Emerging Technologies for Automated Data Collection

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Prepared for
Safety and Traffic Operations Section
Texas Department of Transportation

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I. BACKGROUND

This report was written by the Safety Division of the Texas Transportation Institute under contract with the Texas Department of Transportation. This report examines the various technologies for automating the data collection process and several emerging technologies that incorporate these technologies. The report includes a summary of recommendations by the author.

Computer hardware, software and data collection technology are continually changing. Computers are getting smaller yet more powerful while new innovative ways of automating the data collection process are becoming more commonly available. These technological changes will affect traffic safety, its databases and its data collection processes. It is imperative for traffic safety professionals to use the most capable technology available.
II. Automated Data Collection Technology

Imagine that you are an employee in the public sector. It makes no difference whether you are working at the local, state or federal level. To do your job in serving the taxpayer, you must have the most accurate and timely information available. You obtain a large amount of this information from data stored in computerized databases. You are a "user" of these computerized data. You must interpret the data and convert it into meaningful information.

This scenario is actually commonplace in the public sector today. Access to a computerized database is a daily requirement. However, less funding to do the same or more work is also commonplace. The public sector must continually search for ways of doing its job more efficiently with fewer resources. Today's computer software and hardware are important tools for access to the large and varied public databases.

Since the introduction of the desktop personal computer (PC), particularly the IBM-PC in 1981, and its associated operating systems and applications software, users have had ready access to computing power on their desktops. The user has the potential for direct access to needed data. This direct access eliminates the time required to describe a data request to a computer technician or data analyst. Also the technicians or analysts are usually responsible for a complex mainframe/minicomputer system as well as any number of other users. Direct access to computerized data reduces the "downtime" experienced when waiting for the data request to be processed, as well as the frequent follow-up requests to refine previous requests for data.
Although access to computerized databases is becoming less of a problem for public sector desktop computer users, another problem is now becoming prevalent: users need accurate and timely data. The requirement is not new, it's just more obvious now that database access is not the problem that it was.

On the surface, accurate and timely data is assumed to be an automatic benefit of computerized databases. Indeed, computers perform their tasks much more quickly than human beings; however, computers only retrieve what is placed in them. So why is accuracy and timeliness a problem? The computers and their databases are not really to blame; the users are the real culprits. Many processes of data collection and verification involve error-prone methods. Much of the data for the public sector is collected on paper, and, once collected, is examined, photocopied, and perhaps even rewritten and interpreted by others before being entered into the computer. This method of data collection and verification has been used since there was pen and paper. But this method is highly prone to human error being incorporated into the data. For example, many handwritten data forms are difficult to read by data entry operators; the operator can easily misinterpret illegible symbols or words and, because of time or geographic constraints, the operator "interprets" the phrase and continues the data entry process. These kinds of errors are very subtle yet corrupt the accuracy of the database immediately. These data entry errors are also difficult if not impossible to detect in the database.

Also, the timeliness of the data can affect the database quality. Computerized databases play a major role in assisting public sector funding decisions. Accurate data is obviously important, but timely data is equally important. Some databases used in funding decisions are missing not weeks or months of data, but years. Accurate and timely databases are used not only for analysis, but for evaluating the effectiveness of research
efforts. Transportation researchers across the nation rely on large databases of crash, roadway, and exposure data to evaluate current roadway safety and to design new methods of making the roadway safer. Questionable accuracy and poor timeliness of these databases only degrade the efforts of researchers evaluating a traffic system where travel volumes continue to increase. Technologies being developed as part of promising intelligent vehicle-highway systems (IVHS) research should help provide methods of making the highways safer, but effects of IVHS are still unknown.

In the United States transportation safety research program, the environment of which researchers are familiar is changing. The medical, property damage and lost productivity costs of motor vehicle crashes is $70 billion annually in the United States. The U.S. Secretary of Transportation targeted safety as a top departmental priority. Continued research will only increase reliance on computerized databases. Therefore, more emphasis on accuracy and timeliness of these databases should be approached. More research is needed for improving crash data collection at the scene to reduce the paperwork and increase the accuracy. Alternative locationing technologies like global positioned satellites should be investigated for potential location accuracy (1).

In recent years, technological advances have helped to reduce the middle steps of data collection by human, error-prone methods. The closer to their origin that data is automated, the more accurate and timely they will be for access. Some of the technological advances have been available for many years and are being innovatively combined with other technologies to create more alternatives to automating the data collection process. Excessive manual handling of data before they are entered into the computer results in untimely databases with highly suspect accuracy.
All databases require entry of data via an "interface" between it and the user. This interface is usually a keyboard and monitor. The user places data into the computer by typing onto the keyboard and responds to any questions or instructions from the computer monitor about the data. There are generally 13 methods of automatic data collection available that circumvent keyboard data entry partially or altogether (2). You will recognize and understand some of these methods immediately; others you may not. Perhaps you have used one or more of the technologies not realizing its impact on the accuracy and timeliness on databases. The methods described in this report for collecting data automatically are:

- Bar Code
- Optical Mark Recognition (OMR)
- Optical Character Recognition (OCR)
- Optical Imaging Processing (OIP)
- Biometric Identification
- Magnetic Ink Character Recognition (MICR)
- Magnetic Stripe
- Radio Frequency Identification (RFID)
- Touch
- Vision
- Voice
- Global Positioning System (GPS)
- Radio Frequency Data Communications (RFDC)
Almost everyone has used or seen the use of bar codes firsthand, whether in a local supermarket or at the airport ticket counter. The pattern of bars and spaces on a bar code symbol can represent any number, letter or symbol in any number of coding formats. Use of bar codes as an automated data collection method accounts for over sixty percent of the world market.

The first standard bar code format used industry-wide was the Uniform Product Code (UPC) in 1973. The UPC was limited to the retail grocery industry at that time; however, it is now widely used in many other industries. Other bar code formats include Code 39, Interleave 2 of 5, and Code 128. Other formats are being considered as standards.

Several types of scanners to collect data from the bar code symbols are used: the light pen, the handheld laser scanner and the fixed laser scanner. Many of us see the fixed laser scanners used in local grocery stores and other retail stores. The light pen and handheld scanners are convenient data collection methods for industries requiring mobility while reading the bar codes. For example, a person responsible for taking inventory in a warehouse can use the light pen or handheld laser scanner to read bar codes on boxes while walking through the facility. The scanners either have built-in microprocessor intelligence for data storage or transmit the data through a cable or through the air by radio frequency or satellite to a computer for storing the data.

Software and hardware for this technology have kept pace with changes in the overall personal computer
industry. The hardware is smaller, cheaper and lighter. The software is better and available for more types of operating systems like the PC-based DOS and Apple environments.

Several uses for this technology in traffic safety can be identified. The vehicle identification number (VIN) on all vehicles is composed of seventeen digits and characters. The VIN is very often copied onto accident reports and other paperwork in either permuted form, or missing several digits, or both. The VIN contains encoded information that can eliminate many other variables in a database, such as the vehicle style, vehicle year, curbweight and other pertinent information about the vehicle. A simple bar code incorporating the VIN is now placed in all vehicles to allow quick and accurate capture for records by a handheld bar code reader. Another use is reading information with a bar code reader from an encoded driver’s license. The information could include even the driver’s name and address if necessary.

One last example of bar code usage is reading inventory information about road signs, vehicles and equipment that is on site. A handheld scanner can be used to read bar code identification for road signs by just driving past the sign at low speed and holding the scanner near the sign.

**OPTICAL MARK RECOGNITION (OMR)**

This technology is also called by another name, "mark sense" technology. OMR relies on an optical scanner to collect the data from a standardized paper form. The form has certain positions marked on it by the user.
The markings are sensed by the scanner which then generates a computer character for that mark's position on the form. Optical scanners today can sense marks on the forms made by pencil or pen.

Uses that are familiar to many for OMR technology are in public surveys and academic testing. The forms have small circles on them and the users then fill in the circles that correspond to the required responses. Even voting precincts throughout the nation are using OMR technology in the voting booths.

One use that should be of great interest in the traffic safety area is the use of accident and citation reports designed for OMR technology. The Uniform Accident Report Form for Michigan (UD-10) has been redesigned for OMR technology for a large portion of the UD-10. The new form was implemented in January 1992 and is scanned into a computer database via desktop scanners. The coded information will be highly accurate and very timely.

A limitation to OMR technology usage without other supporting methods is that data not amenable to OMR cannot to be collected in a timely manner on the form. For example, a person's name could be printed on a form much more quickly than filling in a large number of marks, one mark for each letter. Include the address and the form could reach a rather clumsy size and result in more time to complete than a non-OMR form. However, use of OMR technology along with other technologies is an attractive method of accurately collecting much of the data that is required in the traffic safety field today.
Optical Character Recognition (OCR)

Broadly defined, OCR technology uses optics to interpret a character-based symbology into computer data format. This definition includes the two previous technologies discussed, bar code and OMR. However, the definition of OCR used for this report is for products and techniques allowing electronic interpretation of printing that humans also recognize: handwriting recognition.

OCR technology, until recently, was a job requiring the same type of device that OMR technology required: an optical scanner. The scanners can read various styles of typewritten fonts as well as well-formed printed letters. Many scanners now have a "learning" capability where they can be taught new fonts and type styles by repetitive scanning and correction of the new styles. Scanning script format handwriting is still in its infancy and very unreliable. Most scanners are fixed scanners in office environments that process large volumes of documents quickly and accurately. The cost for the scanners, as with other desktop computing products, is falling while their power is increasing.

However, recent developments with PCs have resulted in the availability of very small, even handheld, computers that can interpret handwriting as it is written onto a clipboard-shaped piece of glass with a metal "ink-pen". These products are called pen-systems and are a brand new technology involving more and more vendors and manufacturers. Products incorporating the concept of pen-systems have been available from several manufacturers for several years, yet the past year has seen an explosion of pen-system products and operating systems in the computer industry. But even with the promise of the new pen-system technology, optical scanners are still quite popular and effective.
OPTICAL IMAGE PROCESSING (OIP)

OIP technology uses the same type of optical scanners that OCR technology uses except the scanner does more than recognition of characters on the documents being scanned. In OIP, the scanner acts like a camera and takes a photograph of the document. This "image" is stored in the database. Along with the image, indexing information is required for each image so it can be retrieved when requested. The indexing can be done at the computer keyboard or automatically when the document is scanned; the document can have certain areas of the form that are read like an OCR scanner. The OCR-interpreted characters are then stored as characters in the index for document retrieval later. Once the image is captured, the original document can be eliminated. Thus the need to inventory physical paper documents can be eliminated with the storage of the images on high-capacity mass storage devices, usually an optical disk.

Just a few years ago, OIP technology was a costly venture because the mass storage devices capable of storing the graphic images were expensive. Now, with the wider use of optical storage technology and its large capacities, OIP technology is a more viable option for many public sector agencies. The use of "jukebox" storage devices have made storage and retrieval of the images much easier also. The jukebox is a device that stores separate optical disks or platters in a manner similar to storing phonograph records on a musical jukebox (thus the name), so that the platters can be automatically mounted and dismounted for retrieval on demand by the computer system.

The use for OIP technology lies in its ability to store millions of documents in a much smaller space than that
required to store the actual physical documents. The document can also be retrieved by multiple user, even at the same time, for reference and verification in a local office or across the nation. The retrieval is totally automatic without use of filing cabinets or clerks to physically find a document (if it can be found). Also, with the high quality laser printers available today, a physical copy of the image can be printed upon request.

**BIOMETRIC IDENTIFICATION**

Biometric Identification is not a new technology, yet it is still a growing technology and still quite controversial. This method of automatic data collection involves capture and classification of certain measurements of the physical human body. The three areas that are most familiar to us are fingerprinting, DNA patterns and retinal patterns. All biometric identification techniques have the same goal: identification of a unique pattern belonging to a person.

Because of its complexity and controversy, little use of this technology is forecast for the traffic safety field and its general data collection needs. If and when the technology becomes more acceptable and less controversial, it is doubtless that its use in traffic safety would be valuable for identification and detection of drivers and perhaps even their physical condition (e.g., drunk, sober, sleepy, etc.).
**Magnetic Ink Recognition (MICR)**

MICR technology has been used for many years. It is commonly used in the marking of U.S. bank checks. The characters and timing marks on the bottom of standard checks are the "codes" that are read by the MICR scanners.

This technology is very well entrenched in the banking industry yet is not used to any extent in any other market. It is a technology that will not soon be eliminated from the banking industry; however, there is no sign that it will be used in any other field, including traffic safety, anytime in the future.

**Magnetic Stripe**

Magnetic Stripe technology is widely used in the banking and credit card industry. It involves encoding a magnetic stripe on credit cards, automatic teller machine cards and even identification cards. The magnetic stripe can contain any type of information that can then be read by a reader device. The reader can be very small and useful as a handheld device.

One large problem with the magnetic stripe technology is the stripe itself is susceptible to magnetic fields. Even passing the card inadvertently near a source of magnetism, including electrical devices, can easily destroy the information encoded in the magnetic stripe. Once destroyed, the card is useless. However,
recent advances in magnetic encoding has included development of a technique to create a stronger magnetic field for the stripe. This has resulted in magnetic stripe technology that is much more reliable and useful as a general data collection technique.

**Radio Frequency Identification (RFID)**

The RFID technology is a general category of automatic data collection and identification. This technology is well suited to harsh environmental conditions. RFID systems consist of electronic tags, antennas and readers. The tag is fixed to one location while the antenna and reader are connected to one another as one functional unit. The tags contain data that can be read by the reader through its antenna. The tags can be "read-only" and "read-write". If read-only, the information in the tag can be read only; if read-write, the tag's information can be read as well as changed by the reader(-writer) \(^{(8)}\).

Since the RFID uses the air for data transmission on radio waves, Federal Communications Commission (FCC) licensing procedures must be used for certain types of transmissions. Generally, the RFID systems use a wide range of radio frequencies. Regardless of frequency, the antenna need only be within a few feet of the tag for successful communication.

Another facet of RFID is the powering of the tags themselves. They can be battery-powered or can draw power from the antenna itself (passive). If equipped with a battery, the tag's power is activated by the
antenna power; once activated, the tag then uses its battery to complete data transmission to and from the antenna. All transmissions between the tag and antenna occur very quickly, within milliseconds, and require very little power for the short transmission time. The batteries in tags typically last for several years.

There are several traffic safety applications for RF/ID technology. One such use that has already been implemented in several locations is placing tags on vehicles passing through toll booths. The tags are read as the vehicles pass by the antenna at the toll booth station. The vehicle only needs to slow down, not stop. The toll is deducted from a pre-paid account belonging to the vehicle owner. This method of data collection by RF/ID is called Automatic Vehicle Identification (AVI) and is discussed later in this report. Another use of RF/ID is dynamic vehicle identification for collecting roadway volume information by vehicle class and other traffic management and monitoring tasks. Still another use is detection of stolen vehicles by enforcement agencies.

TOUCH

Data collection by Touch has existed for several years. Touching a "sensitized" computer screen or pad in a certain location generates data for the computer. Touch technology is a keyless alternative to data entry. It actually augments the keyboard functions and in certain applications replaces it. Touch technology is very useful in applications where character-by-character data collection is not necessary. Some general examples are point-of-sale and factory control operations.
Traffic safety applications are varied. One example is a touch-activated driver display and response system showing vehicle location on a roadmap and vehicle condition. Another use is in public access applications such as city map locators and roadside rest area information centers.

VISION

Vision technology involves use of a video camera to capture and process images and even to automatically make decisions based on computerized interpretation of the image. Applications using vision technology are very expensive and usually involve custom-tailoring to each user’s needs.

Some examples of the technology’s use include quality control in production assembly lines and use in specialized medical procedures. Traffic safety uses include not only the obvious IVHS-related activities, but also automatic identification procedures necessary in both enforcement and engineering tasks. Enforcement use of vision technology include capturing images of speeding vehicles for identification for ticketing and adjudication. Engineering use includes capturing images of pavement conditions in a moving vehicle for visual enhancement and analysis.
Voice technology for automated data collection seems a very natural means of communication since humans use voices to communicate while doing almost everything. To have a device understand our words as we speak them, and to immediately have that information understood and stored, is the ultimate in a human-to-computer interface. Voice technology is growing in its capabilities just as the other technologies in this report.

It is well suited for users needing hands-free operation of the technology. Currently, the vast majority of systems require training to the operator's voice. Just as you can have difficulty understanding new spoken accents, the voice system must also learn to interpret the words it encounters; it must be trained to the operator's voice.

Some real limitations still exist for voice technology. The vocabulary of voice systems is limited and the operator must know the particular phrases that can be understood by the system. The system must recognize the particular operator's voice; when a new operator is involved, the system must be trained for that operator. Voice systems require discrete utterances of the phrases, but using discrete syllables and sounds is not part of the natural way that we speak. So the operator must learn how to speak to the system. These systems are susceptible to background noise when being used. Some noises can be interpreted as utterances and mistakenly recognized as valid input. Added to all of this, voice systems are expensive.

The uses of voice technology, while ignoring some of the limitations, include any number of tasks. The system's hands-free type of operation is well suited for the medical field and its use by drivers is very attractive as well. A driver could control by voice many of the details that currently require him or her to look
away from the roadway: climate control, radio volume, vehicle speed and other vehicle conditions. The
vehicle could even respond by voice to the drivers request for information. IVHS research will advance this
technology similarly to the vision technology described earlier.

GLOBAL POSITIONING SYSTEM (GPS)

GPS is an exciting technology for all users of data that require a physical global location to be part of the data
elements requiring collected ⁷. GPS is the incorporation of U. S. satellite technology with the standard
longitude and latitude coordinated system for our planet; it is used to calculate a very exact longitudinal and
latitudinal location of any point on the planet using high-orbit satellites. GPS is making inroads into the
Geographic Information Systems (GIS) analysis packages available today. GIS software uses map-based
graphics to show database information spatially for analysis by the user. Very accurate locations can be
supplied to the GIS packages by using the GPS technology.

GPS was created by the U.S. Department of Defense (DOD) for use not only for defense purposes, but also
for civilian purposes. The system is managed by the U.S. Coast Guard. It functions by having an earth
receiver that communicates with satellite-transmitted signals. Locations are calculated based on principles
of traditional land-surveying: triangulation onto the desired location. Basically, three satellites are used for
the triangulation process with a fourth satellite used to correct minor timing errors. Obviously, GPS relies on
a line-of-site requirement to the satellites.

The accuracy of GPS can range from a centimeters to 100 meters. The accuracy is dependent on the quality of the ground receiver and on the operation mode of the satellites when the location is requested. The DOD, for strategic purposes, can selectively degrade the accuracy of the satellite signals; this is called Selective Availability. When the signal is degraded, civilian use of GPS comes into question. However, another method of GPS use not affected by Selective Availability is still available, Differential GPS (DGPS). DGPS allows location accuracy for civilian purposes regardless of the signal quality from the satellites. DGPS requires the placement of fixed earth receivers at known locations. The dynamic earth receiver can then use the satellites to get the triangulated position and the fixed reference point to calculate the location. Using DGPS allows accuracy within a meter. Texas is installing ten regional reference points (RRP) around the state for just this purpose. Sometime in 1992, all 24 satellites should be in place providing 24-hour, worldwide coverage for GPS use.

Uses for GPS, particularly in the public sector, are exciting. Every highway department, law enforcement agency, health department, utility department and others will be able to use GPS for accurate locationing of roadways, street signs, power poles, traffic accidents, patrol vehicles, potholes, health problems, etc. Once these locations have longitude/latitude assignments, information about the locations can be analyzed in a more complete manner (see the GIS discussion later in this report). Use by trucking companies and other fleet management businesses will profit from knowing exact locations of their equipment. Soon one of the most difficult data elements to capture accurately, location, will no longer be a problem for the many fields
Radio Frequency Data Communications (RF/DC)

RF/DC is simply the technology of radio frequency transmission of signals. This technology actually supports all of the previously described technologies. It provides a wireless link between the data collection process and the database application. Without it, RF/ID and GPS would be impossible. Although RF/DC generally requires a FCC license, users can incorporate broadband spectrum (low frequency) transmissions to usually avoid the licensing requirement. As can be seen in the RF/ID technology, radio transmission is a major advantage when *real-time* database updates are required for an application.
III. Integrating Data Collection with Emerging Technology

There are several emerging computer technologies that allow the data collection technologies already discussed to be integrated and used in combination. These technologies are:

- Geographic Information System (GIS)

- Mobile Display Terminals (MDT)

- Laptop Computers

- Pen-System Computers
Geographic Information System (GIS)

GIS is a software package that allows analysis of spatial data and its attributes (or data) on a computerized map. GIS has been available for almost 20 years. The data can be shown on the map in various ways at user discretion for analysis and reproduced on a plotter or printer. GIS is also called automated mapping/facilities management (AM/FM) because its main users have been in agencies involved in mapping and environmental management.

Until recently, GIS products required specialized minicomputer and UNIX-based workstations, but compatibility between GIS manufacturers and products was nonexistent. Now these systems are available on standard desktop DOS-based computers and there is some compatibility between vendors. With compatibility comes the ability to share maps and databases with users of varying GIS products. The future for GIS products will rely on the ability to integrate their capabilities with conventional computer processing needs and database formats that already exist.

As mentioned in the Global Positioning Systems discussion earlier, GIS packages can incorporate longitude and latitude coordinates into their mapping systems. This integration of GPS and GIS will only serve to strengthen both technologies in the future. GIS can be used by a number of professions. Following is a list of just a few examples of GIS applications:

- Traffic accident and citation incidents
- Crime incidents
• 911 emergency tracking
• Hazardous material tracking
• Vehicle routing and tracking
• Environmental planning
• Utilities management
• City zoning
• Pipeline maintenance
• Tax appraisal
• Legislative redistricting

According to Texas State Comptroller John Sharp, "From 65 to 90 percent of information managed by public or private enterprises is spatially related. And if you can visualize an object, you can understand the task easier and faster [3]. Mr. Sharp has suggested implementing a statewide GIS that will be accessible by all government agencies, whether the agency is local, regional or state level. This suggestion is being pursued be several of Texas state agencies [13]. Information is critical to functioning in the public sector. The useful lifespan for information is approximately 20 years [11], but the lifespan may be as high as 50 years for spatial map information. Computer hardware and software lifespans are about five and ten years, respectively. Being able to pool information and share it seems cost-effective compared to keeping information in a certain format useful only to the agency that "owns" the data. Digital map data to allow users to start using a GIS are available from several sources including the many vendors of the software [12].
MOBILE DISPLAY TERMINAL (MDT)

MDT technology is used in law enforcement applications. It incorporates a computer monitor and keyboard in the patrol cars and communication with a base computer system at a central location within the enforcement agency. MDTs are mentioned here because of their use of RF/DC technology and their communication capabilities with the other law enforcement databases around the country. When an officer is making a traffic stop or other task, information about the person and vehicle are displayed on the screen. Knowing this information allows the officer to decide what to do: make the stop, call for assistance, etc. Inclusion of data collection technologies from Chapter 2 can expand the MDT into a data collection device for magnetic stripes, bar codes and perhaps even video and voice image digitizing for storage on the central computer. Combining technologies with the MDT as part of a long-term plan would not be effective. The same capabilities could be added to a laptop computer and the user would gain all the MDT capabilities plus local computing power in the vehicle.

LAPTOP COMPUTERS

Laptops are simply desktop PCs that are much smaller, lighter and battery-powered. They are mentioned here because of what they are; they are becoming more applicable to field use much like the MDT’s. As a matter of fact, the laptops could replace the MDT concept, communicate with the central computer radio, and still give the officer a local computing capability that is not available with MDTs.
Laptops or notebook computers are currently available with 386 and 486 CPUs as well as very large capacity disk drives, megabytes of random access memory (RAM) and even high-resolution color monitors in a very compact box (usually less than 7 pounds). Modems can also be place into the laptop, which then can be used with regular and cellular telephones or the standard police radio frequencies.

Laptop computers have been used by the St. Petersburg Police Department in police cars since 1984 (16,17). It has been very successful and the department has plans of further implementation of the various capabilities of the laptops, which number nearly 500 now. They collect data on all citations and accidents as well as various officer-activity reporting requirements. A recent internal survey found 90 percent of the officers thought their reports were more accurate and legible than in handwritten form; only five percent of those surveyed wanted to return to handwritten reports. According to the administrative officers, the reports indeed are more accurate, timely, and much easier to read. Another interesting aspect of the use of laptops was that the officers felt that as much as 30 percent more time was available for them to do hands-on police work in the field.

Officers in Wake County, North Carolina also use laptops in their patrol vehicles (17). The software is actually a modified version of that used in St. Petersburg. The computers have sped reporting and greatly increased the accuracy of officer reports for accidents and citations. Now when officers are assigned to patrol duty (following a 16-hour training course on computers), they receive a laptop along with the vehicle and sidearm. Officers can complete reports at the scene, in the car, or even at home, and then transfer the data by telephone to the central computer. Investigators can begin working on those reports needing further investigation before the field officer’s shift ends.
The Fremont, California Police Department uses laptops in its patrol cars as well. They incorporate a modem/laptop/radio linkage so that the laptops act as MDTs as well as allow filling out accident and crime reports. They foresee transfer of mugshots and fingerprints over the radio through the laptop environment.

In the traffic engineering arena, an 1989 evaluation by the Technical Services Division of the Maine Department of Transportation found that use of a handheld microcomputer as a data collection device was feasible. The evaluation considered various engineering data including maintenance inventories, traffic surveys, bridge inspections and pavement condition surveys. The findings were very positive for a microcomputer replacing the sometimes cumbersome and error-prone manual recording of data collection. The findings also suggested waiting for technology to proceed before purchasing any products, but did feel investment in new technologies was an advantage because of their benefits to public agencies. (This evaluation is about two years old, so the evaluator could see the rapid changes to technology on the horizon that are now here.)

**Pen System Computers**

Pen system computers represent technology at the cutting edge of advancement. These systems are generally the size of a clipboard, but have the capabilities of laptops and communicate with the user by a pen device. The user can use the pen to "write" on a glass plate incorporated into the system. Although many
of the systems can plug into a keyboard, the pen serves as the primary communication interface. Pen systems use various operating systems and methods of handwriting recognition (OCR). When the user writes on the pen system glass pad, the computer interprets the characters either in OCR mode or in graphics mode. When in graphics mode, the system stores the pen's strokes as graphics (like a signature); when in OCR mode, the system converts the pen strokes to ASCII characters similar to what is done when a keyboard is used.

The outstanding power of all these capabilities is that the glass pad can be used to display a form similar to any paper form you can imagine. The user then can "fill out" the form as if it were a real piece of paper, but without the paper. The data is stored on memory or on a hard disk in the pen system. Once captured, the data is automated and can be downloaded or copied to a central computer for analysis.

The pen system has effectively taken the storage and size attractiveness of the laptop and the handwriting comfort and paper reporting requirements of any public job and combined them into one piece of equipment. This seems to be what is needed for data collection in the field while incorporating various data collection technologies mentioned in Chapter 1. So what's the catch? The only "catch", if there is one, is that the technology is very new. New technology tends to be difficult to justify because of the lack of standards and for the usually high cost related to cutting-edge technology.

However, the technology is new only to the general computer industry; it is actually in use in public and private sector agencies already. Your first experience with pen systems has probably already happened, you just didn't know it at the time. The United Parcel Service (UPS) package delivery company maintains a very
efficient, accurate and timely delivery service. To enhance their capabilities further, UPS began using a pen system product designed specifically for their needs in September 1991. The system has a built-in bar code scanner and a small pad for writing a signature. The bar code scanner is used for reading the code on each package while the small pad is used to digitize the signature of the delivery recipient. Once captured in the pen system, this information is uploaded to the UPS central computers. This is a strong message to other computer users on the benefits of pen systems in the field.

The Federal Highway Administration (FHWA) has contracted to perform a pilot study of handheld microcomputer devices for use in the field mainly by police and emergency medical services agencies. This pilot study is still in the early stages of site selection for up to ten sites.

Another FHWA contract involves a research study with goals similar to those of this report: to assess how new and emerging technologies could be effectively used to collect accident data. The researchers will examine the accident data collection process at the state and local level to obtain a better understanding of the process. They will also identify areas where new technologies may be applied.

The Michigan Office of Highway Safety has a pilot project underway using technology that includes optical scanners, GPS, GIS, pen systems and microcomputer database management software to automatically capture data for traffic accidents and citations. The local agencies have access to their data in the database designed for traffic safety analysis while still supplying information to the state. The results of this project will then be implemented on a statewide basis upon successful development and demonstration of the pilot. The pen system that will be used in this pilot project is the GridPad by Grid Systems Inc; the database
management software, TRASER, will be used to maintain the crash, citation and arrest data on microcomputers.

Grid Systems Inc. has a pen system computer available and in place in many places throughout the country called the GridPAD (21). It uses a proprietary forms generation package, yet it is highly functional. The hardware has all the "amenities" of the laptops, namely a backlit screen, a hard disk, etc. The system also has a pen device that acts not only as a pen, but as a bar code reader. Capabilities in the near future include a GPS locationing module. With these capabilities and the firm presence of Grid in the marketplace, their pen system is working while the other brands are still establishing themselves.

Again, the technology is very new and will be unsettled for a time. GridPAD, however, has its feet on the ground and is pressing forward successfully in the pen system arena.
IV. Example Implementations of Emerging Technologies

This portion of the report gives examples of agencies that have implemented one or more of the different technologies discussed in Chapters II and III. These examples are not all government agencies, but are representative of the different ways the technology can be used.

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Sacramento County, California officials use a handheld bar code scanner to improve data entry effort for traffic design data \(^{22}\). The scanner replaces the need to type data entry items that occur repeatedly in the process of capturing the data. This procedure has reduced typing errors by about 80 percent and lowered data entry time requirements by 20 to 40 percent.

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The Los Angeles County Department of Public Social Services has implemented the first civil application of an automated fingerprint system \(^{23}\). It is called the Los Angeles County's Automated Fingerprint Image Reporting and Matching System (AFIRM). The system is used to ensure welfare service is given to those who are entitled to it; Los Angeles County has the largest General Relief Program in the country. The county lost about $1.6 million to fraud in the 1989-1990 fiscal year. AFIRM runs on a microcomputer running UNIX instead of the usual minicomputer or mainframe system that fingerprinting requires.
Automatic Vehicle Identification (AVI) technology is being actively implemented in several areas of the United States. As of March 1991, there were at least nine cities developing AVI/Toll technology including Golden Gate Bridge, San Diego Bridge, North Dallas Toll Road, Houston Hardy Toll Road, New Orleans Bridge and the New York/New Jersey Bridge and the Indian Nations Turnpike in Oklahoma.

Los Angeles area enforcement agencies are testing several products using RF/ID technology for vehicle identification on a county-wide basis to track stolen vehicles. The system incorporates a "tag" with a unique ID placed in vehicles. Each tag's location can be detected by RF/DC and shown on a map at a central location. If the vehicle is stolen, the owner notifies the authorities and the system locates the vehicle via radio communication. Three vehicles have been recovered so far.

Tulare County, California Department of Public Social Services (PSS) is fighting more caseloads and less funding by implementing automated data entry at touchscreen kiosks using expert system software. The system, called CLEAN, allows an applicant for family assistance to enter data into the kiosk system instead of filling out a long application form by hand. The expert system software asks questions according to answers to previous questions and minimizes the time needed to answer meaningless questions. The kiosk
contains instructions in six languages and has a voice module for using audio questions. The system has been successfully used by illiterate and hearing-impaired applicants. The system generates an application form when complete that is accurate and legible for the caseworkers to review and verify. The kiosks are actually PCs with a touchscreen and optical storage device. Each PC is linked to a mainframe system for immediate upload of applications and worker verification processing as it occurs.

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A voice technology system by Voccoli, Inc. is being used in a Ford assembly plant for final inspections of vehicles (27). The system incorporates a headphone and microphone device for communication with the system. It is preprogrammed with a flowchart of questions and information to request by voice from the user. The user responds to the questions by voice using a predefined library of words. Once the system is "taught" the vocabulary library using the user's voice, it can be used by that user for input. The system can run all day on batteries and is able to send data to a computer for collection as the data is generated. It runs on batteries and runs up to 24 hours without recharging. Use of the system, named Talkman, has eliminated clipboards, manual keying, daily tallies and data classifying requirements from the inspection process. Talkman increased the speed of inspections a great deal and provided immediate feedback to supervisors about the inspection status and problems in the vehicles that could be handled rapidly.

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The Syacuse, New York Police Department installed an optical image scanning system to scan their criminal
cases paperwork. The department handles 120,000 criminal cases per year that generate about 500,000 paper documents. Many of these documents were being photocopied for distribution to other agencies and departments, which totalled approximately four million copies per year. Looking for cost savings and efficiency of operation, the department implemented the optical image scanning technology; analysis showed implementation of the system would allow two officers back out on the street and eliminate four civilian positions. A six to seven year payback was calculated for this implementation. The system has worked well for this department. One unusual part of this system is the large amount of high-speed magnetic disk storage used along with the standard optical disk storage space. The high-speed disks contain the documents that are 0-7 days old. This was found to be the most requested document age from the image system for daily workloads. Once the document reaches 8 days of age, it is moved to the slower, long-term optical disk storage.

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The Rochester, New York Police Department implemented an optical imaging system similar to the Syracuse system above, yet for a different reason. Rochester wanted efficiency not in the internal document requests, but in external requests for accident and crime reports outside the department. The department generates around 215,000 reports for other public and private organizations per year. To handle this situation, the optical imaging system can print hard copies of requested reports and send the optical image via fax modem to a requestor. Now requests are handled in one or two days compared to months previously.

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Global Positioning Systems have been used by the U.S. Forest Service in Missoula, Montana for mapping fire boundaries and roads. They expect GPS to play a greater role in their resource management responsibilities in the future.

In California and Montana, GPS systems on tractors are used to accurately administer chemicals to fields. This method protects from overapplication and unnecessary chemical release into soil and water tables.

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General Motors is testing an IVHS navigation system for cars along the Santa Monica, California freeway. Sensors along the road communicate with passing vehicles containing the navigation equipment. A centrally located computer monitors the roadside sensors and broadcasts the information to the moving vehicles. The vehicles have a CRT to show a digital roadmap indicating the locations of traffic tieups and congestion. A voice synthesizer can also be used to tell the driver about problems; this eliminates the driver’s eyes leaving the road to look at the map. While the vehicle receives this information, it is in turn broadcasting the vehicle’s speed, direction and location back to the computer for incorporation into its database. This year, GM will enhance this concept in Orlando, Florida. It will have information on local event schedules, emergency services and travel accommodations.

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The Trimble Navigation company has compiled many ideas for the use of GPS technology. One worthy of mention for the traffic safety field involves mounting a GPS receiver to a vehicle. When a crash occurs, a device attached to the air bag or other triggering system would activate a cellular telephone. The phone would dial 911 for assistance and also be able to send the exact coordinates of the crash almost immediately and without human intervention.

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California recently implemented a public information system named Info/California. It involves the use of kiosks located in 15 public access areas including libraries and malls. The pilot project, authorized by the state legislature, will last for nine months. Users of the system can choose from service areas including education, employment, welfare assistance, family assistance, health, legal assistance and vehicle/transportation assistance. Driver's licensing and ticket information can be accessed. This system is a promising beginning to a type of "backbone" for a statewide government access method for many more kinds of information available for public consumption while reducing the workload on government staff.

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September 1991 was the first anniversary of Chicago's Parking Enforcement Automation (PEA) system. Parking tickets and meter collections represent a large amount of revenue for any city in fiscal straights like Chicago. Before PEA implementation, Chicago had an unpaid ticket backlog of 17 million, two million tickets not even in the system, and it took two years to get court dates for contesting a ticket. PEA involves
handheld computers with scofflaw lists and portable terminals connecting to a mainframe system. The mainframe allows license plate status checks. The scofflaw lists are used by "boot van" patrols to locate vehicles with a minimum threshold of unpaid tickets. When located, a "boot" device placed on the vehicle disabling it until the tickets are paid. A higher threshold of unpaid tickets triggers more drastic action: the vehicle is towed and impounded until the tickets were paid. Chicago also has moved ticket hearings and administration into regional centers and scans all tickets into an optical imaging system. The tickets can then be instantly retrieved at the hearing centers.

PEA has been a great success and is even expanding. Chicago is linking with law enforcement agencies in Indiana and Wisconsin because of the number of out-of-state motorists frequenting Chicago. Ticket revenue has risen dramatically and the city is starting a driver license suspension program that will raise revenues even higher.

In addition, Chicago is implementing a GIS to track the unpaid tickets. The GIS is used to map areas where vehicles with unpaid tickets frequently park so the boot van can more easily locate the offenders. Broken parking meters are also located for repair crews.

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In Hamilton County, Indiana a pilot project is underway implementing a tracking system for drug-influenced drivers and other traffic offenders from the time of ticketing or arrest until the adjudication process is complete (34). The system incorporates use of a laptop computer for collecting ticketing information and generating the
ticket by an officer, a desktop computer in each of the courts and software to maintain the database both at the enforcement agency and each of the court locations. A project of this scale requires full cooperation of the enforcement agencies and the courts.

The California Department of Motor Vehicles (DMV) has taken a proactive stance to implement technological advancements to provide better public service and to enhance its operations. Their record-keeping system is especially applicable to this effort. California instituted a combination magnetic strip driver license/identification card in early 1991. This card contains a hologram, a digitized photograph and signature, as well as a magnetic stripe. Physically the card resembles the ATM bank cards and is totally computer generated. The hologram protects against counterfeit cards. The digitized photograph and signature are maintained in the DMV drivers license database. All information necessary for generating the card is in the computer so that new cards can be mailed to citizens without having their pictures remade or standing in line for renewal. When a citizen loses the card, the DMV can simply mail a new one to the owner without requiring an office visit. The photographs are placed on the card at the left or right side, dependent on the age of the owner.

Law enforcement and other agencies can use the cards with magnetic-stripe readers to automatically collect information about the card owner quickly and silently through access to the DMV computer. An officer making a traffic stop can run the card through the reader and immediately receive data silently about outstanding warrants or license suspensions. Courts have quick access to driving records and can facilitate
immediate update to conviction records. Even merchants are allowed access to limited DMV data using the card to verify check payment information.

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All of the systems described in this chapter are representative of the various technologies available for collecting data automatically where the data is being generated by the persons that know that data best. Agencies throughout the country involving law enforcement, courts, highway departments and public health are either watching other agencies develop their own systems, or are actually involved in the implementation of systems to collect data accurately and in a timely fashion.
V. Summary and Recommendations

Throughout the public sector, computer technology is playing a larger role in the functioning of its agencies. The technological changes dealing with computers directly impacts the way agencies do business. The computers and the databases used by these agencies is becoming more integrated with day-to-day agency activities. Therefore, agencies must learn to incorporate appropriate new technology into its functions as that technology becomes available.

This is no different in the transportation and safety research fields. Agencies will be directly affected by IVHS research as well as the capabilities of GIS software and the sharing of information that each agency maintains. Accurate and timely data is vital for the agencies to do their jobs effectively. But what is the purpose of using and sharing information drawn from the agencies' databases if that data is of questionable integrity? Database integrity (accuracy and timeliness) begins with a sound data collection process. Just as database analysis is performed with appropriate and effective techniques to obtain accurate information, the data collection process must also use appropriate and effective technologies to obtain accurate and timely data. Today, technology is available that before could only be imagined. This technology must be used when it can meet an agency's data needs better than technology already in place. A data collection technology offering a more accurate and timely database should be used as soon as the technology allows. The sooner it is put into place, the sooner an agency will benefit from the information in the database.

Readers of this report will undoubtedly draw their own conclusions about the potential uses of new technology in their own areas of expertise. However, this report confines observations and recommendations for use
of the technology to the traffic safety field.

One automated data collection technology in this report can immediately be eliminated from discussion: magnetic ink character recognition (MICR). This technique is firmly entrenched in the banking industry and other more flexible technologies exist for traffic safety needs.

The bar code, magnetic stripe, RFID and GPS technologies all have immediate uses for field activities in traffic safety. Automated data collection needs in the field by law enforcement and engineering professionals will find these technologies immediately functional and easily used. But these capabilities would be even more powerful if they could be incorporated into a single unit. The one technology that can best incorporate these data collection techniques is the pen system.

Pen systems are obviously cutting-edge technology and perhaps a risky venture for general users. However, the GridPAD is an example of a pen system that is already being used in many locations. Pen systems like the GridPAD can incorporate bar code pens, magnetic stripe readers, radio frequency communication equipment and GPS receivers. Of course the laptops can incorporate the same equipment, but the laptops are actually bulkier than pen systems and do not lend themselves to the attractive handwriting recognition capabilities of the pen systems. Most pen systems can use internal hard disks and external full-sized keyboards as well. This particular capability makes the pen system as functional in the field as a laptop. For agencies not ready to leap into pen system technologies, the laptops are still a fine intermediate step as they can incorporate all the necessary automatic data collection technologies. The laptops offer a fine replacement to the MDTs used in many law enforcement agencies.
The pen systems and laptops can do everything of which the MDTs are capable, but the pen systems/laptops give the officers local computing power within the vehicle. They are also more portable than MDTs, and they can be removed from the vehicles easily for tasks in the office or at home while still maintaining communication with the central agency computer. Pen systems/laptops are smaller than the MDTs, and thus require less space in the vehicle; space in police vehicles is always a premium concern to the officers.

As technology advances even further in the near future, the use of biometric identification, touch, vision and voice data collection technologies will become more viable and less expensive. But waiting for these technologies before implementing any technology is shortsighted. Implementing today's new technology does not stop that same technology from functioning in the future. Ways of enhancing current technology with new capabilities should always be examined. Many current technology cannot do the job as well as new technology, such as pen systems. Most current data collection processes involve many people and many steps: namely, people filling out paper forms, data entry clerks to interpret and enter the forms into the database, and a large number of data edit checks in the computer to eliminate as many human errors as possible. Pen systems and the other new technologies offer the first real opportunity to automate the data collection process in the field by a method as old as any book, namely, pen and paper (or glass).

What about the data analysis processes in the office once the data is automated? Is there technology to assist in day-to-day office duties? The use of laptops, flexible database software and GIS systems incorporated with optical scanning systems are powerful methods for data access and analysis. Optical scanning systems eliminate warehousing needs for paper documents and give the user a fast, reliable retrieval system for viewing and printing copies of original documents. The GIS packages are ideal tools for
management of spatial data, and since spatial data is vitally important in the traffic safety field, GIS applications should be implemented and used as a data analysis and management tool. The implementation of GIS should include a reliable database management system to support the GIS, but should not necessarily be an integral part of the GIS. The GIS must be able to share data with other GIS packages of other agencies as well as incorporate new data from non-GIS database management systems in-house and in other agencies.

What about the agency that decides to take a wait-and-see attitude concerning these technologies? Caution is a healthy characteristic of a public agency. However, if the agency is waiting to see others' successes or failures with new technologies, the agency may be lulled into waiting while the benefits of the technology pass it by. Agencies must be proactive in using new technologies. Computers and their associated technologies are here to stay; we can use new technology effectively in our jobs or we can watch while others use it.

As stated earlier, agencies must be cautious with new technology, yet proactive. Therefore, I recommend a project to implement the type of technologies described in this report. The project would provide a means of designing and implementing applicable new technologies into the traffic safety arena without each agency waiting on the other for implementation. The project would implement and prove the technology for both its practical and economic benefits to traffic safety. This concept of proving the new technology should then be an on-going process, since the technology will continue to evolve in the foreseeable future. A small committee (5 to 7 people) of traffic safety professionals should be available for assessing and reporting upon the results of implementing these technologies; however, this committee, if used, should not be allowed to restrict the scope of technologies that can be tested.
The first technologies to be implemented and examined should be those that deal with the collection and automating of the traffic safety data in the field. A prototype police vehicle should be outfitted with a pen system, radio, and other equipment to perform, at a minimum:

- automated capture of crash, citation and arrest data on local storage device or by radio to a central location.
- automated collection of driver’s license information.
- automated collection of vehicle identification information.
- automated driver and vehicle license verification by radio.
- automated location information using global positioning systems.

This type of prototype implementation and evaluation performed at the state level will not only provide concrete information vital for decisionmaking at both the state and local level but will also strengthen the state’s leadership role in the area of traffic safety.
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