident and compare this to the officer's reading. The problem with this approach is finding a method to determine the "true" location. There are various methods that could have been used, each having serious disadvantages. The primary problem with this approach was the potential for biasing results in favor of a technology due to the choice of method for determining the true location.

For example, if it were assumed that GPS readings were an accurate way to determine the "true" location and all locations as recorded by GPS *and* GIS were compared to this "true" GPS reading, the results would have been biased toward GPS, because GPS readings will tend to agree more with GPS readings than with GIS readings. On the other hand, GIS readings might be deemed more appropriate for use as "true" because users will ultimately be using locations in the form generated by the GIS (e.g., "on main street, 100 ft. west of main & green streets"). This, of course, would tend to bias results in favor of GIS. Another possibility would be to compare both readings to a "true" location arrived at through a third system. There are several potential problems with this system. First, the method used to translate each reading to the third type may still benefit one type of reading over the other. For example, if all readings are translated to an English language location, the GIS may be at an advantage, since officers who use the GIS properly are generally guaranteed of at least recording the correct road and roughly the correct spot on that road, whereas even the most accurate of readings from GPS receivers may suffer in the process of translation to English language location, depending on the method used to place that location on a road on the GIS map. It might be possible to use a surveying team to determine true locations, but this would be too costly to do for more than a handful of accident locations.

It was decided that there would be a fundamental difficulty in attempting to evaluate the accuracy of GPS and GIS readings by comparing them to a "true" location, because there is no practical way to determine the true location without biasing the results. The approach that was taken, therefore, was to use a measure of the *agreement between readings* as an indicator of accuracy. That is, if a reading made using a certain system was accurate, it stands to reason that subsequent readings made using the same system would result in the same (or nearly the same) reading. So, the measure of accuracy for GPS-recorded locations is the difference, or disagreement, between original and followup GPS readings, and the measure of accuracy for a GIS-recorded location is the disagreement between original and followup GIS readings. If disagreements are significantly smaller for one type of reading than for another, it would tend to indicate that the former system is more accurate.

Obtaining Disagreement Data - To obtain the data needed to perform the analysis, officials at each site were asked to go back to the accident scene to make a followup location reading for each accident using the same technology used by the officer for the original reading. In addition, a second reading was taken using the other technology (the one not used by the officer). This was useful for two reasons:

(1) It eliminated the need for those conducting followup visits to determine, for each accident, the method of accident location used for the original determination. It also eliminated the chances of mistakenly taking a reading with the wrong equipment.

(2) It made it possible to compare location readings made using *different* equipment in order to gain insight into the inter-equipment reliability. This information turned out to be very useful in understanding the results.

In order to allow those conducting followup visits to find the accident location, officers conducting the original investigation were asked to mark the spot at which the reading was taken by spray-painting a mark at a spot on the side of the road as close as possible to the point at which the reading was made. The side of the road was to be used so that followup investigators, who could not necessarily stop traffic to take a reading, could take a reading safely. It is important to note that the decision to compare followup readings with those taken *where the reading was made* focused the results on differences between subsequent readings, and tended to eliminate the effects of errors caused by differences between the *actual accident location* and where readings were taken. In other words, if an accident occurred at an intersection, but the investigating officer was forced to stop the cruiser 18 m from the intersection, both initial and followup readings were taken where the cruiser was stopped. The error in accuracy caused by not taking the reading at the exact accident location (e.g., the point of first impact) is not a part of the measure of accuracy.

It was known that weather-related road conditions (e.g., snow or ice on roadsides) might be such that the paint mark would not still be visible when the followup visit took place. At the time the plan was made, the data-gathering period was scheduled to begin in spring and last until fall. Unfortunately, problems obtaining hardware pushed the start of data gathering at most sites back until fall. This, coupled with unusually inclement weather in the Midwest, led to a large percentage of accident locations that could not be found for followup readings in Wisconsin. Most of what was learned in Wisconsin, therefore, comes from the experiences of implementing and using the systems, rather than from a comparison of initial and followup readings.

Calculating Disagreements - Both GPS and GIS readings were saved to a database in the form of degrees, minutes, and seconds of arc for both longitude and latitude. A second of latitude is equal to about 31 m. The actual distance varies slightly from the equator to the poles. The number of meters per second of longitude is about 31 m at the equator and diminishes to zero at the poles. In the three sites that were using GPS and/or GIS, a second of longitude is equal to about 21 m.

Disagreements (in feet) between the officer's reading and the followup reading were calculated using the formula below. Degrees, minutes, and seconds of arc were converted to seconds. Lat^O represents seconds of latitude as recorded by the officer, Lat^F is the followup latitude in seconds, $Long^O$ is the officer's longitude in seconds, and $Long^F$ is the followup longitude in seconds. Seconds of latitude were converted to feet using "x," where x equals the number of feet per second of latitude at each site. Seconds of longitude were converted by using the cosine of the latitude multiplied by the feet per second at the equator (101.45 ft/s [30.92 m/s]). The actual distance between the officer's location and the followup location can be determined by finding the square root of the difference in longitudes, plus the difference in latitudes. This results in the following formula:

$$Disagreement=\sqrt{((Lat^O-Lat^F)*x)^2+((Long^O-Long^F)*(\cos Lat^O*101.45))^2}$$

This formula was used to create variables representing the disagreements between initial and followup GIS readings, initial and followup GPS readings, and, for some sites, followup GIS and followup GPS readings. Results of these analyses are found later in this report in the Results section.

As mentioned above, the GPS and GIS were both used in Washington and Wisconsin, and GPS alone was used in Iowa. Difficulties in Wisconsin related to weather and other factors limited the ability to gather followup locations. For this reason, it was not possible to conduct a meaningful analysis of GIS and GPS accuracy in Wisconsin.

Accuracy and Completeness of Paper Forms vs. Computerized Forms

To determine the effect of using computers on accuracy and completeness of the accident data, sites were asked to provide staff to check both computer-generated reports and a sample of paper forms for errors. Generally, this was done as part of the review of forms that is normally conducted by the supervising officer. In Iowa, reports were also checked by staff at the Iowa Department of Transportation. Errors were counted and classified as examples of either missing data or inaccurate data. In Iowa, there were also some cases of illegible or unintelligible entries. The number of errors per form were tabulated and analyzed to determine differences between paper forms and computer forms and between computer type (e.g., pen-capable vs. standard).

Cross tabulations were created showing the number of errors on individual data elements by data entry method (i.e., paper vs. computer or for different computers). This was done only for elements for which there were a significant number of errors and it was done separately for all error types. An adjusted standardized residual was computed for each cell as a means of identifying data elements for which one data entry method was significantly over-represented in errors. The adjusted standardized residual in a contingency table (computed as the residual of a cell divided by an estimate of its standard deviation) can be used to determine where, within a contingency table, observed cell frequencies are significantly higher or lower than expected, based upon marginal frequencies. The magnitude (and direction) of this statistic can be interpreted in the same manner as a z-score, i.e., greater than 1.96 indicates a cell whose observed frequency is significantly greater than expected at the 0.05 level. An adjusted standardized residual less than -1.96 indicates that the observed cell frequency is significantly less than expected. It should be noted that there is no way of knowing from this analysis whether one computer type was over-represented or the other was under-represented, i.e., whether performance with one data entry method seemed superior because officers performed well with it, or because they performed poorly using the other.

Ultimately, circumstances in New Jersey and Washington made it impossible to conduct a controlled study of differences in errors between paper and computerized forms. Therefore, only a discussion of the experience in Iowa and Wisconsin is included in the results section. Washington officials responsible for checking accident reports for errors did report that accident forms of both types submitted during the study appeared to contain few errors and that they did not notice a difference between paper and computerized forms in terms of the number or nature of errors encountered.

Studies of Data Entry Speed

Speed of data entry was analyzed, both in terms of time necessary to complete the report and time spent entering data into individual cells.

Time to Complete Report

Data for time to enter computerized reports came from officers' estimates of time to complete them. In interviews, officers also reported verbally the differences in time to complete the report between paper and computerized forms. Officers filling out paper forms used for the study of data accuracy were also asked to estimate the time they spent on each report and to write that time on the report. Because of problems experienced by New Jersey officers, it was not possible to do a meaningful study of data entry times from the New Jersey data.

Data Entry Time Per Data Element

Analyses of differences between computer types and the time it takes to enter one element of data were performed. Each case in these analyses consisted of the time spent entering data into one cell of the report. These times were derived from a log file created by the accident reporting software. Each time the user exited a data element field, the name of the data element, the date, and time (to the nearest second) would be recorded as an entry in the log. Time spent in each field was calculated as the difference between the time the user exited the previous field and the time he or she exited the current field. There was no way to identify what the user was doing during the time spent in that field. In other words, if an officer spent 8 s in a name field, there was no way to tell from the log whether that consisted of 8 s entering the name or 3 s entering the name preceded by 5 s determining what the name was. Likewise, if the officer entered a field and put the computer down for 10 min before returning to data entry, the time spent in that field would include that 10 min. This contributed to individual field times that were on the order of 1 or 2 days. Since these times were highly skewed, the time variable was transformed to normalize the data. Both log and square-root transformations were performed.

The log file also contained entries that represented cells that were being passed through on the way from one cell to another without data actually being entered in them. While this certainly contributed some noise to the data, there's no reason to believe that officers did this any more with one computer type than with another, so it did not likely bias the results by contributing to lower mean data entry times for a given computer type.

Analyses were performed in two ways: (1) including all cases and (2) including only cases in which data elements took less than 10 s to enter. The second analysis was performed under the assumption that data entry times of more than 10 s included time spent finding information or performing other tasks and were not, therefore, indicative of pure data entry times and would not likely show differences in data entry times between computer types. Both analyses would have included cases in which no data were actually entered in a cell that was being passed through on the way from one cell to another. A time of 10 s was arrived at somewhat arbitrarily. The distribution of data entry times was such that there was no obvious point at which the frequency of data entry times dropped sharply to indicate a point at which true data entry times stopped and only artificially inflated entry times remained. Interviews with police officers indicated that 10 s seemed like a reasonable cut-off point to use.

Learning Effect

To evaluate the extent to which there was a learning effect and how it may have differed by computer type, mean times to enter individual data elements were analyzed for differences across time. This was done in Washington and Wisconsin only, as New Jersey had too short a data-gathering period for the results to be meaningful, and Iowa used only one type of computer.

Study of Practicality

Information for evaluating the practicality of the technologies under study comes from officers' responses to questionnaire items and personal interviews. Questionnaire items concerned personal preferences and the ease with which the technologies could be mastered and used. Questions concerned the different computer types, GIS, GPS, data entry methods (e.g., optical character recognition and scrollable lists), and collision diagramming tools.

During the data-gathering period, each time officers changed from one computer type to another, they were asked to complete a "Computer Questionnaire" containing questions about their experiences with and feelings about the computer they just finished using. Each time officers changed the peripheral location-finding technology they were using (i.e., GIS, GPS, both GIS and GPS together, or neither), they were asked to complete a "Peripheral Questionnaire." Where officers were asked to rank technologies in order of preference, answers were used from the last ranking they made of all questionnaires completed. This was done under the assumption that answers on the last questionnaire represented those made when officers had the greatest amount of experience with the technologies and the greatest amount of information on which to base an opinion. Many of the answers given on this questionnaire were in an open-ended (i.e., fill-in-the-blank) form. To determine the extent to which all officers agreed with common responses to open-ended questions, a second "Post-Study Questionnaire" was created in which these issues were presented in the form of multiple-choice questions. Finally, in Iowa, New Jersey, and Wisconsin, it was possible to conduct personal interviews with some of the participating officers in order to gain further insight into the information supplied on the questionnaires.

Study of Sturdiness

Information related to the sturdiness of the technologies under study came from officers' responses to questionnaires and interviews with local agency officials responsible for supplying the equipment to officers and handling maintenance issues.

Study of Costs

This project was intended only to demonstrate the feasibility of implementing these technologies. It is not possible to assess the cost benefits of using these technologies because to do so, it would be necessary to implement them fully. It *is* possible to discuss the cost involved in acquiring the technologies used in this study. It should be noted that these were the costs at the time that the hardware and software were being procured (late 1994 and early 1995) and that such technologies are known for rapid changes in cost. Tables 22 through 25 (on pages 53 through 56) show the cost of the hardware and software purchased by the participating agencies.

RESULTS

This section describes the results of the various studies across all sites.

STUDY OF DATA ACCURACY AND COMPLETENESS

Because much of the results concerning effects of emerging technologies on data accuracy and completeness come from the same analyses, the results will be discussed together. The various studies concerned with accuracy and/or completeness include:

- Study of GPS and GIS accuracy.
- Accuracy and completeness of paper forms vs. computerized forms.

Study of GPS and GIS Accuracy

This section of the report discusses the results of the studies of GPS and GIS accuracy in the States that used GPS and/or GIS: Iowa, Washington, and Wisconsin. Washington and Wisconsin used both GPS and GIS.

Iowa

In Iowa, there were actually two different studies done, one in West Des Moines and one in Des Moines. It should be noted that while officers in Iowa were equipped with a differential corrections receiver, interviews with officers after the study revealed that there was a great deal of difficulty getting the units to work. In addition to this, the fact that the differential corrections receiver was a separate unit and required extra cabling to connect with the computer and an extra antenna, it was considered too unwieldy to use and was often removed. Therefore, results cannot be interpreted as the accuracy that should be expected from differentially corrected GPS.

West Des Moines - In West Des Moines, data were gathered according to the plan used in Washington and Wisconsin. However, Iowa did not elect to use GIS; therefore, there is no information on GIS accuracy or the agreement between GPS and GIS readings. In some cases, hardware problems made it necessary for officers to fill out paper forms in the field and commit the data to the computer form upon return to the station. In those cases, GPS readings were collected later. It was not possible to identify for the analysis the cases that were not collected at the time the officer was first recording accident data. It has been estimated that these instances were about 10 percent of all cases.

Des Moines - Rather than having officers collect GPS data as part of the accident reporting process, Des Moines elected to conduct a study in which GPS readings were made at a subsample of accident locations in two separate followup visits. The reasons given by Des Moines officials for deciding not to have officers collect GPS data were the difficulty involved in learning and operating the equipment, time involved in using the software and acquiring locks on satellite signals, and GPS equipment was awkward and unwieldy in the police cruiser. While this decision prevents obtaining the results of GPS use by Des Moines police officers in actual accident reporting, the decision does provide feedback as to what will need to be done to make the use of the GPS system for accident location more acceptable to the users of the equipment. The data from Des Moines also provide some information on the accuracy of which the GPS was capable in the field, without including the effects of use under actual accident reporting conditions. This is because, while data were recorded at actual accident locations, the officer taking both GPS readings had more training in the use of GPS hardware and software than did most officers in this study and he/she had more time available for collecting the data and fewer distractions.

In West Des Moines, there were 415 cases in which officers collected GPS data and followup data were also collected. Disagreement between initial and followup readings ranged from 0 to 1095 m. The mean disagreement between GPS readings was 86.67 m and the standard deviation was 115.53 m. In Des Moines, there were 282 cases of multiple readings for the same locations. Disagreements between original and followup readings ranged from 3.86 to 371.71 m, with a mean of 58.47 m and a standard deviation of 49.49 m. Differences in mean disagreements between Des Moines and West Des Moines were statistically significant ($p = 0.000$). Table 2 shows the number of disagreements falling into each of five distance categories:

Table 2. GPS disagreement in Iowa.

Group	Percent of Cases	
	West Des Moines	Des Moines
Disagreement ≤15 m	8.7	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

Washington

In Washington, there were three variables that were useful in understanding the accuracy of the location-finding technologies:

- *GIS Disagreement* - the difference in feet between the officer's GIS reading and the followup GIS reading.

- *GPS Disagreement* - the difference in feet between the officer's GPS reading and the followup GPS reading.

- *GIS-GPS Disagreement* - the difference in feet between the followup GIS and the followup GPS readings (not to be confused with a comparison of officer and followup readings made using GIS and GPS together).

When extreme outlying cases were removed, the mean disagreement between GPS readings was 1333 m, the mean GIS disagreement was 876.3 m, and the mean GIS-GPS disagreement was 120 m. Since the values for all disagreement variables were highly skewed, a log transform was performed prior to testing to determine whether differences in means were statistically significant. Using these transformed variables, independent samples T-tests of disagreements by technology type showed that the differences in means were not significant between GIS disagreement and GPS disagreement ($p = 0.841$). Paired samples T-tests between GIS and GIS-GPS readings, and between GPS and GIS-GPS readings, showed that the difference in means was statistically significant between GIS-GPS disagreements and GIS disagreements ($p = 0.000$) and GPS disagreements ($p = 0.001$). Table 3 shows percentages of cases falling into each of five distance categories.

Table 3. GPS and GIS disagreement in Washington.

DISTANCE	Percent of Cases		
	GPS-Disagreement (N=57)	GIS-Disagreement (N=94)	GIS-GPS Disagreement (N=230)
0 m	14.6	5.9	14.0
0.3 - 30 m	4.2	4.7	17.6
30.8 - 305 m	58.3	75.3	66.5
305.1 - 3048 m	12.5	8.2	0.5
3048.3 - 30,480 m	6.3	4.7	0.9
> 30,480 m	4.2	1.2	0.5

The fact that GIS-GPS disagreements are much smaller than the GPS disagreement and the GIS disagreement would tend to indicate that a large source of variance between officer and followup readings was the officers' difficulty in obtaining correct readings. If the source of variance had been inaccuracies in the GIS or GPS systems themselves, or if the variance had been due to the person collecting followup readings having difficulty using the systems to obtain a correct reading, the followup GIS-GPS disagreements would have more closely resembled GIS disagreements and GPS disagreements.

It should be possible to make GPS and GIS location determinations with a higher degree of accuracy than was evidenced in Washington. The mean disagreement found for GPS readings was 1333 m. The higher level of agreement between followup GIS and GPS readings indicate that a large portion of the GPS and GIS error is in the original officer's reading. There are a number of possible explanations for the apparently high level of error in officers' readings compared to between-technology followup readings:

- *Time Available/Time to Get Satellite Lock* - The person who was responsible for followup readings had as much time as necessary to get readings and had none of the distractions associated with police work. In addition, he/she was able to leave the GPS receiver on continuously, so that a lock was maintained on the GPS satellites. This made it possible to get a GPS reading in a few seconds. The police officers also had the ability to leave the GPS running, but had problems with other software conflicting with the GPS software. In addition, officers driving unmarked cars often chose not to leave the GPS antenna mounted when not at an accident scene. Often, police officers were called away from the accident scene a few minutes after arriving. For these reasons, officers were often not able to get a lock on the GPS satellites while at the accident scene. Officers were asked the average time needed to get a lock on satellites and the percentage of time they had to leave the accident location before obtaining a lock. The mean for responses in Washington was about 8 min to get a lock and they needed to leave the accident location 17.5 percent of the time prior to getting a lock. It has been suggested that some very large disagreements in officers' and followup GPS readings were a result from readings that could not be made at the accident location and were recorded elsewhere later.

- *Number of Satellites* - The GPS software allowed users to collect a reading as soon as a lock was obtained on three satellites. However, the longer the receiver was left on, the more satellite signals that could be received. The more satellite signals received, the more accurate the signal. Since the GPS receiver used for followup readings was left on constantly, followup readings were generally based on four satellites. Officers' readings were more likely to be taken after achieving a lock on only three satellites.

- *Training* - The person conducting followup readings was far more familiar with the operation of the accident location hardware and software than the officers. Officers were scheduled to receive 10 h of training in the use of the accident reporting hardware and software. For the sake of officers who were not very familiar with computers, much of this time was spent learning how to operate in the Windows environment and performing other tasks not directly related to the GIS and GPS hardware/software. Some additional Windows training was provided to officers as part of another project. Not all officers were able to attend all of the training sessions. While it would obviously have been beneficial for officers to receive more training, it would have been difficult or impossible to have the additional access to officers necessary to provide more training. It is possible that, with more training, officers would have been able to use the GPS and GIS to record more accurate readings.

- *Use of GPS and GIS Together* - The research design called for officers to record locations under four configurations: (1) no location-recording equipment, (2) GIS software alone, (3) GPS software/hardware alone, and (4) GPS *and* GIS equipment in a configuration that allowed a GPS location to be recorded and read into the GIS software for faster, potentially more accurate GIS readings. There were 103 accidents reported by officers equipped with both GPS and GIS technology. Of these, only nine cases (9 percent) included both types of location-recording equipment. This would indicate that officers were not taking advantage of the ability to use both GPS and GIS.

The person conducting followup readings was equipped with both GPS and GIS and was asked to take readings with both at each accident location. This made it possible for him to compare readings from the two different technologies for accuracy. In many cases, he used the equipment in the manner described under configuration 4 (above) because he found that it worked faster than using each separately. Under this configuration, if a GPS reading was taken that was highly inaccurate, the GIS would provide a check for the GPS reading by placing the location at a point that was obviously incorrect. The followup GPS reading could then be retaken. The person who took the followup readings has indicated that a GPS reading was taken first, in order to speed the process of finding the GIS location, in about 95 percent of the cases (as opposed to 9 percent of the officers' cases). He further estimated that about 10 percent of the time, a GPS reading was retaken when the GPS location, as placed on the GIS map, appeared questionable. This would help explain the greater accuracy of the followup readings and would tend to show that using both GIS and GPS together leads to faster GIS readings and may contribute to more accurate GPS readings.

- *Lack of Usefulness* - It had been intended that both GIS and GPS would pass their locations on to a database that would then provide a description of the accident location that could be entered into the report form in a format acceptable by Washington (e.g., "on Main St., 50 feet west of 5th St."). Unfortunately, this database could not be completed in time for use with this study. It was necessary, then, to ask officers to determine and enter the location in the way they always had, plus take a reading using the GIS and/or GPS. Since it was not necessary to make GIS or GPS readings in order to complete the report, officers would not be as highly motivated to take a reading or to take care to make an accurate reading.

- *Unknown Signal Quality* - The GPS software would tell officers when it was possible to take a reading, but it would give no information as to the quality of that reading. It was therefore possible to take readings with a lock on only three satellites (as discussed above) or when a differential corrections signal was not being received. In fact, there may have been many cases in which there was no differential correction signal due to the fact that differential corrections came into the computer via a serial card that malfunctioned frequently.

Learning Effect - Washington was the one site where sufficient location data were gathered over a long enough time for an analysis of changes in accuracy over time. Figure 1 shows changes in accuracy of location readings over the course of the data-gathering period. Because the location disagreement readings were highly skewed, the variable being graphed is actually a log transformation of the original disagreement value. Note that the GIS-GPS disagreement line appears as it does because followup readings were taken intermittently throughout the data-gathering period. Followup readings lagged behind officers' readings in order to allow a backlog of locations to build up that could be visited more efficiently.

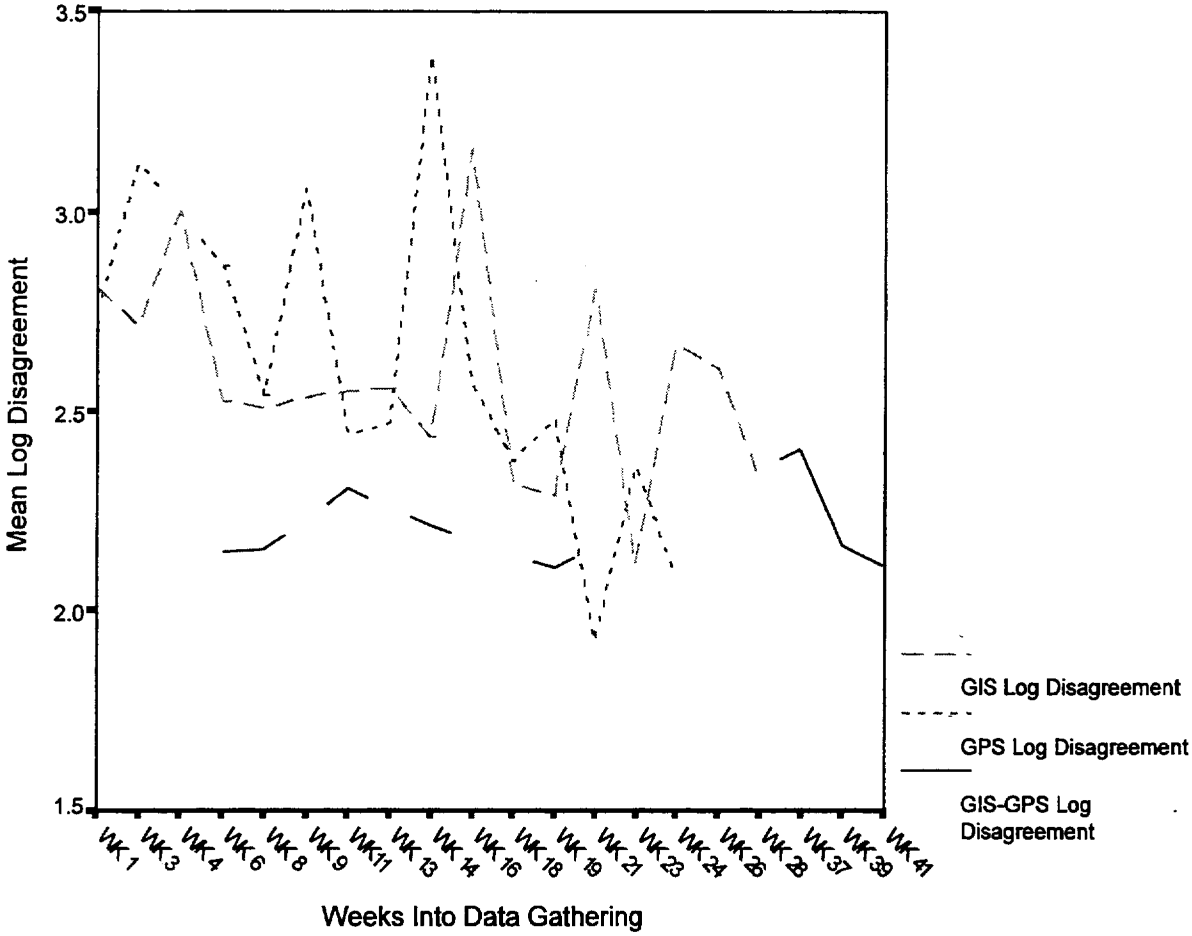


Figure 1. GIS and GPS disagreement over time in Washington.

A regression analysis was performed that found that there was a significant downward trend for both GPS and GIS disagreements (one-tailed significance for log GPS disagreement, $p = 0.034$; for log GIS disagreement, $p = 0.027$). There was no significant reduction in GIS-GPS disagreement over the course of the data-gathering period. This would tend to indicate that officers were able to get increasingly more accurate readings over time, while followup readings did *not* become more accurate over the course of the study. This bolsters the theory that one of the reasons for differences in accuracy between officers' and followup readings was the amount of training and experience with the technologies.

Effect of Users - The number of officers using the GPS and/or GIS in Washington made it possible to perform a meaningful analysis of the effect of user (officer) on location accuracy. When all cases are analyzed, there was no significant effect of user on either GIS disagreement or

GPS disagreement. When extreme outliers and a case for a user with only one sample were removed, the effect of the user on GIS disagreement and GPS disagreement is still not significant, although it comes close to significance for GIS disagreement ($p = 0.09$). This is not surprising given that the GIS requires far more user input.

Effect of Computer - An analysis was performed to determine whether there was any interaction between computer type and GIS and/or GPS location accuracy. None was found.

Summary of the Study of GPS/GIS Accuracy

GPS Accuracy - While all officers who were using GPS in this study were equipped with differential corrections receivers, the evidence indicates that in many cases, it may not have been working or was not being used. The results, therefore, cannot be considered an accurate reflection of the accuracy that is possible using differentially corrected GPS technology. What *can* be said with some certainty is:

- Before attempting to implement a system for using GPS to gather location data for accident reporting, all systems and subsystems will need to be thoroughly tested.

- To be accurate, the system will need to be implemented in such a way that it can be used easily. Components such as differential corrections receivers must either be attached in such a way that they can remain securely connected, or be made part of a docking system so that they can be attached and detached easily. Care will need to be taken to ensure that equipment associated with the GPS does not interfere with movement within the cruiser.

- Some means should be devised for keeping GPS receivers running in order to maintain a lock on GPS satellites. This is because there may not be time to start the process of obtaining a lock on satellites upon arriving at the accident and to be able to obtain a lock prior to having to leave the accident scene.

- The system should be designed so that it either provides some information to help determine the probable accuracy of the reading, or does not allow the reading to be used unless there is a lock on at least four satellites.

GIS Accuracy - The GIS used in Washington and Wisconsin as part of this study were first attempts by the participating agencies at creating a GIS for location finding as part of the accident reporting process. At both sites, the systems suffered from problems that could have been fixed if more development time had been available. Officials in Washington have indicated that newer versions of the ArcView software have been released since the Washington GIS was created that would contribute to a significant improvement in the GIS, in terms of both ease of use and reduction in time to run the application.

Conclusions as to the accuracy of the GIS must depend on the results of the Washington study because so little data were available from Wisconsin. This study found that the GIS was neither more nor less accurate than the GPS in terms of the agreement between readings by multiple users at the same location. GPS accuracy could be significantly improved by taking steps such as those described above, in which case, GPS might be more accurate. How to improve the accuracy of GIS readings is somewhat less apparent. It might be accomplished by improving the GIS in such a way as to include more features and landmarks on the map to aid in location identification, by providing more training, or by making it quicker and, therefore, easier to use. Many of these improvements could be achieved today through the use of improved software and more powerful hardware than was available at the time of this project.

Accuracy and Completeness of Paper Forms vs. Computerized Forms

Iowa

It should be noted here that the accident reporting software used at all sites in this study was based upon a program first developed for the State of Iowa and implemented in Des Moines and West Des Moines. The software used in Iowa was more highly developed than that used in the other sites and included automated checks for missing and inaccurate data that could not be made available to the other sites using the time and funds available for this project.

An analysis of data completeness and accuracy was performed for 475 accident reports that were completed on paper forms and 478 accident reports completed on computers. Computerized reports came from both Des Moines and West Des Moines. Paper reports came only from Des Moines since all officers in West Des Moines were using computers for accident reporting. Reports were checked and errors were noted, first by the supervising officers, then by officials at the Iowa Department of Transportation.

The number of errors was tabulated and categorized into three types of errors: (1) missing data, (2) inaccurate data, and (3) data that were unintelligible. An analysis found a mean of 3.24 errors per paper accident report and 1.10 per computerized report. The difference in means was statistically significant ($p = 0.000$). Figure 2 shows the number of errors for each error-type category, as well as the number of cases containing no errors, for paper and computerized forms.

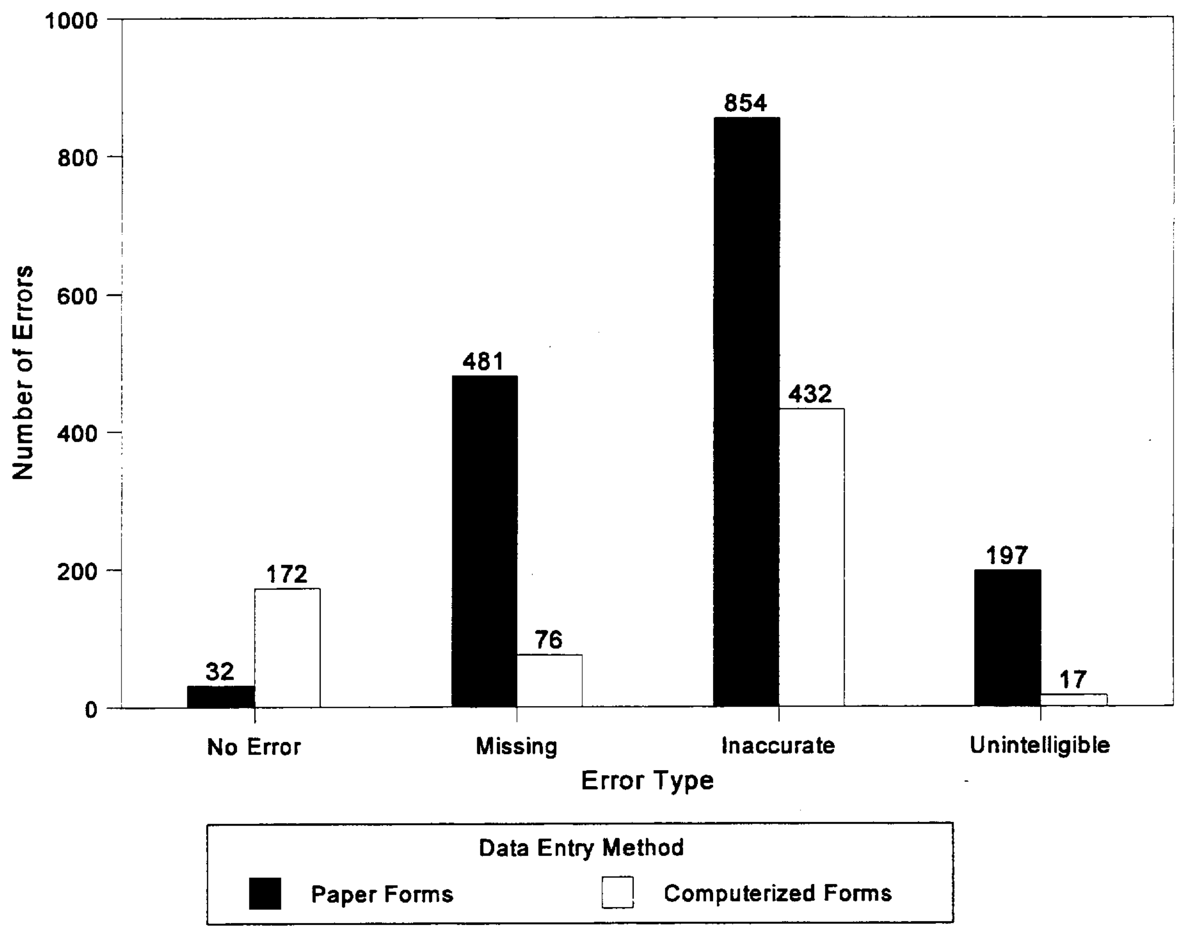


Figure 2. Comparison of errors by error type in Iowa.

Missing Data - There were 557 errors involving missing data. The data elements associated with 10 or more errors are listed below. These nine elements accounted for 75 percent of all errors involving missing data.

Table 4. Frequent missing data errors in Iowa.

Data Element	Paper Forms	Computerized Forms
Day of the Week Code	132	0
Distance From Milepost or Intersection	82	7
Vehicle Style	73	0
Vehicle Model	31	0
Collision Diagram or Element Thereof	26	3
Damaged Area of Vehicle	24	0
Collision Type	17	0
Zip Code	0	16
Initial Direction of Travel	11	0

There were four data elements for which officers were significantly more likely to omit data when using the *paper forms*. In fact, for these elements, all cases of missing data were from paper forms. They were: Damaged Area of Vehicle, Day of the Week Code, Vehicle Model, and Vehicle Style. All errors for Collision Type and Initial Direction of Travel were also from paper forms. The lack of statistical significance for this difference is due to the relatively low number of these types of errors. All cases of missing Drivers' Zip Codes were from *computerized forms*.

Inaccurate Data - Of 1286 errors classified as inaccurate, 90 percent fell into 1 of 24 categories of data elements. Discussions with officials at Iowa DOT indicate that some of the errors identified in the error checking process may not actually have been errors. These are primarily cases in which data as coded by the officer do not match information given in the narrative. Persons responsible for error checking were basing their judgments largely on the information in the narrative. Often, the officer is aware of information not available in the narrative that caused him or her to code the accident form differently. For example, the narrative may say "driver stated that accident occurred due to brake failure"; however, vehicle defect is not given as a contributing factor. This may be because the officer has evidence that the brakes were functioning normally and that the driver's statement was an attempt to cover for his or her own improper driving. Data elements for which it is likely that police officers' original entries were correct are marked with an asterisk (*) in table 5.

Table 5. Frequent inaccurate data errors in Iowa.

Data Element	Paper Forms	Computerized Forms
Vehicle Type Code	87	67
Collision Type	83	62
Roadway Geometrics	107	7
Character of Roadway	68	37
Driver-/Vehicle-Related Contributing Circumstances*	53	47
Initial Direction of Travel	49	29
Vehicle Action	42	16
Total Amount of Property Damage	29	25
Type of Accident	44	8
Damaged Area of Vehicle*	40	9
Vehicle Model	23	18
Point of Initial Impact*	28	11
Traffic Controls*	17	12
Road Class Code	13	12
Collision Diagram*	9	13
Narrative*	9	10
Roadway-/Environment-Related Contributing Circumstances*	13	3
Surface Conditions*	14	1
Location of Accident	11	3
Vision Obscured*	7	7
Approximate Cost to Repair or Replace*	10	3
Vehicle Body Style	7	5
Vehicle Defect*	9	1

* Data element for which it is likely that police officer's original entry was correct.

Data elements that were more likely to be judged inaccurate on paper forms included damaged area of vehicle, roadway geometrics, surface conditions, and type of accident. Data elements that were more likely to be judged inaccurate on computerized forms included collision type, driver-/vehicle-related contributing circumstances, collision diagram, total amount of property damage, and vehicle type code.

Unintelligible Data - Of 214 errors related to unintelligible data, 48 percent were related to 1 of 5 data elements:

Table 6. Frequent unintelligible data errors in Iowa.

Data Element	Paper Forms	Computerized Forms
VIN Number	25	0
Narrative	20	3
Driver's Name	21	0
Vehicle Model	19	0
Collision Diagram	3	12

For unintelligible data, the only data element that was significantly associated with a particular data entry method was the collision diagram. The statistical significance here probably stems from the fact that it is the only cell in which the majority of cases are from the computer cases (nearly all other cases are from paper forms). That the majority of unintelligible data are from paper forms is not surprising given that one of the advantages projected for computerized accident reporting is that the keyboard-entered data are likely to be more easily read than handwritten entries on paper forms. The number of computerized collision diagrams deemed unintelligible is probably related to the fact that the collision diagram was the only part of the computerized report that involved hand-entered information, as opposed to typed characters. That there would be more problems with a computer-generated diagram than a paper form may be a function of the reduced resolution of the computerized diagram and difficulties drawing on the computer screen as compared to paper.

Wisconsin

In Wisconsin, a study was done on the accuracy of data for 273 paper forms and 156 computerized forms. Errors were separated into two types: missing data and inappropriate data (data that had been entered, but had been identified by Wisconsin officials as being inaccurate). Unlike Iowa, there was no separate check for unintelligible entries.

Initial analysis found an error rate for computerized forms that was 83 percent higher for missing data and 55 percent greater for inaccurate data. Differences in mean errors between computerized and paper forms were statistically significant for missing data (p=0.006), but not for inaccurate data. However, interviews with Wisconsin officials and police officers revealed that there was a problem with the accident reporting software that caused it to lose the information entered into the "reportable accident" cell. It was also revealed that the "severity" and "medical transport" cells were often not filled out because, although they were required to be entered for all cases, the software was designed to only allow them to be entered in cases where the officer had entered that an injury had occurred. Since it can be assumed that, were this program actually to be implemented, there would be sufficient time for pilot testing to identify problems such as this, it seemed reasonable to remove these data elements from the error counts and rerun the analysis. When cases involving these data elements were eliminated from the analysis, the computerized forms actually had a slightly lower mean for missing data, with mean missing data errors for paper forms reduced to 0.48 and the mean for computerized forms reduced to 0.44. This mean for computerized forms is 8 percent lower than for paper forms, as opposed to 83 percent higher when all data elements are included. The difference in means is non-significant (p=0.756). The mean number of errors per report by error type and data entry method is shown in table 7. These means are for errors after removing those elements affected by limitations of the software.

Table 7. Mean errors in paper vs. computerized forms in Wisconsin.

	Paper Forms	Computerized Forms
Missing Data	0.48	0.44
Inaccurate Data	0.20	0.31

Of 41 data elements for which there were more than 1 instance of missing data, there were 5 elements for which officers performed better using the computer. Those were "estimated distance from cross street," "speed limit," "manner of collision," "extent of damage," and "truck and bus information." In interviews with Wisconsin officials and police officers, no one could identify a reason for these elements being over-represented.

There were three elements for which officers performed better using the paper form. These were the three elements identified as being difficult or impossible to enter due to limitations of the software ("reportable accident," "severity," and "medical transport").

Of the 26 data elements for which there were more than 1 instance of inaccurately coded data, there were 2 elements for which officers performed better using the computer: "ejected?" and "most harmful event."

Officers' interviews suggested that the improved performance for the element "most harmful event" may have been due to the fact that this element is one of the more difficult to code correctly and that the officers participating in the study who used computers may have had more experience than those who filled out the paper forms. There were no suggestions as to why the "ejected?" field was under-represented for errors on the computer.

There was one data element for which officers had significantly fewer errors using paper forms. This was the element in which officers recorded whether the accident involved a commercial motor vehicle. Officers and officials interviewed had no suggestions as to why this data element was under-represented for errors on the paper forms.

Summary of the Study of Data Accuracy for Paper Forms vs. Computerized Forms

There is no question that in cases in which there is an automated process for checking the accuracy and completeness of the computerized forms, as there was in Iowa, that the number of missing and erroneous data elements can be reduced when computers are used. This reduction comes not just from the computer catching errors that might otherwise have gone through, but by giving officers feedback concerning errors. It was reported that in Iowa after officers first began using the automated error checking, the program was initially identifying a relatively high number of errors. The number of errors identified by the computer dropped quickly soon after officers began getting feedback concerning the accuracy and completeness of their reports. Even in Wisconsin, where there was no automated error checking, the evidence indicates that (once the software has been thoroughly tested) there will be no loss of data accuracy and that there could be an improvement from the use of computerized accident reporting.

The results would tend to indicate that, even without error checking, officers should be able to turn in reports that are comparable to paper forms in terms of completeness and accuracy. In fact, when one considers that officers in this study were just learning how to use the computers, and that officers filling out paper forms had far more experience with them, it seems entirely possible that, in time, performance on the computer might have surpassed that on paper forms. Officers who were interviewed expressed the belief that they were more likely to enter data for some elements when using the computer because the computer prompted them for the information.

STUDY OF DATA ENTRY SPEED

The study of data entry speed includes analyses of time to complete the entire report, data entry times per data element, and learning effects on data entry speed.

Time to Complete Report

Iowa

In Des Moines, Iowa, the information that was supplied for the study of time to complete the report came in the form of data from activity logs. For each accident, the total time spent investigating that accident and completing the report was logged. While these totals include noise in the form of time spent on case-related tasks other than completing the report, there is no reason to believe that this noise would differ for accidents reported using computer forms vs. paper forms. An analysis of total time spent at the accident found a mean time of 72 min for accidents reported using paper accident forms and 112 min for accidents reported using computer reports. The difference in these means was highly significant ($p = 0.000$).

Washington

In Washington, officers from nearby Pierce County were asked to estimate the time to complete each paper form they submitted and to write the estimate on the form. Estimates of time to complete paper forms were made for 342 accidents. These times ranged from a minimum of 5 min to a maximum of 60 min. The mean time to complete a form was 25.62 min.

Officers participating in the study estimated the average time to complete a computerized report. Times ranged from 17.5 to 60 min, with a mean estimated time of 36 min.

Wisconsin

In Wisconsin, 798 accidents on paper forms were examined. Of these, officers reported an approximate length of time to complete the form for 553 forms. Minimum time reported was less than 1 min. Maximum time was 180 min. Mean estimated time to complete the report was 34 min. Estimated times to complete computerized reports ranged from 20 to 40 min and averaged 32.5 min. While the mean estimated time to complete the report was actually lower for the computerized report, interviews with officers revealed that they were under the impression that it took them longer to complete the computerized report. It may be that using estimated times masked the true differences and that it did, in fact, take longer for computerized reports. It does appear that officers estimating time to complete the report were considering "normal" accidents that had fairly low times (40-min maximum), whereas the mean for paper forms included more involved reports (up to 180 min) that increased the mean.

Summary of the Study of Time to Complete Report

When information from all sites was evaluated, it would appear that officers were taking more time to complete the computerized reports. It would also appear, not surprisingly, that the difference in completion times between computerized and paper forms can be reduced over time as officers become more familiar with using the computerized form. Given this fact, the large differences in time to complete computerized cases vs. paper report cases in Iowa is somewhat puzzling because officers in Iowa had far greater experience using the computer. It is important to remember that completion-time data in Iowa came from activity logs and contained much time spent on tasks other than completing the accident report.

Data Entry Time Per Data Element

Iowa and New Jersey

There was not sufficient data from New Jersey and Iowa to perform a meaningful analysis of data entry time per element. In addition, the analysis would not have been meaningful for Iowa since its purpose was to describe differences between computer types, and there was only one type of computer being used in Iowa.

Washington

Analyses were performed in two ways: (1) including all cases and (2) including only cases in which data elements took longer than 10 s to enter. In both cases, there was a statistically significant tendency for officers to take slightly more time using the pen computer ($p = 0.000$). While this would seem to indicate that using standard computers was faster than using pen-based computers, it should be noted that the statistical significance found is most certainly due to the large sample size and the actual effect of size is extremely small, indicating that there was probably no sizable effect of computer type on data entry time. In any case, the differences between computer types amount to about 40 ms per element entered. This would amount to a savings of only about 4 s for every 100 elements entered. This difference in mean time could easily be a result of the fact that the standard computer was a faster (50 MHz) machine than the (33 MHz) pen-based computer.

Wisconsin

In Wisconsin, analyses were based upon data from the entry of more than 45,000 individual data elements. Times ranged from less than 1 s to 80,105 s. An analysis of data entry times found no significant differences between computer type when analyzing all cases. When filtering out cases with times greater than 10 s, only analyses of the log of time (as opposed to actual time or the square root of time) showed a significant difference between computer types. This difference was extremely small; data entry times were about 1 percent faster on the IBM 360P.

Summary of the Study of Data Entry Time Per Data Element

The results of this study indicate that there is no real advantage, in terms of data entry speed, of using one type of computer over another.

Learning Effects

In Washington and Wisconsin, there were sufficient data to perform analyses of the differences in learning effect between computer types. While these analyses were extensive, they ultimately showed no differences that were worth reporting.

STUDY OF PRACTICALITY

Information for the study of practicality comes from questionnaire data and interviews with participating officers. For the sake of efficiency, all sites will be discussed together for each issue in this section.

Ranking of Configurations

Officers were asked to rank paper forms and the various system configurations in order of preference. Results include only data from Washington and Wisconsin. New Jersey is omitted because it did not use GPS or GIS, and there were too few responses on this question from Iowa to be able to say anything meaningful. Table 8 shows the mean relative rankings by site.

Table 8. Ranking of configurations.

	Paper Forms	Computer Alone	Computer w/ GPS	Computer w/ GIS	Computer w/ GPS & GIS
Washington	0.38	0.58	0.54	0.51	0.52
Wisconsin	0.64	0.66	0.55	0.42	0.42

It is interesting to note that both sites ranked the computer higher than the paper forms. While the difference in Wisconsin is small, it may be that Wisconsin officers would have ranked the computer higher had they had more time to get used to it, as Washington officers had. These relatively high rankings for the computer may also reflect the belief, stated by many officers, that using the computer is not particularly difficult and that using computers in the field for police work, including accident reporting, is inevitable.

Officers had a harder time seeing the benefit of using GPS and/or GIS for location finding. This is not too surprising given that, as implemented in this study, there was no benefit to the officer in using these technologies. Comments made by Wisconsin officers on questionnaires indicate that they had far more problems using the GIS and getting what they felt were satisfactory results than in using the GPS. This may explain why both configurations involving GIS were ranked well below all other configurations.

Ranking of Computer Type

Across all sites, officers who used both pen-based and standard computers tended to prefer the pen units because they provided more flexibility in terms of user interface, i.e., officers could choose between the pen or the keyboard, whereas with the standard unit, they were limited to the keyboard and the pointing device embedded in the keyboard. There were some officers who stated a preference for the standard laptop over the pen-based computer. This was generally because they found no particular advantage in using the pen and saw a disadvantage in the potential for losing it or having it malfunction.

In Wisconsin, officers used both one-piece pen computers and smaller pen computers with detachable keyboards. Officers indicated that they recognized that the difference between the computers represented a tradeoff between the increased portability and flexibility of the computer with a detachable keyboard vs. the convenience of one-piece construction and the ease of viewing with the unit having the larger, color screen. The officers seemed to prefer the advantages offered by the one-piece computer.

Rating Practicality of GPS and GIS

Officers were asked how practical they considered the use of GPS receivers and GIS software to be as part of the accident reporting system (compared to not using them). The tables below show responses to questions related to the practicality of GPS and GIS across all sites that used them.

Table 9. Rating practicality of GPS and GIS.

How practical was the use of a ***GPS*** receiver as part of the accident reporting system (compared to not using it)?				
	Iowa	Washington	Wisconsin	ALL SITES
1. Much less practical	1	2	3	6
2. Somewhat less practical	2	1	0	3
3. About the same	0	3	2	5
4. Somewhat more practical	0	2	1	3
5. Much more practical	0	1	2	3
MEAN RATING	1.67	2.89	2.88	2.70

The majority of people who responded to the question on GPS practicality were from Washington and Wisconsin. Their mean rating can be interpreted as saying that they found using the GPS only slightly less practical than not using it. In the absence of any real benefit to be gained (by them) in using the GPS, this can be considered a positive outcome. Reasons given for judging GPS to be practical included a perceived potential for highly accurate locations and ease of use ("all you have to do is push a button"). Reasons for judging GPS to be impractical include: experiencing problems getting it to work; GPS readings must be done at the scene; heavy traffic does not allow recording accident locations in intersections; it was not always possible to get a lock and locations were, therefore, not always accurate; the accident reporting program required users to enter some data before starting the GPS software; and, as implemented, recording GPS readings was unnecessary extra work.

Table 10. Rating ease of learning GPS.

How easy was it to learn to use the ***GPS*** receiver?				
	Iowa	Washington	Wisconsin	ALL SITES
1. Very difficult	0	0	0	0
2. Somewhat difficult	1	0	2	3
3. Somewhat easy	2	3	0	5
4. Very easy	0	5	6	11
MEAN RATING	2.67	3.63	3.50	3.42

As suspected, the GPS was perceived to be relatively easy to learn to use, with the mean rating falling about halfway between "somewhat easy" and "very easy."

Table 11. Rating practicality of GIS.

How practical was the use of the GIS software as part of the accident reporting system (compared to not using it)?			
	Washington	Wisconsin	BOTH SITES
1. Much less practical	4	4	8
2. Somewhat less practical	3	3	6
3. About the same	2	1	3
4. Somewhat more practical	1	0	1
5. Much more practical	1	0	1
MEAN RATING	2.27	1.63	2.00

The mean rating of the practicality of GIS corresponded to "somewhat less practical" (than not using it). Ways in which GIS were judged to be practical included the fact that it could rapidly provide a distance from an intersection and that it was possible to record locations after leaving the accident scene. A primary reason given in Wisconsin for the GIS being impractical was the fact that there were errors in the map, e.g., intersections that existed in real life that were not on the map, a lack of associated data for certain areas, and mislabeling of roads.

Table 12. Rating ease of learning GIS.

How easy was it to learn to use the GIS software?			
	Washington	Wisconsin	BOTH SITES
1. Very difficult	1	0	1
2. Somewhat difficult	3	2	5
3. Somewhat easy	6	5	11
4. Very easy	1	1	2
MEAN RATING	2.64	2.88	2.74

The GIS was considered less than easy to learn to use and harder than GPS to use. This is to be expected, given that the GPS was intended to be a push-button operation (i.e., push a button on the computer screen to activate the GPS, then push another to transfer readings into the database). The GIS, in contrast, required the user to actually *use* the program to manipulate maps, request more information, and place and replace the accident location on the map. It seems likely, however, that the rating of ease of use for GIS could be improved in the future by using improved software and more powerful hardware to eliminate some of the problems experienced by the users in this study.

The number of cases in which officers chose not to gather either GPS or GIS information also provides an indication of the perceived usability of these systems. In Washington, of those accidents reported by officers using computers equipped with both GPS and GIS, 23 percent of the accidents included GPS readings and 46 percent included GIS readings. Of those equipped with GPS alone, 34 percent included GPS readings. Of those equipped with GIS alone, 39 percent included GIS readings. While it was not necessary for officers to gather this data for the purpose of completing their report, they had been asked to gather readings for every case. It seems likely that had the technologies been easier to use, there would have been greater compliance.

Data Entry Methods

Officers were asked about methods of data entry afforded by the use of computers. In some cases, the type of method was related to computer type (pen vs. standard). Officers reported ease of use for:

Computer Keyboards - the standard QWERTY keyboard used on computers.

Virtual Keyboard - this is a small keyboard represented on the screen that allows users to type by touching the pen to the virtual "keys." It would mainly be used on pen computers when the keyboard has been removed.

Pick Lists - in which the user is presented with a number of possible entries for a field and can select one by scrolling through choices using cursor keys, a pen, or other pointing device. Pick lists are used a great deal with both pen and standard computers.

Optical Character Recognition (OCR) - OCR is a means of entering characters by handwriting them on the screen with the pen device. Software makes a determination of what character was intended and converts the handwritten character to an ASCII character.

Officers reported how easy it was to use these methods compared to all other methods of entering data on a computer. The tables below show the number of officers responding to each alternative, along with the mean rating, for each site and across all sites. Responses that an officer did not use a data entry method were not figured into the mean rating. It seems reasonable to assume that not using a given data entry method is an indication that it is considered not worthy of use.

This may have been true to a large extent. However, the fact is that little time was spent in training on the use of the two data entry methods most likely not to be used — OCR and the virtual keyboard. This was primarily because trainers, having experience with the use of these methods, did not feel they were very useful. Responses to questions concerning the usefulness of these data entry methods may be, to some extent, a self-fulfilling prophecy.

Actual Keyboard

Table 13. Rating ease of use of an actual keyboard.

	Iowa	New Jersey	Washington	Wisconsin	TOTALS
1. Much harder	0	0	0	0	0
2. A little harder	1	0	0	0	1
3. About average	1	4	7	4	16
4. A little easier	0	3	0	1	4
5. Much easier	2	1	7	4	14
Did not use it	0	0	0	0	0
MEAN RATING	3.75	3.63	4.00	4.00	3.89

Users rated the keyboard as a little easier to use than other methods of data entry. There was, interestingly, no correlation between users' self-reported familiarity with the keyboard and their rating of the ease of use for the keyboard. This would tend to indicate that the keyboard is a relatively easy means of data entry, even for new computer users.

Virtual Keyboard

Table 14. Rating ease of use of a virtual keyboard.

	Iowa	New Jersey	Washington	Wisconsin	TOTALS
1. Much harder	2	2	2	5	11
2. A little harder	1	5	3	2	11
3. About average	0	0	0	1	1
4. A little easier	0	0	0	1	1
5. Much easier	0	1	0	0	1
Did not use it	1	0	7	0	8
MEAN RATING	1.34	2.13	1.60	1.78	1.80

Those officers who used the virtual keyboard found it to be more than a little harder to use than other means of data entry. Reasons given for not liking the virtual keyboard included difficulty in seeing the keys (especially on the smaller Fujitsu unit) and the virtual keyboard's taking up space on the monitor, thus reducing the amount of the form that could be seen at one time.

Optical Character Recognition

Table 15. Rating ease of use of Optical Character Recognition.

	Iowa	New Jersey	Washington	Wisconsin	TOTALS
1. Much harder	0	3	1	2	6
2. A little harder	2	1	4	1	8
3. About average	2	3	0	3	8
4. A little easier	0	1	1	1	3
5. Much easier	0	0	0	0	0
Haven't used it	0	0	8	0	8
MEAN RATING	2.5	2.25	2.17	2.43	2.32

The rating given to the optical character recognition corresponded with a point about halfway between "about average" and "a little harder." The primary reasons for not liking OCR was the need to enter a character multiple times in order to get the software to recognize it as the desired character. In interviews with users, the general consensus was that while the ability of the OCR software to recognize a high percentage of characters was impressive, it is still not ready to be used as the primary means of data entry.

Pick List

Table 16. Rating ease of use of pick lists.

	Iowa	New Jersey	Washington	Wisconsin	TOTALS
1. Much harder	0	0	0	0	0
2. A little harder	0	0	2	0	2
3. About average	1	4	2	3	10
4. A little easier	0	2	5	2	9
5. Much easier	3	2	4	2	11
Haven't used it	0	0	0	0	0
MEAN RATING	4.5	3.75	3.85	3.86	3.91

The results indicate that officers found pick lists to be an effective way of entering data — more effective than using the virtual keyboard or OCR, and on par with keyboard entry. Many of the pick lists used had two columns, one containing the code that would be entered in the report and the other containing written-out descriptions of what the code stands for. This made it possible to use them as a reference list to ensure entry of the correct code. On the other hand, it was possible to simply enter the code rather than use the pick list, if desired, as long as the code was on the list. Where pick lists are very long, the ability to enter a few characters to get to the general vicinity of the item on the list is desirable. An adequate amount of training in using pick lists is also recommended; some officers complained of having to scroll down through long lists, unaware that they could move faster through the list using techniques that are available with a scroll bar other than simply scrolling down an entry at a time, e.g., paging down.

Summary of Ratings of Data Entry Methods

The results would indicate that officers preferred using the actual keyboard and pick list to the virtual keyboard and OCR. Wisconsin is the only site to have made extensive use of the Fujitsu, which was the only computer that could be considered a "palm-pad" type (i.e., small, with a removable keyboard for use by holding the computer in one hand and the pen in the other). Using a computer in this way, with the keyboard removed, makes it necessary to use either the virtual keyboard or OCR for entering text into such fields as names, vehicle identification numbers, and the narrative section, where pick lists can't be used. Difficulties experienced by the officers in using the virtual keyboard and OCR cast some doubt on the feasibility of palm-pad computers for accident reporting. It should be mentioned, however, that it may be possible in the future to circumvent these problems to some extent by use of magnetic stripe or bar code readers for entry of driver and vehicle information, and by reattaching the keyboard for entering narrative information.

Collision Diagramming

Using computers for accident reporting necessitated a system for creating a collision diagram on the computer. Two types were used — Electronic Ink and Drag & Drop. Electronic Ink is essentially drawing on the screen with the pen. Obviously, this was only possible on the pen-based machines. Drag & Drop involved using a commercial product (VISIO) that allows users to draw diagrams by selecting pre-made objects, moving them into a drawing area, and manipulating them (e.g., by resizing, bending, rotating, etc.). The VISIO program is sophisticated and requires a fair amount of training to learn. Troopers in Wisconsin were not issued the VISIO program.

Officers were asked, for both Electronic Ink and Drag & Drop diagramming, how easy it was to learn to use and how useful it was once they learned how to use it. Officers were asked to make these ratings compared to drawing diagrams on paper forms.

The tables below show the number of officers responding to each alternative on the questions concerning ease of use for both systems along with the mean rating.

Table 17. Rating ease of use of Electronic Ink diagrams.

"Compared to drawing an accident on paper, how *easy* was the ***Electronic Ink*** diagram?"					
	Iowa	New Jersey	Washington	Wisconsin	TOTAL
1. Much harder	1	3	3	5	12
2. A little harder	1	3	4	2	10
3. About the same	1	2	0	0	3
4. A little easier	1	0	2	1	4
5. Much easier	0	0	1	1	2
Haven't used it	0	0	0	0	0
MEAN RATING	2.50	1.88	2.4	2.00	2.16

Table 18. Rating usefulness of Electronic Ink diagrams.

"Once you learned how to use it, how *useful* was the ***Electronic Ink*** diagram?"					
	Iowa	New Jersey	Washington	Wisconsin	TOTAL
1. Not useful at all	0	1	3	2	6
2. Somewhat useful	1	4	2	1	8
3. Fairly useful	2	3	2	3	10
4. Extremely useful	1	0	1	2	4
Haven't used it	0	0	2	0	2
MEAN RATING	3.00	2.25	2.13	2.63	2.43

Table 19. Rating ease of use of Drag & Drop diagrams.

"Compared to drawing an accident on paper, how *easy* was it to draw one with the ***Drag & Drop*** collision diagram?"					
	Iowa	New Jersey	Washington	Wisconsin	TOTAL
1. Much harder	0	1	4	0	5
2. A little harder	1	2	4	0	7
3. About the same	0	2	0	0	2
4. A little easier	2	3	3	0	8
5. Much easier	1	0	3	0	4
Haven't used it	0	0	0	8	0
MEAN RATING	3.75	2.88	2.79	N/A	2.96

N/A = Not Applicable.

Table 20. Rating usefulness of Drag & Drop diagrams.

"Once you learned how to use it, how *useful* was the ***Drag & Drop*** collision diagram?"					
	Iowa	New Jersey	Washington	Wisconsin	TOTAL
1. Not useful at all	0	1	2	0	3
2. Somewhat useful	0	0	2	0	2
3. Fairly useful	2	6	2	0	10
4. Extremely useful	2	1	7	0	10
Haven't used it	0	0	2	8	10
MEAN RATING	3.50	2.88	3.08	N/A	3.08

N/A = Not Applicable.

It is interesting that officers considered the Electronic Ink diagram to be more difficult to use (compared to drawing on paper) than the Drag & Drop diagram given that it is much more similar to drawing on paper than the Drag & Drop program. The Drag & Drop diagram, being essentially a computer graphics program, required learning skills such as moving and manipulating windows and objects on the screen. Once officers had learned how to use it, however, they seemed to feel that it was not difficult to use.

Some officers preferred the simplicity of the Electronic Ink diagram, but across all officers, the Drag & Drop diagram was considered to be more *useful.* Advantages cited for using the Electronic Ink diagram were the ability to use pre-drawn roadway templates and to erase. Disadvantages included the low level of resolution, jaggedness of diagonal lines, difficulty in using standard diagramming templates, and a dislike of drawing on screen for unspecified reasons. The primary advantage given for using the Drag & Drop program was the "professional" appearance of the diagrams it produced. Also mentioned was the ability to do simple or complex diagrams, depending on what the situation required. Those officers who disliked the Drag & Drop diagram felt that it was difficult to use and that the sophisticated diagrams it provided were not necessary for most officers and accidents.

In a followup questionnaire, officers were asked which they would prefer to have and use for collision diagramming. Out of 27 officers responding, 8 (30 percent) said they would prefer continuing to draw the collision diagram on paper. Two (7 percent) said they would prefer to use the Electronic Ink diagram alone. Eight (30 percent) would prefer to use the Drag & Drop diagram alone and nine (33 percent) would prefer to be able to use either Electronic Ink or Drag & Drop, depending on the accident.

STUDY OF STURDINESS

Information for the study of sturdiness of the technologies under evaluation comes from officers responses to questionnaires and reports from the personnel at each site who were responsible for maintaining and servicing computers and other hardware.

Officers used a four-point scale to rate the sturdiness of computers used in the study. The results are shown in table 21.

Table 21. Rating sturdiness of computers.

	IBM 360CE	IBM 360CS	IBM 360P	Compaq	Fujitsu
1. Not sturdy at all	0	0	1	0	4
2. Somewhat sturdy	2	0	4	2	2
3. Fairly sturdy	7	5	17	1	3
4. Extremely sturdy	3	2	8	1	0
Mean Rating	3.08	3.29	3.07	2.75	1.89

In general, the IBM machines were rated as being more sturdy than the Compaq or Fujitsu machine. That the IBM's would be rated similarly is not surprising since they are constructed similarly. The higher rating of the IBM 360CS may be related to the fact that it was used only in New Jersey where the data-gathering period was short and problems may not have had time to develop. Officers in New Jersey did not rate the 360CS much differently than the 360P (the other computer they used).

Ratings for the Compaq machine came only from Iowa. It should be considered that officers there have been using the Compaq for far longer than participating officers at other sites have been using their computers. So, it is possible that officers rated the Compaq lower because the equipment was older and has had far more time to develop problems.

While officers in Wisconsin tended to rate the Fujitsu machine as less sturdy than the IBM 360P, there were no actual reports of problems with either unit breaking down. Officers and Wisconsin officials who were interviewed expressed the belief that the lower ratings for the Fujitsu were probably based on a perception of sturdiness based on the size, weight, materials used in construction, and the fact that the Fujitsu came in two parts that were connected by cables.

A common source of problems on these portable machines was the monitor. On the IBM machines, the few complaints of hardware malfunctions involved monitors that needed to be replaced. The general experience was that these units were repaired quickly. Another problem that occurred with pen computers concerned malfunctioning pens. These problems ranged from pens that needed frequent calibration (in order to ensure that the on-screen cursor appeared where the pen touched the screen) to pens that did not function at all. Because pens were separate from the computer, they could easily be dropped or fall out of their holders. For this reason, they were more likely to be lost or damaged. Some sites mitigated this problem by attaching pens to the computers with light nylon cords.

STUDY OF COST

The following table has been included to indicate the costs associated with the implementation of these technologies. Items included represented those that local officials deemed necessary to get started with a small group of officers. Costs include one-time purchases of items such as desktop computers for use as a central station for the maintenance of data. Cost are those that were in effect when this equipment was purchased in late 1994 and early 1995. Note that the number of units of each piece of equipment does not necessarily equal the number of officers who participated. For example, Washington had 16 officers participating, but only needed 9 GPS receivers because only 8 officers, plus the person responsible for followup accident locating, were equipped with GPS at any one time.

Costs for New Jersey are for the equipment that was purchased for use in the study. Delays in acquiring this equipment forced participating agencies in New Jersey to borrow equipment in order to participate. Therefore, costs listed for New Jersey are for equipment similar to that actually used, but are not the exact costs.

Short descriptions of the equipment used appear in table 22. More complete descriptions appear in Appendix C.

Table 22. Computer/equipment/software costs - Iowa.

Description of Equipment	# of Units	Unit Cost	Total Cost
486 Desktop, 100 MHz, 1-Gb Hard Drive, 16-Mb RAM, and Software	1	$6,661.00	$6,661.00
Compaq Concerto, Pen-Based 486 Computers, 33 MHz, 250-Mb Hard Drive, 8-Mb RAM; Software: Pen for Windows, CIC Handwriter for Windows	12	$2,636.00	$31,632.00
Global Positioning Systems (GPS): Trimble Mobile GPS Gold Development Kit (Includes Card and Receiver Antenna)	12	$1,271.00	$15,252.00
FM Portable Paging Receiver, RTCM-104 Output	12	$375.00	$4,500.00
"Premium One" Meter Service (12 Months)	12	$600.00	$7,200.00
TOTAL			**$65,245.00**

Table 23. Computer/equipment/software costs - New Jersey.

Description of Equipment	# of Units	Unit Cost	Total Cost
IBM ThinkPad, Non-Pen-Based Model 360CE 486/50-MHz Computers, 8.4-in (21.3-cm) STN, 340-Mb Hard Drive	6	$3,017.00	$18,102.00
IBM ThinkPad, Pen-Based Model 360PE 486/DX2-50/25 Computers, 9.5-in (24.1-cm) STN, 340-Mb Hard Drive	6	$3,686.00	$22,116.00
8-Mb RAM Upgrade	12	$381.00	$4,572.00
Microsoft Windows for Work Groups	12	$50.00	$600.00
VISIO V4.0 for Windows	12	$134.00	$1,608.00
CIC Handwriter for Windows	6	$235.00	$1,410.00
Serial Null Modem Cable	4	$11.00	$44.00
IBM dc Adapter for ThinkPad	12	$156.00	$1,872.00
Battery Charger	12	$204.00	$2,448.00
Extra Battery	12	$196.00	$2,352.00
Protective Carrying Case	12	$78.00	$936.00
LaserJet Printer	1	$1,450.00	$1,450.00
Printer Cable	1	$10.00	$10.00
Toner Cartridges	4	$115.00	$460.00
TOTAL			**$57,980.00**

Table 24. Computer/equipment/software costs - Washington.

Description of Equipment	# of Units	Unit Cost	Total Cost
IBM ThinkPad, Pen-Based Computers, Model 360P, 9.5-in (24.1-cm) STN, 340-Mb Hard Drive, 20-Mb RAM, 2620-50F	9	$4,611.28	$41,501.52
IBM ThinkPad, Non-Pen-Based Computers, Model 360CE, 8.4-in (21.3-cm) STN, 540-Mb Hard Drive, 20-Mb RAM	9	$4,763.00	$42,867.00
IBM dc Adapter for ThinkPad	17	$162.35	$2,759.95
Smart Modular Technologies PCMCIA Serial Card	9	$150.40	$1,353.60
Geographic Information System (GIS) Software - ESRI ArcView	9	$861.23	$7,751.07
Trimble, PCMCIA Mobile GPS Gold Card NavBeacon XL Differential Receiver	9	$3,578.76	$32,208.84
IBM PC-DOS to MS-DOS Upgrade	17	$51.67	$878.39
Microsoft Windows for Work Groups	13	$144.13	$1,873.69
CIC Handwriter for Windows	20	$55.03	$1,100.60
VISIO Express	18	$48.46	$872.28
ac Adapters for ThinkPads	2	$72.78	$145.56
Printer Cable	2	$7.55	$15.10
HP LaserJet 4+	2	$1,653.46	$3,306.92
Mouse for ThinkPads	17	$64.69	$1,099.73
Mouse House	17	$4.94	$83.98
3.5-in (8.9-cm) Disks	10	$19.77	$197.70
Targus Carrying Bags	17	$64.92	$1,103.64
TOTAL			**$139,119.57**

Table 25. Computer/equipment/software costs - Wisconsin.

Description of Equipment	# of Units	Unit Cost	Total Cost
Fujitsu Stylistic 500, Non-Pen-Based Computers, 486/50, 170-Mb Hard Drive, 20-Mb RAM	5	$4,175.00 (Approx.)	$20,875.00
IBM ThinkPad, Pen-Based Computers, Model 386PE, 486/50, 340-Mb Hard Drive, 20-Mb RAM	5	$4,300.00 (Approx.)	$21,500.00
Geographic Information System (GIS) Software - ESRI ArcView 2.1	7	$902.00	$6,314.00
Trimble, PCMCIA Mobile GPS Gold Card (Capable of Real-Time Differential Correction at 1- to 5-m accuracy), NavBeacon XL Differential Receiver (Radio Receiver for Differential Correction From the U.S. Coast Guard)	6	$3,252.50	$19,515.00
Miscellaneous cables, mounts, cases, and other items were also purchased for the equipment			
TOTAL			**$68,204.00**

SUMMARY

USE OF COMPUTERS FOR ACCIDENT REPORTING

Officers adapted well to the idea of using computers for accident reporting. When asked which they would prefer to use, 74 percent of participating officers expressed a preference for computers over paper forms. In interviews with officers, the general feeling was that the use of computers was beneficial and inevitable.

Evidence from this study indicates that, with sufficient training, officers can submit computerized forms that will be at least as complete and as accurate as the paper forms that they are accustomed to using, if not more so. With programming added to check the report for missing and inaccurate entries, computerized reports can greatly reduce the number of errors and omissions.

As for speed of data entry, the general impression from both data and interviews with officers is that it took significantly longer to complete a report using the computer. Officers reported taking twice as long to enter reports on the computer when first starting out. With practice, they could reduce that to 25 percent to 33 percent longer. There was some evidence that this difference could be further reduced with more practice and improvements to the program. There was doubt as to whether computer entry would ever be faster than using paper forms. This being said, it should be noted that accident reporting software can and is being made part of larger programs that allow sharing of information between reports. An officer need only enter information about individuals and vehicles once and that information can be shared between computerized accident reports, citations, exchange of information forms, and other supplemental forms. By using such a system, it may be possible to realize an overall savings in data entry time. The software used in this study was designed to be part of such a system; however, since the focus of the study was on accident reports alone, only the accident reporting function was included. When one considers the potential for eliminating entry of redundant information in multiple reports, using the computer may ultimately be a time saver for police officers. Entering data directly into the computer also saves the time it takes someone else to key the data into a database from the paper form. When all things are considered, use of a computer by police officers for accident reporting can provide an overall savings in time and cost that could not be demonstrated within this project.

PEN COMPUTERS VS. STANDARD LAPTOPS

This study found no clear-cut advantage to using either pen-based or standard computers for field accident reporting. Neither speed nor accuracy of data entry was affected by the use of the pen. Those who are considering using mobile computers for accident reporting should consider the following advantages and disadvantages of pen-based computers when deciding which system to use:

User Preference - More officers preferred using the pen computer. For the most part, officers felt that the pen provided a more user-friendly interface. They acknowledged that using the pen was not always the ideal method for entering data, but pointed out that having the pen made it possible to use it or not, depending on which was most appropriate. Some tasks, such as drawing a collision diagram with Electronic Ink, made it necessary to use the pen. Other tasks, such as using the Drag & Drop collision diagram, were far easier when using the pen than when using the TrackPoint-type device.

Potential for Problems - The pen hardware and software provide an extra potential for problems not found with standard computers. Pens can be lost or broken, although this problem can be minimized by attaching the pen to the computer. During this study, a significant number of complaints regarding malfunctioning hardware concerned uncalibrated and/or malfunctioning pens.

Problems Associated With Specialized Equipment - Because fewer pen computers are manufactured, there may be problems obtaining the computers, as well as replacement parts. There may also be a tendency for specialized equipment such as this to lag behind more common equipment in terms of computing power, processor speed, available memory, hard-disk space, etc.

PEN COMPUTERS WITH REMOVABLE KEYBOARDS

In Wisconsin, where officers had the opportunity to use computers with both removable and permanently affixed keyboards, the clear preference was for the permanent keyboard. Officers acknowledged that the smaller size of the removable-keyboard unit could be an advantage at times, but that this was far outweighed by the inconvenience of handling a two-piece unit connected by cables. One of the primary advantages projected for the removable keyboard was the ability to carry the computer with one hand and enter data with the pen while moving around outside the cruiser. Officers did not take advantage of this ability. The reason for this was a combination of the need to unplug numerous cables (keyboard, power, GPS receiver, differential corrections receiver) and a tendency to view the accident reporting process as taking notes outside the vehicle and completing the report in the vehicle or at the station. Perhaps if officers had been able to take advantage of the ability to use the computer with the keyboard removed, they would have found more reason to like it.

USE OF GPS AND GIS FOR FINDING AND RECORDING ACCIDENT LOCATIONS

Both GPS and GIS technologies show a great deal of promise for use by officers in reporting accident locations. There were many problems encountered in this study, which resulted in frustration and inaccurate readings when using GPS and/or GIS. Most of these were due to the fact that the agencies involved were just beginning to learn how to use these technologies for accident reporting. To a great extent, these problems can be solved in the future by addressing the following issues:

Maintain Satellite Lock - For various reasons, officers were not able to leave the computer and/or GPS software running in order to maintain a lock on satellites. This resulted in a need to re-establish a link each time an officer arrived at the traffic scene. Officers reported that it took several minutes to do this and that often they were called away from the accident before a lock could be established. Another problem that contributed to the difficulties in recording GPS readings was the fact that officers had to enter some data elements before the GPS software could be started. This added to the likelihood that they would be unable to record the location before being called away. It would be helpful if the GPS reading was available constantly. Many police jurisdictions are currently considering the use of a GPS receiver in police vehicles that would transmit an officer's location to a central station for increased security and efficiency in dispatching. The most efficient way to gather GPS data for the accident reporting software would be to take advantage of this receiver to make GPS readings immediately available to the software. The software would need to be made so that the reading is recorded as part of the accident file as soon as possible after the report is started. This way, if it is necessary to leave the scene quickly, the GPS reading will have been taken.

Eliminate Cables - An ideal implementation of GPS would reduce the number of GPS-related cables that must be attached to the computer. This might be accomplished by use of a docking station and/or by putting as much of the GPS system outside the computer as possible. Officers in this study found computers with multiple GPS-related cables attached to be extremely unwieldy. They also experienced some difficulties keeping cables attached. These problems were partially responsible for officers in West Des Moines deciding not to use the differential corrections receiver and officers in Des Moines deciding against use of GPS altogether. These problems may have also contributed to the lack of GPS accuracy in Washington.

Continue Development of GIS - The Geographic Information Systems that were implemented in Washington and Wisconsin suffered from factors that would not be as great a problem today and will likely be less of a problem in the future. Among these are a lack of sufficient computing power in the field computers, GIS programming using early versions of the GIS software, insufficient data, not enough time to develop and test the program before implementation, and lack of expertise in programming. Those who are interested in the use of GIS for location finding should be encouraged to do so, with the understanding that there will be a great deal of work necessary to gather GIS data, program, test, and revise the GIS before it can be fully implemented.

Use GIS and GPS Together - The results of this study indicate that using GIS and GPS together may make it possible to take advantage of the best features of both. One of the more time-consuming aspects of using the GIS was locating and zooming into the accident location. Using the GPS reading as a guide can facilitate this step. One of the biggest shortcomings of the GPS is that it provides a description of the location that is not particularly meaningful to either the officer or the State records system. Use of a GIS provides a means for officers to check the accuracy of the location, as recorded by the GPS and assigned to a roadway by the GIS, and correct it, if necessary. Submitting the location to the State accident records system as a point on a roadway is far more useful than submitting it as latitude and longitude coordinates. Use of GIS with GPS may also make it easier to use a GPS signal that is not differentially corrected, since officers who are adjusting the accident location within the GIS can probably do so as easily with a location that is 30 m off as with one that is 3 m off.

Make GIS/GPS Useful to User - One of the main complaints officers had concerning use of GIS and GPS was that it was an unnecessary effort. Before police officers can be expected to use GIS and/or GPS for location finding, the process will have to represent, at least, little or no extra work and, at best, a substantial reduction in overall work. It had been hoped that the systems that were implemented in Washington and Wisconsin would be able to reduce officers' work by allowing them to automatically fill in some accident location information from the GIS. Unfortunately, there was insufficient data available in Washington to do this, and officers in Wisconsin found it easier to determine the location using traditional means and to fill in the location manually rather than use the GIS. Ultimately, however, it should be possible to develop a system that is relatively quick and easy to use, and enables the officer to generate a great deal of information from the GIS. It may be possible, for example, to fill fields for road name, distance from crossroad/milepost, county/township, and road surface from the information in the GIS. The officer would be able to review the information prior to having it automatically entered into the report.

Build Computer and Other Systems Into Vehicle - This would mean essentially treating these systems as a subsystem of the vehicle itself. While this is one of the more difficult-to-achieve recommendations presented here, the benefits of such a step would be many. It would help to alleviate problems such as exposed cables and loose hardware shifting around, getting in the way, and accidently being disconnected. It could help make room in the driver compartment by facilitating the moving of some system components to the trunk. It would also help accomplish some of the items mentioned above, such as connecting the accident reporting system to a GPS receiver that is constantly on.

COLLISION DIAGRAMMING

Overall, the officers who participated in this study preferred the Drag & Drop-type collision diagram over the Electronic Ink diagram. This was primarily due to the more professional-looking results provided by the Drag & Drop diagram. However, 33 percent of the officers said that they would prefer to have both systems available to use as appropriate for different accidents. About a third said they would prefer to continue using paper for collision diagrams. The Drag & Drop diagram used in this study was an off-the-shelf product (VISIO Express™) that was fairly complex and allowed for many types of diagrams besides collision diagrams. It did not allow users to draw on the screen the way they could with the Electronic Ink diagram. It seems likely that a product could be developed specifically for collision diagramming that would simplify the Drag & Drop aspect and allow users to draw in certain details that were more easily drawn than added as objects. Such a product could appeal to all the officers who expressed a preference for Electronic Ink and/or Drag & Drop diagramming and might also win over some of those who expressed a preference for drawing on paper.

ENCODED DRIVER'S LICENSE AND VEHICLE REGISTRATION DOCUMENTS

Although it was not possible to evaluate technologies such as magnetic stripes and bar codes on licenses and/or registrations as part of this study, the possibility still exists that in the future these technologies will make it possible to automate part of the data entry process. Such a system could speed data entry, increase data accuracy (except where the encoded information is inaccurate), and facilitate the use of a smaller computer with no keyboard. There is a great deal of interest in such a system on the part of the officers who participated in this study.

ISSUES ENCOUNTERED IN IMPLEMENTING TECHNOLOGIES

This section is included to describe some of the problems encountered during this study that were not initially considered part of the study, but were seen by study participants to have significant bearing on the use of new information technologies. Agencies contemplating the implementation of similar technologies may be able to recognize these problems and take steps to avoid them or minimize their effect.

General Institutional Issues

For any agencies wishing to implement these and other emerging technologies, there will be difficulties to overcome. Participation in this project brought some of these difficulties into focus for the agencies involved. Some of the major issues concerning institutional barriers to the implementation of emerging technologies are discussed below.

Needs of Participants - Public, private, State, and local entities are involved in the development and use of the technologies and underlying data universes used in crash-data collection. Each of these entities has unique business needs for the data it collects, maintains, and uses. These needs will determine the types of data gathered and also the periodicity of the updates. These needs may limit the access they provide to their data. Their needs will also determine their need for advanced technologies for data collection, manipulation, and data communications.

Leadership/Standards/Architecture/Clearinghouse Functions - Leadership in information technology development and coordination is fragmented; it can be found locally, in various State agencies, in universities and research institutions, and in the private sector. The disparate needs, areas of expertise, and budgets of the many involved entities may result in territorial behavior in lieu of cooperation. In some cases, conflict may be difficult to avoid. For example, a certain agency may be tasked with planning the purchase or development of a system to be used by many agencies, with those other agencies being asked to contribute to the cost of using that system. A plan that might be appropriate for the planning agency could be based on the use of a certain piece of computer hardware or software, used by that agency, *but not by others*. The planning agency is then put in the position of having to decide between a plan that would have other agencies contribute to the implementation of a system that they cannot use without a major change in their computer system, or a plan that goes against their own best interests.

Funding - Information technologies are relatively expensive. Many counties and municipalities have legacy hardware and software systems. The expense of these data/communications systems results in much built-in inertia against change. Purchases of complex extensive systems with many component parts often occur over several budget cycles. Local governments resist repeated purchases or updates of such systems, especially when they are perceived as meeting State or Federal mandates. In some cases, local agencies may not be aware that there will be continuing costs for using these statewide information systems that will be passed on to the municipalities in addition to whatever upfront costs are incurred.

Rate of Technology Change - Information technology changes so rapidly that procurement decisions are outdated before many municipal procurement systems, especially in larger communities, complete their paperwork. By the end of the last round of purchases, an entire system may be out of date. Information technology businesses have short life spans and replacement parts for equipment that is only a few years old, but no longer in production, may be greater than the present value of the equipment. The required training and retraining for repeated hardware and software changes also drains increasingly limited local resources, especially in smaller jurisdictions.

Proprietary Equipment - Purchase of proprietary hardware and software systems causes discontinuity in data flow. Without clear standards and an information clearinghouse, purchasers rely upon vendors for information on which they base their system and equipment purchases. The result is that decisions are sometimes made without understanding the potential for problems if an attempt is ever made to incorporate this single isolated system into a larger system. For example, one of the participating sites experienced problems integrating different local agencies into a single radio communications system capable of accessing State data because the different agencies involved used proprietary communications systems (Electrocom and Motorola). The State used one system, while approximately 70 percent of the county and municipal enforcement agencies used another and thus could not access the State radio system. Possible options for solving this problem include: (1) local agencies purchasing the same proprietary system used by the State, or (2) the State reprogramming its proprietary system to accept communications from other proprietary systems.

In another example, in one State that participated in the study, agencies that made an investment in GIS technology early in its development owned systems that could not be integrated with more advanced GIS systems purchased later by other agencies. In this case, the passage of time contributed to the formation of a barrier that prevented the successful integration of these systems.

A common problem with proprietary equipment, such as some brands of PC-compatible systems, is upgradeability. For example, a number of well-known PC manufacturers produce workstations that are upgradeable only with proprietary components (e.g., motherboards, power supplies) that typically command higher prices than off-the-shelf PC-clone components. In a worst-case scenario, proprietary upgrade or replacement components may only be available from the high-cost after-market because the manufacturer has gone out of the PC business. In such cases, a replacement part could cost as much as the original cost of the entire computer.

These examples point to the advisability of thorough planning, taking pains to look at the big picture in terms of what other agencies are doing, as well as looking as far ahead as possible to assess possible future needs. Agencies should avoid, as much as possible, plans that include use of proprietary systems and take into account, when planning hardware and software purchases, that the chosen system may eventually need to function with other systems in use by other agencies.

GIS Base Maps

During this project, both Washington and Wisconsin experienced problems in creating a GIS that were related to available base maps. In Washington, it was not possible to create a GIS that would return an English-language description of all accident locations because base maps containing that information were not available for county roads. The county was in the process of creating those maps, but they would not be finished in time to be used as part of this project. This led to a situation in which it was considered a redundant effort for the State to create the maps, yet the maps were not available elsewhere.

In Wisconsin, there were maps available, but differences in the maps led to problems with making them part of one integrated GIS. Differences in the GIS base maps in Wisconsin stem from the fact that they are created for 2,592 different units of government that collect and maintain a large variety and amount of land information, and which are governed by 600 laws and administrative rules. Each county's system reflects its own business needs, which are much more complex than the needs of any single State agency.

No uniform statewide standards were set for the county, municipal, or private industry-based maps, and the result is a wide variety of proprietary hardware and software systems that employ differing levels of resolution, timing for updates of information, etc. The resolution for county base maps, in general, is much higher than has been traditionally needed by the State Department of Transportation, reflecting their differing business uses for the data. For example, in Wisconsin, the State Highway System GIS base maps and some local agency maps are based on a resolution of 1:48,000' vs. some local systems with resolutions as high as 1:30'. Agencies wishing to create a statewide GIS will need to overcome the problems of integrating maps of differing resolutions. Decisions will also need to be made to determine which resolution to use, whether a certain resolution can be considered ideal, or whether there *is* no resolution that could be considered ideal because of the differing needs of potential users.

Planning for a location control mechanism such as "link-node" may overcome some of these reference system standardization issues. A problem is that, in many States, the reference system only provides location control on the State-maintained system. This leaves local roads without a standardized location control. Planning for such a system should occur at a high level, and the process should include all interested parties so that their business needs are addressed.

Another issue in base map maintenance concerns updates. Each time a map is updated atthe county or municipal level, its counterpart State map should also be updated and vice versa. Provisions must be made for determining which agency will do this, which agency will fund it, how often the updating should be done, and who will make these decisions.

To summarize, agencies wishing to develop a GIS will need to decide whether to create maps specifically for this application or to take advantage of existing maps. Existing maps created by and for other businesses and agencies have been created to support a wide range of needs that differ from organization to organization and probably differ from those of the agency creating the GIS. Using these maps will require extra effort to make them work together within the same GIS and to suit the needs of the users of that GIS. On the other hand, creating maps from scratch for use with the new GIS is liable to be an expensive, and to a large extent, redundant effort. Planning will be required to make provisions for updating the maps to keep all maps current and in agreement with each other.

Training

Except for the State of Iowa, where the Mobile Accident Reporting System (MARS) had been in effect for some months, none of the other sites selected were involved with or experienced in using either pen-based or non-pen-based computers. Many of the officers involved had little computer experience and/or were not familiar with Windows or software that ran under Windows as did MARS.

This did not seem to discourage the officers in their training, although, in retrospect, it would have been beneficial to the training sessions if all the officers had at least a knowledge of Windows prior to commencing training in MARS. It would also have helped to speed up the training.

Most officers felt that they should have had more training before being asked to go on-line with the computers and software for reporting accidents. However, it was very difficult to gain access to the officers for providing training and it probably would have been impossible to provide more under the circumstances. While officers were able to use the technologies in the field, there was some resistance to using them that was related to the dearth of training. It is suggested that agencies that are contemplating the implementation of technologies such as these endeavor to not underestimate the amount of training that may be necessary prior to implementation.

At all sites, officers were identified who were either computer-conversant, knew Windows, or, in some cases, had acquired experience using the software used in this project (MARS, VISIO, GIS, etc.). These officers could then function as training aides. Fellow officers went to those "key" officers for assistance when needed. This appeared to work quite successfully. Everyone was able to follow the regular training under the curriculum that had been developed for the project and then additional training, if required, was provided by the "key" officers. Another practice that has been successful in assisting officers in learning to use these technologies is to provide time for users to assemble and discuss problems they have encountered. Often, there will be someone in the group who has also encountered that problem and has discovered the solution.

Procurement of Technologies

There were a number of problems experienced during this project, most of which were due, either directly or indirectly, to the procurement of hardware and software related to these technologies. Much of this was due, in turn, to the extremely high rate at which these technologies were changing. Indeed, any study of "emerging technologies" is likely to experience such problems, since such technologies are, almost by definition, in the process of changing as they are being studied.

Difficulties in procuring equipment ultimately affected the study in that the amount of time for testing hardware and software prior to implementation was greatly reduced. This led to problems that would normally have been discovered before the technologies were put to use by the officers, and which may have adversely affected the performance of the technologies and the officers' opinions about their practicality.

The following is a list of problems that arose across sites as part of the procurement process. It is included here in the hope that agencies desiring to implement these or other technologies can be made aware of the potential for such problems and can take steps to avoid them.

- Most of the sites had to use State "bid lists." When equipment specified by the project was not on the bid list, it was very difficult and sometimes nearly impossible to convince the purchasing authorities of the need for that specific equipment. In some cases, for example, the specific portable computers being used in this study were not on the bid list. In other cases, there were *no* portable computers on the bid list.

- Some of the computer vendors could not supply the specified equipment at the time the equipment was required. In some cases, they could not supply it at all. Some vendors who were selected went out of business before equipment could be purchased. Vendors' and manufacturers' estimates of whether and when products would be available could not be depended upon.

- The computer equipment selection and purchasing processes took several months. During that time, administrations that had given their approval for the project and authorized the purchase of the equipment were replaced by new administrations. This meant that the entire process had to start all over again. In some instances, the person responsible for procurement was not made aware that this needed to be done. In one case, the computer that had been approved for purchase was no longer available from the manufacturer by the time the purchase was approved, a bid was accepted, and the funds were made available. This required that the entire process begin again in order to get approval to buy the newer computer that replaced the one originally requested.

- In at least one instance, an order for a certain model of computer was honored by a vendor and the equipment was delivered. Approximately 1 month later, the vendor announced an improved version that was available for delivery. Attempts by the site to have the vendor replace the original equipment or upgrade it were unsuccessful.

It should be noted that some of the difficulties experienced were related to the fact that the purchasing process required some degree of coordination between four different sites, all operating under different circumstances and involving different procurement procedures. Such a situation is unique to this project. In addition, the research project imposed certain requirements and deadlines that would not normally have been a factor. Although these same kinds of purchasing obstacles could face anyone implementing such a project, the need for coordination across four separate sites and cooperation with the research team added to the normal purchasing difficulties.

Hardware and Software Compatibility Problems

Considering the number of pieces of hardware and software that were brought together within this study, the number of compatibility problems encountered was thankfully small. This is likely a testimony to the state of the art of these technologies and the fact that most hardware and software used was purchased "off-the-shelf" and had been well designed and tested by the manufacturers for compatibility.

Nevertheless, there was considerable effort expended to correctly configure the machines, peripherals, software, and operating systems (i.e., Windows 3.11 and DOS) to work properly. It would behoove any agency considering the use of these or any other emerging technologies to begin by acquiring and configuring one set of hardware and software to be certain that there are no insurmountable compatibility problems.

There were some problems mentioned by the sites that did affect the performance of the technologies and that bear mentioning here. Some of the inaccuracy of GPS readings experienced by officers in Washington may have been due to problems with malfunctioning PCMCIA serial ports. These problems were solved when the malfunctioning devices were replaced with a different unit made by a different manufacturer. Washington also experienced problems related to the use of a DOS-based program for completing citation forms that was developed outside of this project. This program would not function properly when started from Windows. For this reason, it was not possible for officers to leave Windows running. This, in turn, meant that officers could not leave the accident reporting software running but, rather, had to start both Windows and MARS before starting an accident report. It also prevented officers from leaving the GPS receiver running, which, in turn, led to long waits while the receiver locked on to satellites.

In Iowa, officers reported having problems getting the differential corrections receivers to function correctly. This, along with the inconvenience caused by cable connections between the differential corrections receiver and the computer, apparently caused some officers to remove and put away the differential corrections receivers. The cause of the differential corrections receiver malfunction was never determined.

Value of This Project to Participants

While there were many difficulties encountered in the course of this project and much of what was originally envisioned could not be accomplished within the limitations of the project, the participants in Iowa, New Jersey, Washington, and Wisconsin generally agreed that participation in the project was valuable. Officials learned a great deal about what is required to put together the various systems used. Officials learned from all of the problems related to training, and acquiring and configuring hardware and software that are described above. At some sites, officials became familiar with how GPS functions, the benefits of differentially corrected GPS, possible local sources of GPS correction signals (e.g., using signals provided by the U.S. Coast Guard vs. signals provided by subscription services vs. building their own transmitter), and relative costs and benefits of all these alternatives. Where a GIS was used, local officials became familiar with sources of maps, programming a GIS and incorporating it into a computerized accident reporting system, and human factors issues involved in making it usable by police officers. Officials at agencies at each site became more familiar with the resources that were available from the other agencies with whom they cooperated.

The police officers who participated entered into the project with varying degrees of interest or reluctance. Most, however, expressed the feeling that these technologies will be part of the future of police work in general, and accident reporting in particular, and that the project was valuable because it provided the opportunity to take a first step into the use of these technologies. And, while the nature and limitations of this project led to the use of systems that were not as polished as they might have liked, this also made it possible to use them in a situation that was less stressful than if it were an actual implementation. Many officers seemed genuinely excited by the possibilities offered by these technologies. Most officers seemed to agree that the use of these and other emerging technologies showed great potential for making their job easier, and that the technolgies they used as part of this study were good ideas that just needed more work.

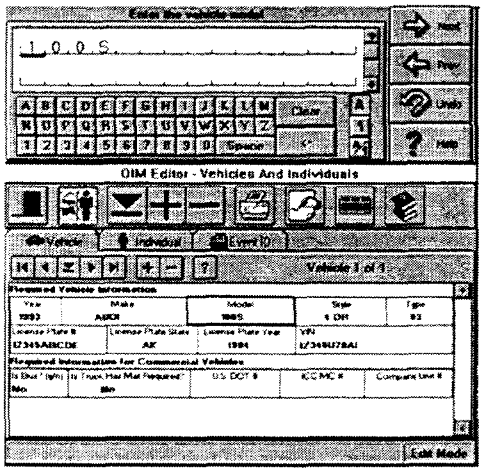
APPENDIX A. DESCRIPTION OF ACCIDENT REPORTING SOFTWARE

Introduction

Officers who participated in this study used the Mobile Accident Reporting System (MARS) component of the Officer Information Manager (OIM). This program was originally developed for use by police officers in Iowa using pen-based computers at the scene to record and store critical crash information. For the purposes of this project, versions of OIM were also developed for New Jersey, Washington and Wisconsin.

The complete OIM is a software system that supports the data management process for officers. It also incorporates a nationwide data communications network for transmitting completed accident reports directly to the DOT mainframe for processing. AMS, in conjunction with the Iowa Department of Transportation, developed this system in Iowa for use statewide. It has been selected as the statewide standard for Iowa, Illinois, Washington, Maine and Connecticut.

The complete OIM software environment can include any type of other reporting functions. The Iowa system currently includes Vehicle Safety Inspections, Operating While Intoxicated, and Electronic Citations. Participants at other sites used only the MARS (accident reporting) component of OIM.



The OIM User Interface

Crash Reporting

The Mobile Accident Reporting System component is an information management tool that is specifically designed to emulate the Investigating Officer's Report. It is application software combined with pen-based handheld computers, a central host workstation, and nationwide data communications. It is designed to support future initiatives such as wireless data communications, magnetic stripe and bar code technologies, Global Positioning Systems (GPS), and multimedia technology. It provides the officer with all of the tools needed to conduct an accident investigation, including error detection and correction while in the field.

OIM includes:

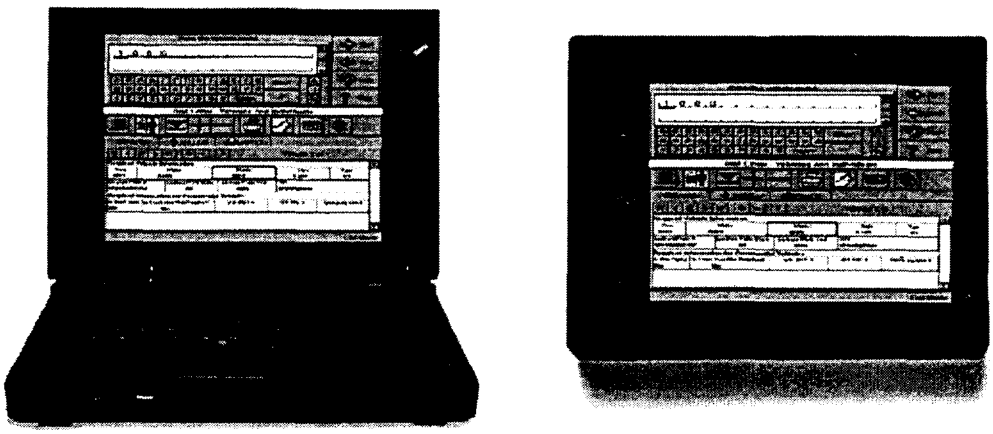
Case Management

Officers can access any accident case available. They manage the processes of completing a report and submitting the report for approval by a superior officer.

The list can be used to view all cases, or selectively, for those that are open, submitted, or rejected.

Accident Characteristics

All accident characteristics are collected by the officer at the time and place of occurrence. Data collected include each unit involved, injured persons, damaged property, weather conditions and accident location. In addition, the officer can sketch a diagram or use a drag-and-drop, to-scale diagramming tool to visually describe the characteristics of the accident. A Supplemental Truck and Bus Form is also included in the system for accidents involving trucks carrying hazardous materials and passenger buses.



OIM runs on Notebook and Pen-based computers running Microsoft Windows for Pen Computing

Driver Exchange Information

In Iowa, each system is equipped with a portable printer to allow the officer to print the driver exchange information for each vehicle involved. This process eliminates the time-consuming task of manually completing a paper form for each driver involved.

Notes

In many cases, officers record freehand notes to help further describe the accident. The OIM used at all sites is equipped with a facility for the officers to collect these notes as "electronic ink". These notes are stored with the accident report on the agency workstation for future reference.

Data Validation

OIM, as implemented in Iowa, has a complete data validation routine. The advantage of this approach is in the detection and correction of errors at the site of occurrence. An accident report that contains errors cannot be submitted to the DOT until it is corrected. Prior to using OIM, officers had no feedback on accidents that contained errors discovered after the fact.

Communications

In Iowa, OIM utilizes an advanced data communications process that automatically transmits all accident information from the local agency to the DOT or other agencies. Prior to using OIM, accident reports were mailed to the DOT, processed in the mailroom, routed to the proper department, and manually keyed into the state's mainframe computer. A process which once took weeks can now be completed in a matter of minutes with no human intervention.

Security

2.1 OIM Access Levels

Access levels define the functions that a user can perform in OIM. There are four access levels: Reporter, Supervisor, Accident Locator, and System Administrator. These levels are modeled after the functions involved in collecting and managing the data that are required by motor vehicle incident reporting.

Reporter - an officer who collects data from motor vehicle incidents. There are currently four types of reporting that officers can perform using the OIM application: Citation, Accident, Operating While Intoxicated, and Vehicle/Driver Safety Inspection.

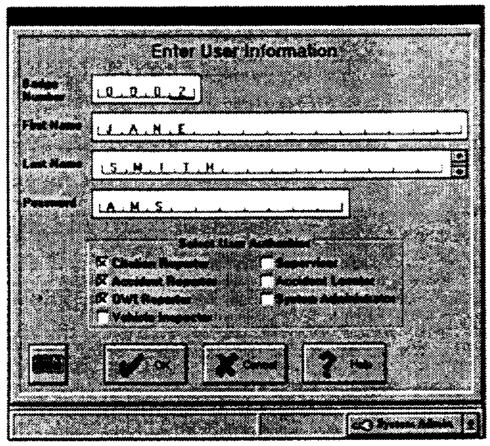
Supervisor - an officer who supervises officers or reviews reports of other officers. This level is intended for those individuals who may need to review the report before it can be passed along to the Iowa DOT.

Accident Locator - an officer who locates motor vehicle accidents reported by his/her department.

System Administrator - an officer who is responsible for maintaining OIM, and thus the access levels of the users. The system administrator may also add and delete users to and from the OIM application.

Access Levels are defined on the User Configuration screen. Only the system administrator has access to the User Configuration screen and can subsequently change an officer's access level. The User Configuration screen for Officer Jane Smith is pictured below. The check boxes in the "Select User Authorities" section indicate the functions available in OIM. If a box is checked, the user has the authority to perform that function (or fill in that type of form). In the example, Officer Smith has access to Citation (ECCO), Accident Reporting (MARS), and Operating While Intoxicated (MOWI) functions.

Other information on the User Configuration screen includes the Badge Number, Name, and Password of the officer. The Badge Number and Password fields are required to login to the OIM application. An officer's configuration can be changed at any time by the system administrator.



User Screens

3.1 Login Screen

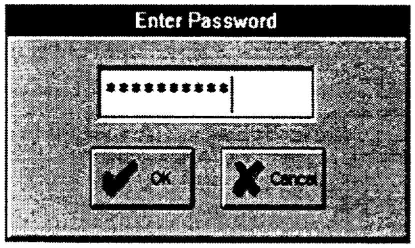
The Login screen controls access to the OIM application. This screen consists of the OIM logo and a drop-down list of authorized users, identified by their badge numbers.

To login to the application, an officer chooses the appropriate badge number from the drop-down list of valid users or types the badge number in the field provided. The user then selects the Login button at the bottom left corner of the screen.

The "About" button provides the user with general information about the OIM application, the "Exit" button returns the user to the previous screen and the "Help" button provides the user with on-line help regarding the Login screen.

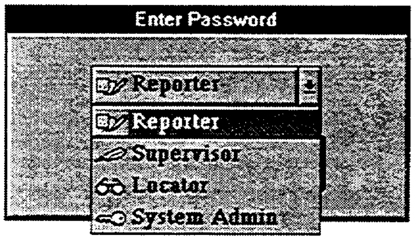
3.2 Password Screen

Password entry is the second step in accessing the OIM application. Each authorized user is required to have a password. The password can be up to 10 characters long and can be changed by the officer at any time. Only the correct password, in combination with the badge number, allows an officer to access OIM.



A password can be entered in several ways: with the physical keyboard, using the on-screen (virtual) keyboard, or utilizing Optical Character Recognition to manually write the password in the password field. For security reasons, the characters entered appear on the screen as asterisks (*). After a password has been entered, the officer selects the OK button.

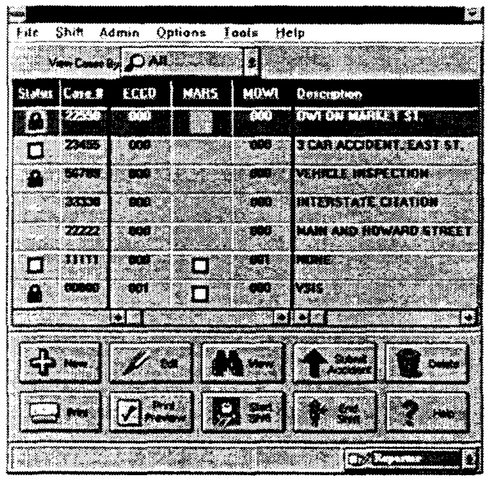
If the password is valid, a drop-down list of the access levels (Reporter, Supervisor, Locator, or System Administrator) available to the user is displayed. The user chooses the access level desired and selects the OK button. Only those access levels available to the user are listed. For example, if a user is defined as a reporter and supervisor, then only the Reporter and Supervisor access levels are listed. Users with a single access level will not see this screen. Instead, this screen is bypassed and the user is automatically logged in with the proper access level.



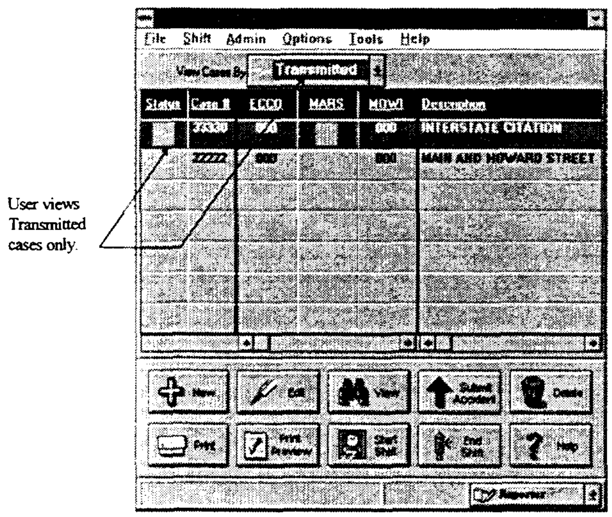
3.3 Event Manager

3.3.1 Description of the Event Manager

OIM is designed around the concept of motor vehicle "events". An "event" is any incident in which an officer is called to perform motor vehicle reporting. The Event Manager is the tool used to organize all of the events reported using OIM. The Event Manager allows officers to easily add, delete, edit, locate, view, and print events. In the complete version of OIM there are four components: Mobile Accident Reporting System (MARS), Vehicle/Driver Safety Inspection System (VSIS), Electronic Citation Component (ECCO), and Mobile Operating While Intoxicated (MOWI) reporting. An event can have many scenarios, and can involve one or several of the components of OIM. For example, an officer may be investigating a motor vehicle accident and may determine that one of the individuals involved should also receive a citation. Both the accident and the citation would be grouped under one "event", which would utilize both MARS and ECCO.



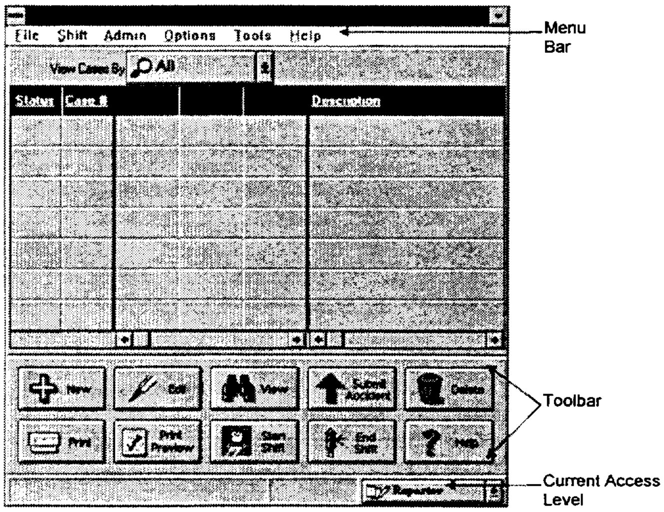
Each event is categorized by a status level. The four event status levels are: All, Open, Locked, and Transmitted. "All" displays all of the events that an officer has reported. "Open" displays events that are being worked on by the officer. "Locked" displays those events which are currently in use by another officer. This means that either the event has been transferred to another field unit or that the event is being manipulated by another user on a networked system. "Transmitted" displays events that have been transmitted to the Iowa DOT. To change the view of the Event Manager cases, the user selects an option from the "View Cases By" drop-down list box. The view will change based upon the event status that is chosen from the list box.



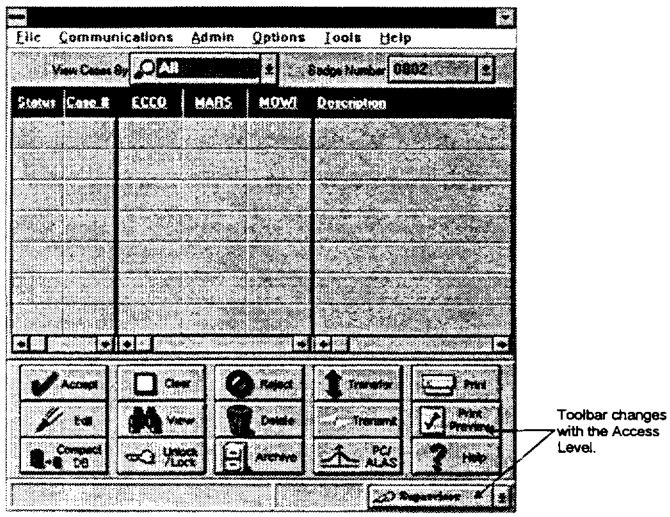
The events displayed by the Event Manager change depending upon the status view selected. In the picture above, the officer has selected the "Transmitted" view. There are two events that have been transmitted to the Iowa DOT and therefore, only the two cases with a status of "Transmitted" are displayed.

3.4 Event Manager Toolbar

The Toolbar is the series of buttons located at the bottom of the Event Manager screen. The buttons represent the most commonly used functions from the Menu Bar, and thus act as a short cut to the Menu Bar. The Toolbar changes depending on the user's access level. It is customized to include only those functions which are required by that user in performing his/her job. In the picture below, the user's access level is Reporter. The current access level is identified by the drop-down list box in the bottom right corner of the Event Manager screen. This picture shows the Toolbar available to a Reporter.

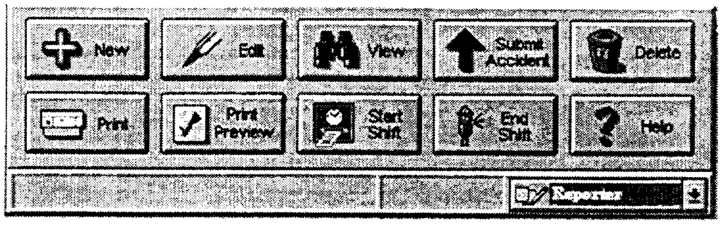


In this example, the user has Supervisor access. The Toolbar changes to indicate the different functions that are available under this access level. The Event Manager screen has customized itself to the access level of the user.



3.4.1 Adding New Events and Editing Existing Events

The process of adding new events or editing existing events begins with the Event Manager Toolbar. To add a new event, the user selects the "New" button from the Toolbar. To edit an existing event, the user chooses the event he/she wishes to edit from the list of events provided and then selects the "Edit" button. When the user selects one of these buttons, the Event Manager is closed and the OIM Editor is displayed on the screen. The OIM Editor is the tool used to report and/or change the information pertaining to an event. There are two main areas of the OIM Editor where data entry occurs: OIM Common Information and OIM Component Information. These areas are discussed in a later section.



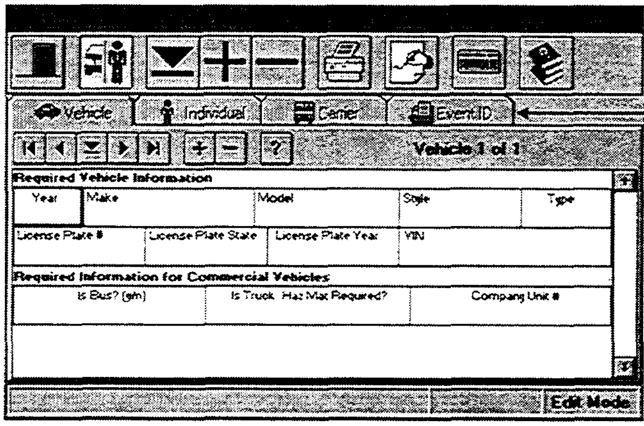
3.4.2 Viewing Events

A user can review event data at any time by selecting the "View" button from the Event Manager toolbar. This function allows the user to navigate through all forms created for a specific event and review the data that were collected. No additions, deletions, or edits are allowed using this function. To view an event, the user selects a specific case from the list displayed by the Event Manager and selects the "View" button. The OIM Editor appears with the Vehicle, Individual, Carrier, and Event ID tabs visible. Additional component-specific forms can be accessed through the OIM toolbar.

3.5 OIM Common Information

Certain data are collected on every OIM report. These data can be categorized into three types of information: general event information, the vehicles involved in the event, and the individuals involved in the event. These groups of information are common to many of the forms that an officer fills out. For example, an officer stops a car for speeding and after doing so, suspects the motorist is driving under the influence of alcohol. The officer must fill out a citation form for the speeding violation as well as an Implied Consent form. Both of these forms require general information about the time and location of the event, the vehicle that was stopped, and the individual who was driving the vehicle. Under the paper-based process, the officer would have to copy the common information down for each form.

OIM Common Information eliminates this duplicate data entry. It is designed around the three groups of common information mentioned above, with an additional group for commercial vehicle reporting. Each group of information is accessed through a tab, similar to the tab at the top of a paper file folder. The four common information tabs are: the Vehicle Tab, the Individual Tab, the Carrier Tab, and the Event ID Tab.

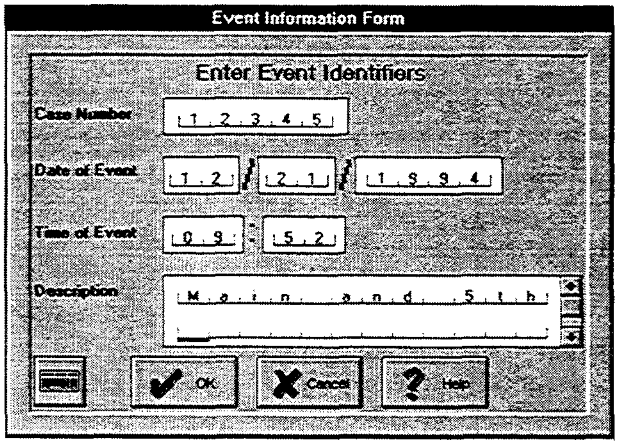


The tabs are designed so that an officer can easily move among them, adding or changing information when convenient. This is done by selecting the desired tab label.

Once the officer has completed the Common Information section, these data can be accessed in forms associated with any of the four OIM components. Each component has list boxes for those sections which require common information. The user can then choose the appropriate information from the list and the common data are automatically entered into the appropriate section of the component form.

3.5.1 Event Identification Tab

The Event Information Form automatically appears whenever an officer is entering a new event. This form records basic information used to identify the event. This form can be accessed at any point during event reporting by selecting the Event ID Tab. The case number and description fields are displayed on the Event Manager as a reference tool for the officer. The date and time fields are used as the default for many of the date and time fields in the OIM components.

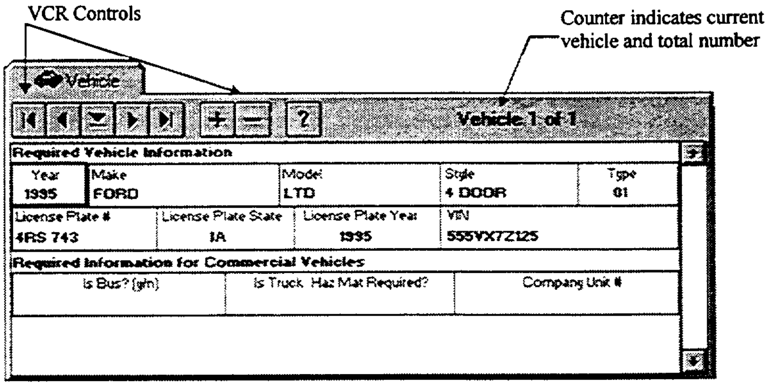


3.5.2 Vehicle Tab

General information regarding the vehicle(s) involved in an event is entered and stored through the Vehicle Tab.

Because an event can involve more than one vehicle, the Vehicle Tab is designed so that the information for several vehicles may be entered. This is done through the use of "VCR" Controls on the Vehicle Tab.

The VCR Controls are a set of buttons, so named because they are similar to those found on a video cassette recorder, that allow an officer to enter or delete vehicles, and to move easily among vehicles once they have been entered. These controls are identified on the picture.



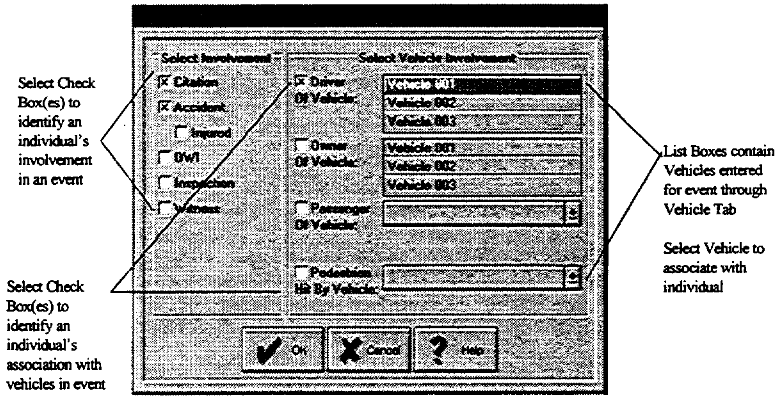

The VCR buttons allow an officer to move among two or more vehicles that have been entered for an event. The first button on the left shifts control to the first vehicle entered for the event. The second button shifts control back one vehicle, so that if the officer is on the third vehicle, pressing this button displays the second vehicle on the screen. The third button lists all of the vehicles that have been entered for the event so that an officer may select a vehicle from the list and display that information on the screen. The fourth button shifts control forward one vehicle, so if the officer is on the third vehicle, pressing this button displays the fourth vehicle on the screen. The fifth button shifts control to the last vehicle entered for the event.

A counter is displayed to the right of the VCR controls to identify the vehicle currently displayed on the screen. This counter is identified in the example above. The first number indicates the position of the vehicle displayed on the screen, and the second number indicates the total number of vehicles entered for this event.


The Plus and Minus buttons are used to add and delete vehicles in the Vehicle Tab. Adding a new vehicle to the event is done by selecting the Plus button. Selecting this button displays the vehicle data entry fields on the screen. The Minus button is used to delete a vehicle from the event. Selecting this button deletes the vehicle currently displayed on the screen. A confirmation request is displayed before any deletion from the database occurs.

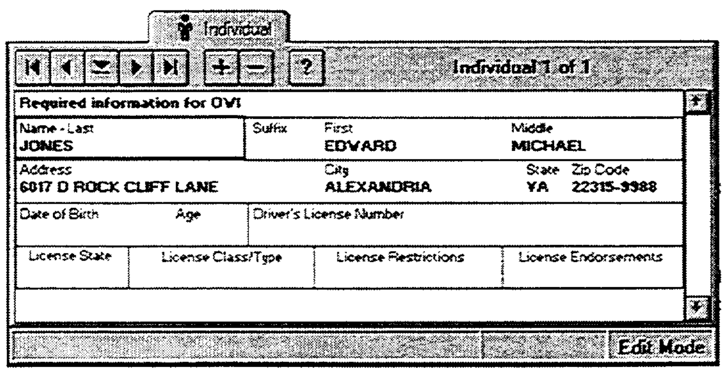
3.5.3 Individual Tab

General information regarding the individual(s) involved in an event is entered through the Individual Tab. The Individual Tab consists of two user interface screens: the Individual Configuration screen and the General Information screen.



The Individual Configuration screen is the first to appear when an officer selects the Individual Tab. This screen details an individual's involvement in the event. The first part of this screen identifies the individual's involvement or activity in the event by marking the appropriate check boxes. The second part determines the individual's association with the vehicles involved by marking the appropriate check boxes and selecting a vehicle from the list box provided. The list box consists of vehicles that have been entered in the Vehicle Tab. If no vehicles have been entered for the event, there will be no vehicles in the list box.

When an officer has completed the User Configuration screen by pressing the OK button, the General Information screen is displayed to the user.



The information required in this section changes depending upon the involvement defined on the Individual Configuration screen. This individual's involvement was defined as Operating a motor vehicle While Intoxicated (OWI). As a result, the required information is for an Implied Consent Form.

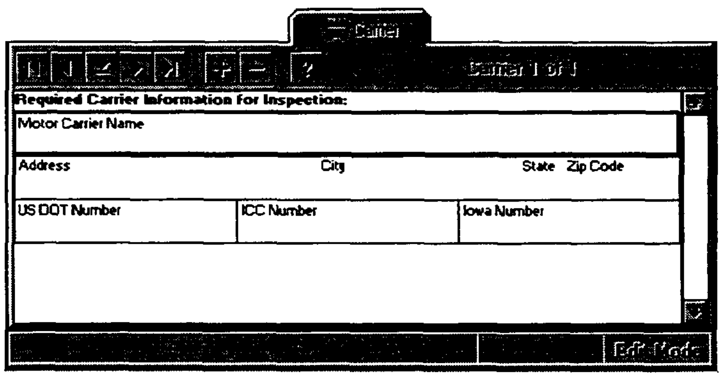
As with vehicles, there can be more than one individual involved in a single event. The General Information screen is designed so that the information for several individuals may be entered. This is done through the use of VCR controls at the top of the screen. These controls allow an officer to enter or delete individuals and to move among these individuals once they have been entered.

The VCR buttons allow an officer to easily move among two or more individuals that have been entered for an event. The first button on the left shifts control to the first individual entered for the event. The second button moves control back one individual in the list. The third button lists all of the individuals that have been entered for the event so that an officer may select an individual from the list and display this information on the screen. The fourth button moves control forward one individual. The fifth button moves control to the last individual entered for the event.

The Plus and Minus buttons are used to add and delete individuals from an event. Adding a new individual to the event is done by selecting the Plus button. When this button has been selected, a new Individual Configuration screen is displayed. Once the individual's involvement has been defined, the General Information screen is displayed. Deleting an individual from the event is done by selecting the Minus button. When this button has been selected, the current individual is deleted. A request for confirmation is required before any deletion to the database occurs.

A counter informs the user as to which individual is currently displayed on the screen. The first number indicates the individual that is currently displayed, the second number indicates the total number of individuals entered for the event.

3.5.4 Carrier Tab



General information regarding the commercial vehicle carrier(s) involved in an event is entered and stored in the Carrier Tab. Carrier information is common to the VSIS and MARS components of OIM.

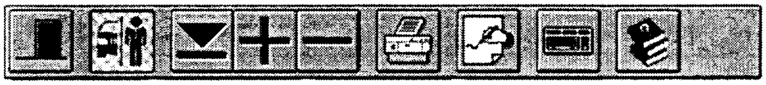
As with vehicles and individuals, there can be more than one commercial vehicle carrier involved in a single event. The Carrier Tab is designed so that the information for several carriers may be entered. This is done through the use of VCR controls at the top of the screen. These controls allow an officer to enter or delete carriers and to move among these carriers once they have been entered.

3.6 Component Selection and the OIM Editor Toolbar

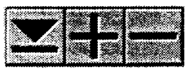
There are currently four components in OIM: the Electronic Citation Component (ECCO), the Mobile Accident Reporting System (MARS), the Mobile Operating While Intoxicated (MOWI) system, and the Vehicle Safety Inspection System (VSIS). Each component contains forms that are needed to fulfill the requirements of that type of motor vehicle reporting. For the purposes of this project, New Jersey, Washington and Wisconsin used only the MARS component.

Component selection is the second main function in the OIM Editor. OIM is designed so that an officer can either complete the OIM Common Information first, or immediately select a component and begin filling out forms pertinent to the event. Components are added using the OIM Editor Toolbar. This Toolbar enables the officer to add or delete components at any time. The entire OIM Editor Toolbar is pictured below, with the three buttons used for component selection identified separately.

OIM Editor Toolbar:



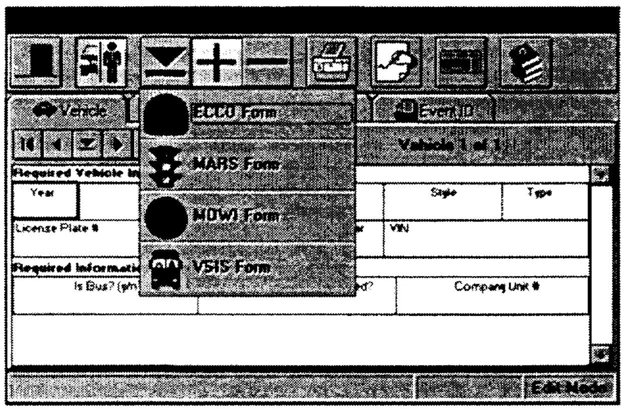
Component Selection Buttons:



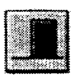
The Plus button allows an officer to select a component to add to the event. When a component has been selected, a rectangular box appears around the component, as in the picture below. Selecting a component from this list displays the required reporting forms for that component. Components can be added and used in any order and in any combination, with the exception of VSIS, the Vehicle Safety Inspection System, which can only be used alone or in conjunction with ECCO, the citation component.

The minus button allows an officer to delete a component form from the event. A list of all forms which have been entered is displayed for the user to choose from. A request for confirmation is displayed before the data are deleted from the database.

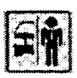
Selecting the down arrow button at the top lists the component forms which have been entered for the event. Once this list is displayed, the user can choose the desired component and the required reporting forms for that component are displayed.



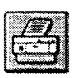
The remaining buttons on the OIM toolbar also represent functions that are available to an officer at any time during the reporting process.



The Exit button returns the user to the Event Manager screen. This function does **not** exit OIM; any data recorded for the current event will be saved.

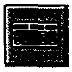


The Vehicle/Individual button returns the user to the OIM Common Information tabs, allowing the user to enter or edit data regarding the vehicles, individuals, or carrier.



The Print Button allows the user to print the appropriate reports for a selected event.


The Notes button allows the user to enter narrative text or freehand notes as supplementary information pertaining to the event.


The Keyboard button activates the on-screen keyboard, which appears immediately for use.


The Help button activates on-line Help, which provides additional information about specific fields, forms, and functions.

For more information about American Management Systems, Inc. and the accident reporting software, contact:

Greg Pellegrino
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Public Safety and Transportation
(703) 267-7030

APPENDIX B. TECHNOLOGY DISTRIBUTION SCHEDULES FOR WASHINGTON AND WISCONSIN

Table 26. Washington distribution schedule.

	Weeks 1-4	Weeks 5-8	Weeks 9-12	Weeks 13-16	Weeks 17-20	Weeks 21-24	Weeks 25-28	Weeks 29-32
Officer 1	360P Both	360P GPS	360CE Both	360CE GPS	360P Both	360CE GPS	360CE Both	360CE GPS
Officer 2	360CE GPS	360P Both	360P GPS	360CE Both	360CE None	360P GIS	360CE GIS	360CE GPS
Officer 3	360P None	360CE GIS	360P GIS	360CE None	360P Both	360P GPS	360P Both	360CE None
Officer 4	360CE None	360P GIS	360CE GIS	360P None	360CE GPS	360CE Both	360P GPS	360CE None
Officer 5	360P GPS	360CE GPS	360P Both	360CE Both	360P GIS	360CE GIS	360P None	360P None
Officer 6	360P GIS	360P None	360CE None	360CE GIS	360CE Both	360P Both	360CE GPS	360CE Both
Officer 7	360CE GIS	360CE None	360P None	360P GIS	360CE Both	360CE GPS	360P GPS	360P None
Officer 8	360CE Both	360P Both	360CE GPS	360P GPS	360P GIS	360P None	360CE GIS	360P Both
Officer 9	360CE None	360CE GIS	360P None	360P GIS	360CE GPS	360P GPS	360P Both	360P GPS
Officer 10	360P Both	360CE GPS	360CE Both	360P GPS	360P None	360P GIS	360CE None	360P GPS
Officer 11	360CE GIS	360CE None	360P GIS	360P None	360P GPS	360CE Both	360CE GPS	360CE GIS
Officer 12	360P GIS	360P None	360CE GIS	360CE None	360CE GIS	360CE None	360P None	360P GIS
Officer 13	360P GPS	360CE Both	360P Both	360CE GPS	360CE GIS	360CE None	360P GIS	360CE GIS
Officer 14	360CE Both	360P GPS	360CE GPS	360P Both	360CE None	360CE GIS	360P GIS	360P GIS
Officer 15	360CE GPS	360CE Both	360P GPS	360P Both	360P None	360P None	360CE None	360CE Both
Officer 16	360P None	360P GIS	360CE None	360CE GIS	360P GPS	360P Both	360CE Both	360P Both

Table 27. Wisconsin distribution schedule.

	Weeks 1-3	Weeks 4-6	Weeks 7-9	Weeks 10-12
	IBM 360P		Fujitsu	
Officer 1	GIS	None	GPS	Both
Officer 2	None	GIS	Both	GPS
Officer 3	GPS	Both	GIS	None
Officer 4	Both	GPS	None	GIS
	Fujitsu		IBM 360P	
Officer 5	GIS	None	GPS	Both
Officer 6	None	GIS	Both	GPS
Officer 7	GPS	Both	GIS	None
Officer 8	Both	GPS	None	GIS

APPENDIX C. DESCRIPTION OF SYSTEMS USED

Iowa

Computer System - Compaq Concerto, pen-based 486 computers, 33 MHz, 250-Mb hard drive, 8-Mb RAM.

Software - Windows for Pen Computing, CIC Handwriter for Windows.

GPS - Trimble Mobile GPS Gold Development Kit (includes card and receiver antenna). FM Portable Paging Receiver, RTCM-104 Output. "Premium One" Meter Service (12 months).

New Jersey

Note: Because the participating agency in New Jersey had a great deal of difficulty procuring equipment for this study, it was necessary for them to borrow computers from another police agency in order to participate. The systems described here are those that were actually used. The ones described in the table showing equipment cost are those that were ordered, but not obtained in time for use in this study.

Computer Systems - IBM ThinkPad 355CS; 486SX/33; 170- or 250-Mb hard drive; 24-cm dual-scan color display; local bus video; 8-Mb memory; 8.9-cm, 1.44-Mb disk drive; Personal Computer Memory Card International Association (PCMCIA) slot (type II or type III); full-size 85-key keyboard with TrackPoint pointing device; serial; parallel; SVGA; keyboard/mouse ports.

IBM 360P 486SX/33; 340-Mb hard drive; 24-cm dual-scan color display; local bus video; 8-Mb memory; 8.9-cm, 1.44-Mb disk drive; PCMCIA slot (type II or type III); full-size 85-key keyboard with TrackPoint pointing device; serial; parallel; SVGA; keyboard/mouse ports.

Software - CIC Handwriter for Windows. VISIO V4.0 for Windows.

Washington

Computer Systems - IBM ThinkPad, pen-based computers, Model 360P, 24-cm STN, 340-Mb hard drive, 20-Mb RAM, 2620-50F.

IBM ThinkPad, standard laptop (non-pen) computers, Model 360CE, 21.3-cm STN, 540-Mb hard drive, 20-Mb RAM.

Smart Modular Technologies PCMCIA Serial Card, VISIO Express.

Software - CIC Handwriter for Windows, Geographic Information System (GIS) Software - ESRI ArcView.

GIS - ArcView 2.0 using maps developed by the Washington State Department of Transportation and Thurston County, WA. When the software was started, it showed a map of Thurston County divided into township geographical areas. Due to the need to load data for the entire county, initial attempts to zoom in on certain areas of the county took several minutes. This was solved by dividing the county map into sections using a grid pattern. The first step in identifying the accident location was to select one of these sections so that only data for that section of the county would be loaded. Similar problems related to time to load data made it necessary to leave road names off the maps until a user requested names for roads on a road-by-road basis. Users could zoom in and out of the map to find the accident location. Users would then click on the location with the pointing device and it would be saved as latitude/longitude coordinates in the accident record database. The persons who created the GIS system used in this study have reported that the system could now be improved a great deal from the original version due to updates in the ArcView software and their increased familiarity with using the software.

GPS - Trimble, PCMCIA Mobile GPS Gold Card, NavBeacon XL Differential Receiver.

The GPS system consisted of a GPS receiver with a PCMCIA card to interface with the computer; a removable GPS antenna mounted outside the patrol car; and a differential corrections receiver mounted in the trunk of the car, connected to the computer via a serial cable, into a serial card located in another PCMCIA slot. The differential correction signal was provided by a U.S. Coast Guard transmitter. GPS software was Trimble Control Panel 4.2.

Wisconsin

Computer Systems - Fujitsu Stylistic 500, Non-pen-based computers, 486/50, 170-Mb hard drive, 20-Mb RAM.

IBM ThinkPad, pen-based computers, Model 386PE, 486/50, 340-Mb hard drive, 20-Mb RAM.

GIS - Software - ESRI ArcView 2.1. Officials of the Dane County Land Information Office (LIO) coordinated the development, and incorporation into the accident reporting system, of the GIS. Much of the programming of the GIS was handled by GeoAnalytics of Madison, WI, under contract to LIO. The GIS functioned similarly to the Washington system. Officers selected a portion of the county and zoomed in and out of the map until they found the accident location, which they recorded by placing a mark on the screen at the location. Unlike Washington, Wisconsin's GIS returned an English-language description of the accident location that they could use to verify the accuracy of the location as determined using the GIS.

GPS - Trimble, PCMCIA Mobile GPS Gold Card, NavBeacon XL Differential Receiver (radio receiver for differential correction from the U.S. Coast Guard) Antenna mounted on dashboard.