FIELD DATA ACQUISITION TECHNOLOGIES

FOR

IOWA TRANSPORTATION AGENCIES

E. J. Jaselskis, Principal Investigator
Associate Professor of Civil and Construction Engineering
Iowa State University

Iowa Highway Research Board
Project HR-366

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Iowa Transportation Center
IOWA STATE UNIVERSITY

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ABSTRACT

This report describes the results of the research project investigating the use of advanced field data acquisition technologies for Iowa transportation agencies. The objectives of the research project were to (1) research and evaluate current data acquisition technologies for field data collection, manipulation, and reporting; (2) identify the current field data collection approach and the interest level in applying current technologies within Iowa transportation agencies; and (3) summarize findings, prioritize technology needs, and provide recommendations regarding suitable applications for future development. A steering committee consisting of state, city, and county transportation officials provided guidance during this project.

Technologies considered in this study included (1) data storage (bar coding, radio frequency identification, touch buttons, magnetic stripes, and video logging); (2) data recognition (voice recognition and optical character recognition); (3) field referencing systems (global positioning systems [GPS] and geographic information systems [GIS]); (4) data transmission (radio frequency data communications and electronic data interchange); and (5) portable computers (pen-based computers). The literature review revealed that many of these technologies could have useful applications in the transportation industry.

A survey was developed to explain current data collection methods and identify the interest in using advanced field data collection technologies. Surveys were sent out to county and city engineers and state representatives responsible for certain programs (e.g., maintenance management and construction management). Results showed that almost all field data are collected using manual approaches and are hand-carried to the office where they are either entered into a computer or manually stored. A lack of standardization was apparent for the type of software applications used by each agency—even the types of forms used to manually collect data differed by agency. Furthermore, interest in using advanced field data collection technologies depended upon the technology, program (e.g., pavement or sign management), and agency type (e.g., state, city, or county). The state and larger cities and counties seemed to be interested in using several of the technologies, whereas smaller agencies appeared to have very little interest in using advanced techniques to capture data. A more thorough analysis of the survey results is provided in the report.

Recommendations are made to enhance the use of advanced field data acquisition technologies in Iowa transportation agencies: (1) Appoint a statewide task group to coordinate the effort to automate field data collection and reporting within the Iowa transportation agencies. Subgroups representing the cities, counties, and state should be formed with oversight provided by the statewide task group. (2) Educate employees so that they become familiar with the various field data acquisition technologies.

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SUMMARY

This report describes the results of the research project investigating the use of advanced field data acquisition technologies for Iowa transportation agencies. The objectives of the research project were to (1) research and evaluate current data acquisition technologies for field data collection, manipulation, and reporting; (2) identify the current field data collection approach and the interest level in applying current technologies within Iowa transportation agencies; and (3) summarize findings, prioritize technology needs, and provide recommendations regarding suitable applications for future development. A steering committee consisting of state, city, and county transportation officials provided guidance during this project.

This report details the investigation of a variety of information gathering techniques and their possible applications within Iowa transportation agencies. Technologies considered in this study included (1) data storage (bar coding, radio frequency identification, touch buttons, magnetic stripes, and video logging); (2) data recognition (voice recognition and optical character recognition); (3) field referencing systems (global positioning systems [GPS] and geographic information systems [GIS]); (4) data transmission (radio frequency data communications and electronic data interchange); and (5) portable computers (pen-based computers). The literature review revealed that many of these technologies could have useful applications in the transportation industry.

A survey was developed to explain current data collection methods and identify the interest in using advanced field data collection technologies. A brief description of each technology was provided to the respondents to help them answer questions related to their interest level in using the various advanced field data collection technologies. Surveys were sent out to county engineers in all 99 counties, city engineers in cities with populations greater than 5,000, and state representatives responsible for certain programs (e.g., maintenance management and construction management). The overall response rate was 100 percent for the state and 85 percent and 88 percent for the cities and counties, respectively. Analysis of the data was performed using statistical software programs: SAS™ and SPSS.

Results showed that almost all field data are collected using manual approaches and are hand-carried to the office where they are either entered into a computer or manually stored. One of the exceptions was related to surveying where a small number of agencies use hand-held computers to collect data. PCs were the most common form of hardware used by all agencies and were located in the home office; few agencies owned portable computers. A lack of standardization was apparent for the type of software applications used by each agency—even the types of forms used to manually collect data differed by agency.

Only a few counties have actually implemented GPS and GIS, but there appears to be significant interest in using these technologies especially for sign, maintenance, and pavement management. The use of portable computers, especially laptops, was

considered for collecting data related to signs, bridges, maintenance, pavement, construction, and surveying. Pen-based computers were appropriate for sign, pavement, and maintenance management. Video logging was of interest to the counties for pavement, bridge, maintenance, and sign management. The use of bar codes was of interest in sign management programs.

Larger cities (population greater than the median of 9,270) had a strong interest in developing a sign management program using bar codes. The use of GIS technology was of interest for pavement, construction, maintenance, and sign management programs as well as for surveying. GPS was of interest as a technology for sign management and surveying. Additionally, larger cities had an interest in using video logging for pavement management. In general, there was a strong desire to use portable computers (laptop, hand-held, and pen-based) to collect data related to pavement, traffic, sign, construction, maintenance, bridge management, and surveying.

Smaller cities (population less than or equal to the median of 9,270) also had a strong interest in using GIS for surveying and pavement management. Hand-held computers were of interest for performing pavement and maintenance management procedures. The use of bar codes for sign management was of interest, but not as strongly as the interest level shown by larger cities.

Several technologies were not of interest to the total sample population of counties and cities as follows: radio frequency identification, touch buttons, magnetic stripes, optical character recognition, voice recognition, advanced imaging, radio frequency data communications, and electronic data interchange. Some of this disinterest may have been caused by a need for additional information regarding each technology or the lack of resources to implement such technologies.

Several of the technologies that were not of interest to the total county and city sample population became of interest when considering transportation agencies with larger populations. In general, cities and counties with larger populations tended to have a greater interest level in using more sophisticated techniques to collect field data compared to their smaller agency counterparts. Smaller transportation agencies, as a rule, were not as interested in applying innovative technologies to enhance their field data collection process.

State respondents were quite interested in the use of several different types of technologies for their programs that were not of interest to all of the cities and counties. The construction management program respondent had an interest in applying bar coding; touch buttons; voice recognition; optical character recognition; advanced imaging; GIS; GPS; EDI; and pen-based, laptop, and hand-held computers. In the area of safety, several technologies were found to be of interest: electronic data interchange, GIS, GPS, video logging, advanced imaging, optical character recognition, voice recognition, touch buttons, magnetic stripes, bar coding, laptops, and pen-based computers. The state surveying respondent was interested in using radio frequency data communication; bar coding; touch buttons; magnetic stripes;

optical character recognition; voice recognition; video logging; advanced imaging; GPS; GIS; radio frequency data communication; electronic data interchange; and pen-based, laptop, and hand-held computers.

Several technologies were of interest in the area of maintenance management: electronic data interchange; GIS; GPS; video logging; advanced imaging; voice recognition; touch buttons; bar codes; radio frequency identification; and pen-based, laptop, and hand-held computers. Moreover, bar codes, radio frequency identification, video logging, GIS, GPS, and electronic data interchange were technologies found to be of most interest in the area of pavement management. The state respondent for sign management was interested in several technologies: GPS, video logging, voice recognition, magnetic stripes, bar codes, radio frequency identification, pen-based, and hand-held computers. The traffic management respondent had an interest in the following technologies: radio frequency identification; touch buttons; advanced imaging; GIS; GPS; electronic data interchange; and pen-based and laptop computers.

As a follow-up to the return-mail survey responses, interviews were conducted to describe some of the field data acquisition technologies in more detail, learn more about how each agency collects data, and identify application areas that would be of interest for future development. Interviewees, in general, were interested in improving their field data collection efforts and realized the benefits of computerized data entry at the source. Each interviewee, however, had a slightly different opinion regarding what application(s) would benefit their agency the most, making it difficult to identify one or two beneficial applications for all Iowa transportation agencies.

As a result of this study, recommendations are made to enhance the use of advanced field data acquisition technologies in Iowa transportation agencies.

(1) Appoint a statewide task group to coordinate the effort to automate field data collection and reporting within the Iowa transportation agencies. Subgroups representing the cities, counties, and state should be formed with oversight provided by the statewide task group. Automation efforts should consider the interest level results from this study and take into account the differing needs between the various agencies (e.g., cities versus counties, large cities versus small cities, and state versus counties). Additionally, the task group should address the need to efficiently integrate data and electronically capture data at the source. To accomplish this goal, more standardized data entry forms can be computerized and shared by all agencies and the number of field portable computers should be increased.

(2) Educate employees at different levels of an agency so that they become familiar with the various field data acquisition technologies. This will assist in identifying potential applications and ease the transition as new technologies are implemented.

In conclusion, this study has provided information on current technologies and critical insights into the interest levels of various transportation agencies in implementing these technologies. It is hoped that this research will be carefully reviewed and used in planning and executing more efficient data collection procedures for Iowa transportation agencies.

1.0 INTRODUCTION

The passage of the Intermodal Surface Transportation Efficiency Act of 1991 has left a great responsibility with cities, counties, and states to implement effective management programs for bridges, pavements, traffic congestion, and safety with other supporting management programs that should also be considered including signs, maintenance, and equipment. Current management programs involve the collection and processing of large amounts of data through the use of standardized forms. This method of information gathering tends to be labor intensive; not only does it create a significant paper trail, but it also requires a great amount of time to manipulate, analyze, and report results. Consideration of alternative data collection methods may be beneficial to streamline the data capture and manipulation process.

This research project has investigated and evaluated the technologies for field data collection, manipulation, and reporting. It has also investigated the interest level in applying these technologies within Iowa transportation agencies and has summarized the findings, prioritized needs, and provided recommendations related to the most beneficial applications within this report. Descriptions of the research methodology, results, and study limitations are also included.

1.1 PROBLEM STATEMENT

The Intermodal Surface Transportation Act has prompted the streamlining of the information gathering process for city, county, and state transportation agencies. Currently in wide use, standardized forms must be filled out manually and subsequently keyed into a computer for data analysis and retrieval at a later time. This method of data capture is labor and time intensive. In fulfilling the demands of the Intermodal Surface Transportation Act, it is important to consider new means of gathering transportation information.

Several technologies exist that can be applied to the transportation industry for better program management. These technologies that could be included are as follows: bar coding, radio frequency identification (RFID), touch buttons, magnetic stripes, video logging, global positioning systems (GPS), voice recognition, optical character recognition (OCR), radio frequency data communications (RFDC), electronic data interchange (EDI), geographic information systems (GIS), and pen-based computers.

1.2 PROJECT OBJECTIVES

This project is aimed at aiding transportation agencies in their attempts to increase working efficiency by investigating and evaluating a number of information gathering technologies for field data collection, manipulation, and reporting. The report will provide a descriptive compendium of these advanced technologies, along with a list of current manufacturers and their applications. In addition to investigating the various technologies, this project will investigate the interest level in applying these technologies within Iowa transportation agencies, and provide recommendations on the technology needs and potential applications for future development.

Information from this project will also assist Dr. Fouad Fanous at Iowa State University in developing an automated data capture system for PONTIS, a bridge management software program, by providing his research team with the most current information related to field data capture. Finally, the technologies described in this study will be useful to Dr. Reginald Souleyrette in developing new GIS applications for the Iowa Transportation agencies.

1.3 METHODOLOGY

The research methodology involved several steps. A literature and vendor search for data capture technologies was undertaken, and then several of these technologies were selected as appropriate possibilities in improving the field data acquisition process. A steering committee, consisting of transportation officials from the state, city, and county levels, was established to provide further guidance in the selection process and during the research process (refer to Appendix A for advisory board members and meeting agenda).

The preliminary information search involved investigating the most current literature available as well as gathering current information provided by advanced technology vendors. Periodicals (*PC World, Automatic ID News*, and *ID Systems*), journals (*American Society of Civil Engineers, Journals of Construction Engineering and Management*), and books related to information technology were used. Several advanced information technology vendors were contacted; a partial list includes Intermec, TPS Electronics, and Videx (bar coding); Grid Systems, Fujitsu, and Inforite (pen-based computing); CompuSpeak Laboratories, Verbex Voice Systems, Vocollect, and Voice Connexion (voice recognition); Dallas Semiconductor (touch button technology); and Rydex, Texas Instruments, QED Systems, and Micron Communications (radio frequency identification).

The next step involved developing a survey to capture each agency's interest level in using these technologies for different programs (e.g., pavement, safety, and bridge management) and identifying the current field data collection approach and the hardware and software used by each agency. This mailing was sent to directors, engineers, and administrators in city and county transportation agencies as well as the Iowa DOT familiar with each agency's field data collection approach. Cities with populations greater than 5,000 were targeted for this study because it was felt that smaller cities would most likely not be interested in using these technologies. SAS™ and SPSS (Statistical Package for Social Sciences) were the two statistical packages used to analyze the data and identify significant trends. Results are summarized in graphical and tabular format.

As a follow-up to the mail-back survey responses, interviews were conducted to demonstrate some of the field data acquisition technologies, learn more about how each agency collects data, and identify application areas that would be of interest. Interviewees, in general, were interested in improving their field data collection efforts and realized the benefits of computerized data entry at the source. Several of the technologies were of interest to them. Each interviewee, however, had a slightly different opinion regarding what application(s) would benefit their agency the most, making it difficult to identify one or two beneficial applications that would be useful for all Iowa transportation agencies. Finally, recommendations are made regarding the enhancement of field data collection operations using the technologies described in this report.

2.0 FIELD DATA ACQUISITION TECHNOLOGY SUMMARIES

This project identified and investigated twelve advanced field data acquisition technologies: (1) data storage technologies (bar codes, radio frequency identification, touch buttons, magnetic stripes, and video logging); (2) data recognition technologies (voice recognition and optical character recognition); (3) field referencing systems (global positioning systems and geographic information systems); (4) data transmission (radio frequency data communications and electronic data interchange); and (5) portable computers (pen-based computers). Following are summaries of the research undertaken for each technology. Each technology is provided with an overall description and discussion of the hardware/software requirements, cost, applications, and limitations. Since there are a plethora of applications for each technology, a list has been provided in the report; for a more detailed description of the applications, the reader is referred to Appendix B. Furthermore, a list of key vendors is included in Appendix C.

2.1 DATA STORAGE TECHNOLOGIES

2.1.1 Bar Coding

Bar coding involves the use of labels with a self-contained message with information encoded in the widths of black bars and white spaces in a printed manner (Adams 1990). Bar coding users can expect an error rate of less than one in one million, compared to one error for every 300 characters entered using manual methods (Palmer 1991). An operator scanning a stack of ten-character bar code labels at the rate of one per second completes the job about twice as fast as a secretary typing an average of 70 words per minute (Sharp 1989).

Bar coding is considered the most popular and cost effective of existing automatic identification technologies and is commonly used in retail and industrial settings all over the world (Sadhwani and Tyson 1990). The success of this technology can be partially attributed to the fact that bar code labels are cheaply produced with standard printing techniques. Also, they are easily and accurately read by inexpensive reading devices; standardization allows labels to be read from differing brands of reading devices.

A bar code system requires equipment (to read and process the bar coded information) and devices (to print labels, including scanners/decoders, symbologies, printers, and labels). Scanners, or "decoders," are either hand-held or fixed-position, and can offer contact or non-contact capabilities between the scanner and the bar code label.

Because of the large number of possibilities inherent in arranging black bars and white spaces, there are many different bar code arrays, or symbologies. There are more than sixty developed symbologies, but only twelve are commonly used today. The most popular are: UPC (Universal Product Code), EAN (European Article

Numbering), Code 39, Codabar, and Code 128. Less popular are as Interleaved 2 of 5, Code 93, Code 49, Code 16K, PDF417, Plessey Code, Code 11, UPScode, and Telepen. Code 16K and PDF417, are 2-D symbologies that contain a larger amount of information than conventional labels. 2-D bar codes labels and their printers are readily available on the marketplace, and labels can be printed on site or by an outside supplier. In both cases, dedicated software is used to print the bar code labels, and varied printing technologies (e.g., dot-matrix, thermal, thermal-transfer, ion deposition, and laser) can be used (Adams 1990). Some bar code labels can be made to withstand harsh outdoor conditions and last for several years. Large bar code labels are also available and can be scanned from up to 40 feet away.

The availability of numerous bar code devices and reduced expenses have helped the development and implementation of extensive applications. A single light pen, or wand, and decoder can cost less than $200. More sophisticated scanners can cost between $300 and $1,000. A common solution incorporates hand-held computers, which can cost from $500 to $1,500. Labels produced by an outside supplier can cost between a few cents each for simple and rudimentary labels to several dollars each for specifically designed and unique bar code labels. However, inexpensive software (priced at $50 or less) can produce bar code labels using standard dot-matrix and laser printers. More sophisticated software (e.g., Windows-based, programmable, and memory resident) can be procured with prices ranging between $100 and $300.

Thermal or thermal-transfer printers are ideally suited for high quality labels and/or extensive usage. These printers usually cost between $1,000 and $10,000 and are useful when labels require higher standards. In general, complete bar coding systems generally cost between $1,000 to $15,000.

Bar coding is extensively used in asset tracking, inventory control, time and attendance recording, monitoring work-in-process, quality control, check-in/check-out, access control to secured areas, shipping and receiving, picking and sorting, property management, warehousing, route management, point-of-sale operations, patient care aids, and many others (*Automatic I.D. News Guide Directory* 1993/1994). Some of these applications are described further in Appendix B.

The most common problems with bar codes are print quality and label durability, as factors such as dirt, grease, ink spread, fading, and temperature can influence the integrity of the label. Also, bar code technology cannot provide users an eyes-free or a hands-free environment, and users must have a line-of-sight to the bar code labels. Finally, human, and not technical, problems are usually the most difficult hurdles to face in bar code implementation. Some of these limitations relate to the lack of knowledge associated with the benefits of using bar codes and also a hesitation towards using new technologies.

2.1.2 Radio Frequency Identification (RFID)

Radio frequency identification (RFID) technology uses super-miniature transponders to collect data and manage it in a portable, changeable database. It communicates routing instructions and other control requirements to equipment, withstands harsh environments, and (in non-line-of-sight uses) operates beyond the capabilities of other automatic identification (Auto I.D.) technologies (Forger 1990). Data from the RFID tag can be expanded using a database program, as a limited amount of information can be stored on a tag. Some RFID characteristics are (1) detect, read and/or write on information tags up to 220 feet away; (2) store up to 240 bits of alpha and numeric data in each tag; (3) withstand temperatures ranging from -40°C to 85°C; (4) withstand high noise levels, and various forms of hazardous contamination of the tags; (5) communicate bi-directionally and multi-directionally; (6) frequently be configured with a variety of other Auto I.D. (and non-Auto I.D.) technologies already implemented on-site; and (7) track products from the time they are raw materials to the time they are stored or shipped away (Amtech 1994).

A RFID system consists of tags (often reusable) mounted on a product or product carrier, an antenna or scanner (which interrogates the tag via a RF link), and a reader (frequently attached to the antenna). Tags are identified as either "read/only" or "read/write." Read/write tags can be reprogrammed over the RF link, while read/only tags have either a fixed code or one that must be changed manually. Most manufacturers encapsulate the tag (and sometimes the reader and antenna too) for durability against shock, fluids, dust, dirt, and other contaminants. Also, the tag, chip, or transponder can be further divided as either passive or active. Active tags are those that contain their own on-board power source, typically a lithium battery. Passive chips are those which convert the RF signal from the reader into a voltage, supplying power to the transponder electronics. Chips range in size from small enough to be injected into an animal's ear to the size of a brick.

The antenna is the conduit between the tag and the controlling unit or terminal. Varying in shapes and sizes, antennae can be free-standing or, for example, buried behind a concrete block wall for detecting personnel badges on passers-by.

Readers, portable or stationary, range in size, and both reading ranges and scanning capabilities vary greatly. Scanning range varies between a few inches to several hundred feet. The RF link may operate on frequency bands ranging from low bandwidths (36 KHz) to high (microwave) bandwidths (2.45 GHz). Lower frequency links cause slower data-transfer rates from tag to system. In addition, a low frequency link forces the antenna/reader to pass by the tag at slower speeds and in closer proximity to the tag. Higher frequencies are more expensive and may require FCC licensing at sufficiently high frequencies.

An interfacing conduit terminal may be required, depending upon the logistical layout and immediate needs of the application. A simple unit provides no more than a communications interface with the outside world, in addition to some form of host support for application processing. While many brands and models of microprocessors would work, most models are IBM-compatible. Modems are required for downloading information from the interfacing terminal to the mainframe or central controlling computer.

Cost is the greatest barrier to implementation of RFID systems, although this is quickly changing. The cost of RFID readers has dropped 15 to 20 percent in 1993 and 50 percent from 1991 to 1993 (Small 1993). At present, the portable hand-held scanners cost $1,000 to $4,000 each. A battery recharging station costs $300 to $500. Software packages sold on the market cost between $300 to $1,000.

The cost of the actual transponder or chip still prohibits the widespread adoption of RFID technology. In general, a passive chip with limited memory and read-only capabilities can run as low as $10, while more sophisticated, recyclable tags (e.g., those used in automated manufacturing plants) cost more than $100 each.

The Automotive Industry Action Group (AIAG) has been actively tracking the development, uses, and standardization of RFID technologies for the past decade. This group has identified several uses of RFID technologies: material identification, transportation tracking, part number identification, shipping and receiving, container identification, vehicle I.D., number information, unit load identification, meter reading, tool handling, equipment maintenance, automatic guided vehicle control, and warehouse functions. A more detailed description of these applications can be found in Appendix B.

Currently most RFID systems are still "closed," meaning one supplier's tags cannot be read by another supplier's readers. There are several groups now working to establish common protocols, technology standards, and commodity standards for RFID applications in specific industries. The work of these organizations is not moving quickly, however, due to associated political, economic, technological, and sociological issues.

RFID systems are also limited by certain physical environments. The RFID systems in operation can be hampered significantly by nearby metals and other RF-linked systems in the vicinity. The strongest barriers to commercial adoption of RFID technologies involve the high-price of the transponder tags and the psychological barriers within the work-force.

Psychological barriers to utilizing RFID technology include the perception of it being too sophisticated, expensive, or time-consuming for an ordinary business or organization to design and implement it; there are also concerns about privacy and the elimination of the need for certain employees (David 1993; Mead 1993; "RF/ID System Tailored to Garment Manufacturer" 1993).

2.1.3 Touch Buttons

Touch buttons are a new technology which boast the operating characteristics of both bar coding and radio frequency identification (RFID) technologies. Touch buttons can do more than a bar code label and cost less than RFID applications. Touch buttons are ideal for applications where more information storage is needed than a bar code label or an RFID tag, but have less systemic flexibility than found with RFID technology.

Touch buttons, also referred to as touch memory buttons or direct contact electronic tags, are instant sources of digital information for the items they escort. All memory buttons sold today are manufactured by a single company, Dallas Semiconductor Corporation, and have permanent, unique registration numbers laser-imprinted into the internal silicon (*50 Ways to Touch Memory* 1993).

Touch memory buttons are like stainless steel, reprogrammable bar codes which can be "imprinted" on demand by a "touch probe" which may be a hand-held or fixed-station device. Memory buttons offer an advantage over paper bar code labels because new bar code labels must be re-printed and replaced in order to be updated. Touch buttons perform at a high level in harsh environments.

With this new one-conductor technology, a memory chip is enclosed in a button-shaped stainless steel package, which offers high durability, low cost, and longevity. They are attached to objects by self-stick adhesive backing, clip-on mounts, or press-on mounting rims. Data is transferred between this stick-on memory chip and a probe or "toucher" with a quick electrical contact to the case. Data flows to and from the enclosed memory chip through its stainless steel case, using the rim as the ground return. These chips can be both read and written while fixed to an object (*50 Ways to Touch Memory* 1993; Glick 1993). Additional operational characteristics of touch button technology include absolute traceability, adaptability, durability, extendable surface area for "touching," multidrop capability, one wire touch protocol, active or passive response capabilities, and accurate rapid data transfer.

Low cost is one of the touch button's greatest benefits. While the memory chips are not as flexible as RFID transponders, the cost of installing and operating most touch button systems pales by comparison. In fact, touch memory button technology can even be cheaper than some bar code systems (Quinn 1993). The cost of individual buttons start at about $1.00 to $5.40 per allotment of 25,000. Such hand-held probes as the touch pen or touch editor run $300 to $400 each, while plain touch transporter probes can cost as little as $26. Meanwhile, downloaded stations run about $150, and software is usually only $100 (Glick 1993; Videx, Inc. 1993).

Since this technology has been on the market less than two years, there are few applications implemented. Touch buttons are being investigated by many companies and agencies conducting pilot projects involving touch button systems. For example, touch buttons are being considered and tested by a few nation-wide moving companies, car rental services, agricultural agencies, industrial saw manufacturers, medical affiliations, security systems and service providers, and utilities organizations (Glick 1993; Kilbane 1993; Quinn 1993; "Touch Technology has Been Evident..." 1993). Refer to Appendix B for a more detailed description of touch button applications.

Touch button technology's primary limitation is that it requires direct contact between the memory button (or its extended surface) and a probe. The monopoly on touch button manufacture may restrict this technology. In addition, most third-party developers, value-added resellers, systems integrators, and consultants marketing touch buttons products are new to this technology. Finally, several inevitable systemic bugs unique to touch button applications may still be undiscovered.

2.1.4 Magnetic Stripes

Data is stored on magnetic stripes by magnetizing zones with alternating polarities. The microscopic particles are magnetized in a north-south direction or a south-north direction. The alternating polarizations are spaced in patterns, creating bits, which are then combined to create characters. Characters may be in any format, whether alpha, alphanumeric, binary, hexadecimal, or numeric. The alternating magnetic patterns can be detected with a "read head." This read head is a "C"-shaped core wrapped with a coil of wire. The read head detects polarizations by currents generated in the coil of wire passing over a magnetized zone (Nickle 1993).

The amount of information that a magnetic stripe contains varies according to application and the length of the stripe itself. Data storage ranges from 25 data bytes for a transit ticket to 640 bytes for an airline ticket. The magnetic stripe of the common credit card is divided into 3 tracks: track no. 1 can hold a maximum of 79 characters, track no. 2 can hold 40 maximum characters, and track no. 3 (Automatic Teller) can hold a maximum of 107 characters (Sheppard 1992).

Currently, most magnetic stripes must be placed on a rigid (.03 inch thick) piece of plastic. The stripes can be read several hundred to several thousand times, depending upon what material was used in making the plastic. Other types of magnetic stripes can be placed on plastic, paper, or composites with thicknesses as little as 7 mils (.007 inch thick). Data on cards this thin can often be read several hundred times before being discarded. With a protective overlay and under ideal conditions, cards can be read over a million times. Card life is reduced when contaminated readers (for instance, by dust, grit, or moisture) are used. Magnetic stripe card degradation is gradual and the stripe can be substantially abused before the data are unreadable (Nickle 1993).

A magnetic stripe system has four primary sub-components: the magnetic stripe card itself, the encoder, the reader, and software for programming.

The card is typically polyvinyl chloride, measuring approximately 3" x 2." One side of the card has a laminated magnetic stripe. A magnetic stripe may also be laid on "thin cards." This type of card is used in the mass transit/transportation industry.

The encoder, a small stationary device, formats areas of the magnetic stripe's tracks in alternating polarizations. If a magnetic stripe card is going to be formatted only once, it is done by the manufacturer of the card. If the intended use of the magnetic stripe card is to store continually updated data, then the purchase of an encoder is essential.

The reader detects the alternating polarizations as the card is passed through the "C" shaped reader head. A reader is generally stationary and mounted for easy access. Readers can be located away from the supporting software. A wire connects the reader to the software system.

The software is the interface between the reader and the output data. It converts the alternating magnetic patterns that the reader detects into a useful format. The software is specific to a particular type of application and equipment. Software is either pre-packaged for a general application or is specially configured for a certain situation; many vendors stock pre-packaged software.

A pre-encoded magnetic stripe card costs $3.00 - $3.50 each for quantities of up to 250 cards. The purchase of large quantities (e.g., 5,000 cards) lowers the cost to $.75 to $1.00 per card. The cost of an encoder depends on the coercivity (the difficulty in magnetizing and demagnetizing) of the magnetic stripe. A low coercivity, stand-alone encoder costs approximately $2,500. A high coercivity encoder adds $300 - $500 to the price. The cost of a magnetic stripe reader ranges from $200 to $1,000. A mid-price range reader costs $400 for interior applications and $500 for exterior use. Software costs vary greatly according to the intended application of the magnetic stripe.

Compared to other electronic information management and data capture systems, magnetic stripes are among the most cost efficient. Without resorting to traditional methods of paper and pencil for storing, updating, and recalling information, magnetic stripes are the least expensive means to record data. Additionally, the basic technologies and applications for magnetic stripes are well established.

Magnetic stripes are used for any cost-sensitive read/write application. Major uses include access control and identification. Magnetic stripes are being used in mass transit, telephone, and vending applications. Magnetic stripe applications also include use in airline tickets, toll collection, driver's licenses, and welfare disbursement. Magnetic stripes allow service providers to supply a simple low-cost card with only a stripe and minimal printing. For example, a driver's license will offer a more accurate identification with the use of a card embellished with photographs, holograms, bar codes (for fixed data), signature panel, and embossing. Magnetic stripe cards are portable, flexible, and reliable, and magnetic data is permanent unless it is erased or the stripe is degraded by abuse, scratching, cracking, or abrasion.

Access control is the most familiar function of magnetic stripes. The data capacity and read/write characteristics of magnetic stripes have resulted in its world-wide use for credit and debit cards. Other applications include security and benefit cards, in addition to prepayment cards (transit tickets, airline tickets, telephone cards, and vending cards). These applications require rewrite capabilities and a substantial amount of data capacity.

The major complaint about magnetic stripes is that they are not completely secure. Data that is encrypted on the magnetic stripe is just as safe as any other card technology, but if the secret PIN (personal identification number) is released, no identification or access control card is secure. High-coercivity often is equated with better security, but high-coercivity stripes are no more difficult to duplicate or counterfeit than the low-coercivity stripes.

The stripe is easily damaged or erased by incidental contact with magnets or strong magnetic fields which will scramble the encoded data. However, high-coercivity cards are less likely to be accidentally erased in such situations. In conditions of very intense magnetic fields, such as the MRI (magnetic resonance imaging) scanners found in hospitals, even high-coercivity cards will be erased.

Another disadvantage of magnetic stripes is that only a small amount of information can be stored on the stripe. If mass storage of data is needed, integrated circuits or touch memory button would be better choices. Magnetic stripes, by their nature, need to have contact with the reader device. If a non-contact reading system is required, bar coding with a laser scanner and RFID systems technology are more applicable.

2.1.5 Video Logging

Video logging provides a way to capture images of a roadway from a moving vehicle. It allows for the viewing of roadway segments without requiring an on-site visit. Various roadway and right-of-way (ROW) features may be viewed using video logging, among these being pavement condition, roadway marking conditions, signs, and ROW width and condition.

The images captured by a camera are generated digitally from a charged coupled device (CCD) computer chip and converted to analog. The analog is represented by measurable changes in the electronic signal, for storage on a disk which may be indexed and edited in the home office (McCall and Whited 1990).

The benefits of video logging technology are numerous. The fact that an image may be viewed while in the field prevents later rescheduling and backtracking that would be necessary to acquire missed mileage. It is less expensive than traditional 35mm film because it eliminates the costs of film, film processing, and transferal onto a laser disk. The image quality is poorer than that produced by 35mm film, but is still accurate and useful.

A video logging system includes a vehicle, a camera(s), a control panel/device, a video disc recorder, a color monitor, and a central processing unit (CPU). The vehicle is typically a van that has been specifically designed or modified to house the video equipment. The cameras must be of sufficient quality to capture the desired images. Multiple cameras may be used, depending on what kinds of data are being collected. The control/panel device organizes and administers the entire system. The video disc recorder transfers the analog signals to storage devices for movement to the indexing/editing computer. A color monitor is useful for on-site viewing of images. The CPU processes the video signal for storage on disc (McCall and Whited 1990).

Software is required to index and edit the stored images. It generally allows a user to clean up the discs, remove extraneous images, edit stored images, and add identifiers of the recorded roadway segment. It also allows for the playback of images at various speeds (McCall and Whited 1990).

The video logging total cost includes the price of software, hardware, and administrative expenses. A high resolution camera costs around $15,000, a laser disc recorder $20,000, an optical laser disc player $5,000, and laser discs $330 each for double-sided discs. Approximately a total of $50,000 is required when support equipment is included. The cost of a vehicle also must be considered. These prices continually change as advancements are made in the video/laser disc image field.

The Iowa Department of Transportation (DOT) has a video logging van it uses for capturing images of interstate and secondary roadways for districts and counties. The Iowa DOT has a modified van with two cameras, one for pavement and forward viewing, the other for capturing the ROW (Anderson 1994). They have an extensive library of laser discs which they use for roadway analysis and comparing older images with recent ones.

Other transportation-related uses of video logging include: identifying unsafe curves, determining safe passing zones and sight distances, monitoring concrete joint stepping, ranking road sections for annual maintenance and rehabilitation programs, and crack detection (Roadware Corporation 1994).

2.2 DATA RECOGNITION TECHNOLOGIES

2.2.1 Voice Recognition

Voice recognition provides a way for users to interact with computers in the same manner as humans do with each other (Stukhart and Berry 1992). Voice recognition has gained popularity because of the decreasing costs and increasing reliability of the technology.

In theory, voice recognition systems offer the best solution for most applications because users can enter data into a computer simply by speaking. However, limitations (such as cost) have restricted the use of voice recognition systems primarily to what are called "busy-eyes/busy-hands" applications. These applications allow users to utilize their hands and eyes while entering data into a computerized system.

Voice recognition converts sound, words, or phrases spoken by humans into electrical signals. These signals are then transformed into coding patterns that have assigned meanings (*Automatic I.D. News Guide Directory* 1993/1994). The error rate is dependent not only upon the hardware and software, but also on the expertise of the human operator.

Voice recognition uses microphones to pick up speech. Analog electrical signals are then produced and are sent to a voice recognition interface card in a PC or a stand-alone voice recognition device. The analog signals are converted into digital values, and these values are later decoded by template matching or future analysis. In template matching, the user must train the system by repeating a given word and indicating the meaning to the computer. Because each person pronounces words differently, one person's template will not necessarily work for anyone else. These systems are called speaker-dependent.

Alternatively, statistical sampling of the speech patterns of a large population sample can create a speaker-independent system. These systems make use of statistical sampling of pronunciation to define features of the words so that the computer will understand words regardless of the speaker.

Voice recognition systems can be used for either isolated words or continuous speech. Continuous speech systems allow the user to speak at a normal rate, while isolated word systems require a pause between spoken words. Isolated word systems are usually cheaper than continuous speech systems, but continuous speech systems offer better interfaces between users and computers.

Voice synthesis can be used to verify the correct entry of data and to guide the user through specific tasks. In addition, the systems are both hands-free and eyes-free. These features have allowed operator's hands and eyes to be utilized in more productive activities such as in laboratory work, inventory control, PC-board inspection, forklift operations, sorting and processing materials, and quality control in automotive manufacturing.

The main benefit of voice recognition systems are they enable workers to record data without using their hands or eyes to do so. Increased worker productivity via voice recognition technology, improved quality management, and efficient data manipulation translate into reduced error rates, higher productivity, and financial paybacks in typically under a year (Byford 1993).

Personal computers are used as the main processor unit for a voice recognition system. In those cases, a circuit board is inserted into the computer's open expansion slot. A microphone and a set of speakers is then connected to the board. Portable computers present another solution; in this case, all the needed hardware is located in a small unit. Finally, the software includes a set of programs that allow the user to train the voice recognition system.

The cost of a voice recognition system (hardware and software) depends upon the attributes required for such a system. Speaker-independent systems are excessively expensive and of questionable reliability; cost-effective solutions currently cannot be achieved with voice recognition systems. Speaker-dependent voice recognition systems range in price from $100 to several thousand dollars. Those with a limited vocabulary and without noise reduction capabilities cost between $100 and $300. The other extreme (a vocabulary limit of several thousand words per application, continuous speech recognition, and with background noise reduction) costs between $600 and $10,000. If portability is required, an additional $1,000 must be added to the cost of a standard system.

The first applications emerged in the 1980s in the aerospace, hybrid-circuit manufacturing, steel, and automotive industries. Recent developments have made voice recognition systems accessible to broader industrial applications in the automotive, transportation, lumber, and pharmaceutical sectors. Refer to Appendix B for a more detailed description of these applications.

2.2.2 Optical Character Recognition (OCR)

OCR is a technology that identifies human-readable symbols and then transfers their identities into machine-readable codes. OCR technology consists of a means of input for raw data entry, a method of transport for the movement of a document in front of the OCR scanner, a scanner that converts reflected or transmitted light into electronic signals, preprocessing of data to prepare it for processing, feature extraction and classification logic, and output (*McGraw-Hill Encyclopedia of Science and Technology* 1992).

OCR can be considered a specialized form of advanced imaging, which uses scanners, advanced cameras or camcorders, and high-resolution color printers to digitize images. These images can be further processed by intelligent software. OCR uses the same hardware and software as advanced imaging, but it also has the capability to interpret images.

Optical character recognition is most beneficial in the area of data transfer to computers. It decreases human involvement in the process and can result in a more accurate database; the output produced is readable by both humans and computer systems.

In order to utilize OCR and advanced imaging systems, data input tools such as advanced image/text scanners, advanced cameras, or camcorders are required. In addition, the user will need a computer with conversion and processing software capable of recognizing the data to be read. If certain outputs are necessary, then an advanced imaging printer/plotter would be required.

The application of the system determines the specific equipment required. For transportation applications, OCR systems are used to view vehicles or license plates. If speed limit control was the user's concern, an OCR system would consist of a high resolution camera or video camera elevated and zoomed towards the roadway, a radar device to determine vehicle's speed, and a computer system that would import images, recognize license plates, and store the data.

The total cost of an OCR system is a function of the application desired. Cameras require better resolutions to ensure the clearance and clarity of the data, and may be required to take pictures of objects moving at a high speed. Generally, OCR cameras cost between $8,000 and $40,000. Software prices also vary depending on the application.

The cost of installing an OCR system for speed limit control in construction zones is approximately $22,000 per lane, or $36,000 per three lanes. When used in pay-toll zones, OCR would take pictures of vehicles that do not pay the toll; such a system would cost $16,000 per three lanes, with an additional $5,000 per added lane (Computer Recognition Systems, Inc. 1993).

OCR is a broad-based technology, capable of being used in a wide array of applications. A sampling of these applications include traffic control, PC-based car license plate reader, contrast enhancement of mail piece images, documents restoration, and high resolution display technologies, and visualization to predict a child's skull growth (refer to Appendix B for information on each of these applications).

The current optical character recognition/advanced imaging systems are approximately 85 percent efficient in terms of accuracy of data input. The accuracy of the system depends on the size and type of the font it was programmed to recognize, and the clarity of the scanned material.

Even the most accurate programs will miss characters, and the error rate increases on pages with small type, dark backgrounds and shading, or degraded print quality, such as faxes or photocopies.

2.3 FIELD REFERENCING SYSTEMS

2.3.1 Global Positioning Systems (GPS)

Global Positioning Systems (GPS), or satellite surveying systems, are used in almost every area of surveying due to its capability to produce accurate results (Wolf and Brinker 1989). Based on observations of transmitted signals from orbital satellites, GPS will allow fairly accurate location of points upon the earth. There are two types of signals; one is a civilian, open access signal known as a C/A code or Standard Positioning Service (SPS), and the other is a defense signal known as P code or Precise Positioning Service (PPS). GPS ground receivers use codes (a series of binary numbers) to acquire and lock onto the signal broadcast from the satellites. These codes are carried by two carrier frequencies, each broadcast by a GPS satellite.

GPS ground receivers measure the time it takes for signals to travel from the satellite to the receiver (Wolf and Brinker 1989). Generally, at least two GPS receivers are used to obtain simultaneous measurements using the translocation technique.

The two main objectives of GPS are navigation and precise positioning. Unlike conventional means of precise positioning, GPS provides for greater "speed, accuracy, lack of intervisibility requirements between stations, operational capability day or night and in any weather," and "in the future, except for surveys of very small scale, GPS could well make conventional surveying by theodolite and tape obsolete" (Wolf and Brinker 1989).

The most important piece of GPS hardware is the GPS geodetic receiver. The receiver picks up the signal sent from the satellite and translates it into a usable form. Multiple GPS receivers allow determination of points that may then be tied together. In addition, the receivers record the data which can be downloaded into a computer.

A geodetic GPS receiver consists of one or more radio channels, an internal clock, and a computer to perform the analyses and store the information (Huxhold 1991). The internal clock is a very important part of the receiver; the distances used in the triangulation process are calculated using the time it takes for a signal to reach the receiver from its satellite origin. High-quality, temperature-controlled crystal clocks, while the least expensive type suitable for GPS instruments, must be constantly powered in order to maintain their accuracy. Rubidium clocks are slightly more expensive but do not need to be continuously powered. Cesium clocks are the most accurate but are expensive and unsuitable for field work due to their bulkiness (Moffit and Bouchard 1987). Inexpensive clocks are commonly used. They allow cost-efficient time measurement accuracy to within a nanosecond (Huxhold 1991).

The cost of a GPS system depends upon the accuracy required; receivers have a price range of $750 to $30,000. The cheapest receivers locate objects on the earth to within a hundred meters, while state-of-the-art receivers are able to locate objects to within a half-centimeter. The necessary computer hardware and software to interpret the GPS data adds to the expense of the system. Once a receiver has been purchased, the receiver may be positioned and the signals utilized.

Several GPS applications have been developed in the areas of agriculture, shipping and navigation, mapping application, transportation management, automatic vehicle location, and navigation. A more detailed description of each application can be found in Appendix B.

GPS is subject to satellite ephemeris errors, errors due to atmospheric conditions, receiver errors, and multipath errors (Wolf and Brinker 1989). Satellite ephemeris errors are due to the inaccuracy in pinpointing the location of a satellite and may result in errors of up to +/- 20 meters (Wolf and Brinker 1989).

Some atmospheric errors are caused by the presence of water vapor resulting in a propagation delay of tens of centimeters. The errors may be corrected by measuring the water vapor with a back-scatter radiometer and considering the results in calculations (Moffitt and Bouchard 1987).

Receiver errors are due to electrical noise and errors in matching the transmittal signals (Wolf and Brinker 1989). Part of the transmittal signal matching inaccuracy may be due to clock inaccuracy. Multipath errors are caused by signals that are reflected from other objects (Wolf and Brinker 1989). The largest errors in GPS are caused by the inexactness of the satellite orbital path ephemeris (Moffitt and Bouchard 1987).

Other limitations include the inability to sight three satellites at the same time in some locations, and the high cost of GPS receivers. The inability to sight three satellites, for example, could cause problems in the central business districts of larger cities where tall buildings may block the direct-line signals needed. In these locations, traditional surveying techniques could be employed from an optimum GPS-determined position.

Finally, while GPS satellites are available now, there is no guarantee that they will be available in the future. The federal government may not approve funding for the maintenance or replacement of the satellites if their primary purpose becomes unnecessary (Huxhold 1991).

2.3.2 Geographic Information Systems (GIS)

Geographic Information Systems (GIS) are computerized database management systems for the capture, storage, retrieval, and display of spatially defined data (Simkowitz 1989). GIS allows multiple users to perform a diverse number of analyses using the same data in different capacities. GIS users have the added benefit of viewing the results graphically and non-graphically. GIS allow new forms of analysis, especially those that were previously thought to be too time consuming and expensive (Souleyrette 1993).

GIS may be integrated with Global Positioning Systems (GPS), which provide a method of gathering data for the GIS. In addition, other data collection technologies (e.g., radio frequency identification and touch memory buttons) may be similarly interfaced with GIS systems.

GIS primarily contain map information which is stored digitally in a database. Utilizing the database, GIS can plot information needed to produce a map. Just as non-GIS information systems do, GIS produce printed reports, but GIS produce a variety of maps as well. Descriptive information stored in a database (attribute data) can be located on a map and used to analyze features of the location. This attribute data can be anything from structures, pavements, and locatable features such as census tracts, to area-specific incidents such as accidents, fires, and crimes.

GIS works by storing data in coverages (layers) with each layer containing a set of features or spatial objects and registering their geographic coordinates. After the data has been input, spatial connections among objects can be constructed and attributes can be assigned. The attributes may then be manipulated through database queries, and the results of these queries can be graphically either displayed on the computer monitor or directed to a printer/plotter.

Essentially, GIS systems are like Computer Aided Design (CAD)/Computer Aided Mapping (CAM) systems in that GIS, like CAD/CAM, offer mapping design and design of visual objects. Unlike CAD/CAM, GIS additionally offers non-visual as well as visual analysis of data, complex graphical and non-graphical handling of data, and analysis of geographically-related analysis data.

Most GIS technologies used today were manufactured by Original Equipment Manufacturers (OEM) and sold to "value-added resellers" or vendors who then designed a complete system tailored to achieve certain performance characteristics for specific fields, industries, or customers. The vendors sell the systems as complete packages including hardware, software, application programs, training, installation, and maintenance.

GIS hardware includes such components as the central processing unit (CPU), a workstation, a graphic display screen, a keyboard, a printer/plotter, and magnetic storage devices. The CPU should be a 32-bit system in order to provide adequate response time and accuracy and precision for the mapping functions. The workstation must be a graphic workstation with a mouse, digitizer, or cursor. In some cases, a digitizing board or table is also included. The graphic display screen should be of high enough resolution to display the graphical information to the users' needs.

GIS software costs anywhere from hundreds of dollars to hundreds of thousands of dollars. Purchase prices range from $500 for software intended for specific, simple purpose to $50 to 100,000 for software intended for complex, highly-involved analysis and display and interfacing with other systems. GIS software may also be developed in-house.

Hardware costs are determined by the needs of the users and the amount of adequate hardware the user currently has. The range of costs commonly associated with hardware falls between about $2,500 to $50,000, depending on the needs of the software and the agency using the GIS (Souleyrette 1993).

Existing applications for GIS are diverse in that uses of spatially-referenced data are spread among many different disciplines. The displaying of data in the form of a map and location identifiers to process and display attribute data about features on a map have uses in many fields. A partial listing of the divergent fields in which GIS has already been used follow: transportation management; construction; urban storm water management models; watershed hydrologic modeling; long-term regional water-resources planning, uplands, wetlands, and submerged ecosystems analysis and management; and education. Refer to Appendix B for a more complete description of GIS applications.

Some limitations of GIS include the inability to handle data that is not locationally related. GIS were designed to handle spatial data and spatial characteristics of data. Therefore, the systems cannot handle data if it is not spatially-related. Other limitations of GIS include cost, startup time, and maintenance issues.

Another limitation of current GIS technologies is that the current software is not designed for general use. The roots of GIS are planning and resource management; therefore GIS designs are more developed for these fields. For example, transportation department data may not be adequately served by the current GIS. Many different types of data might be kept for highways within a system; highway segments associated with one attribute type might not fit well with segments associated with other attribute types. Pavement width might be constant between two log-miles, but pavement type may differ within this region. Most GIS systems do not have the capability to support such data models without tradeoffs in the maintenance and storage of data (Travis et al. 1990).

2.4 DATA TRANSMISSION TECHNOLOGIES

2.4.1 Radio Frequency Data Communications (RFDC)

Technically speaking, radio frequency data collection (RFDC) systems are not automatic identification (Auto I.D.) technologies, because they do not collect raw data. RFDC links automatically collected data (via bar codes, optical character recognition, magnetic stripes, touch memory buttons, or other automatic data collection devices) and transmits them to a central controlling computer.

In warehouse management, RFDC often refers to a hand-held or fixed-position scanner system or data collection terminal with a keyboard and a display. It links the controlling computer system with the workers to eliminate the cumbersome use of clip boards, scratch paper, and business forms. RFDC systems will enable a field employee who possesses a portable, wireless terminal to communicate with his or her operation's controlling computer via a radio link.

One of RFDC's key payoffs is that company staff can instantaneously and accurately collect on-site data and transmit it to decision-makers without the use of hardwire links. This is ideal for conditions where a great deal of movement or physical flexibility is required, as in the case of warehouses and processing plant floors. An RFDC system eliminates the need for managers to wait for a report, voucher, or order form to be filed.

The first two signs of economic savings resulting from RFDC-based warehousing usually arises in reduced excess inventory. For example, a million dollars' worth of "active stock" (stock that turns around at least once a year) can be recovered by not producing or receiving it. Subsequently, additional savings are manifested in the reduced cost of "carrying" those items, which involves labor, space, damages, maintenance, insurance, and utilities, usually running an additional 20 percent to 30 percent. Inventory reductions will also show up in increased inventory turn-arounds. A real-time, paperless system shortens the operational lead-time traditionally needed and efficiently utilizes available resources.

The sources of the automated data collection are most frequently bar codes. However, as mentioned earlier, magnetic stripes, OCR, and touch memory buttons also provide data sources which can communicate with an RFDC scanner. For example, magnetic stripes on personnel identification badges could be scanned using portable or fixed-station slot scanners. The data collected would be transmitted back to a controlling computer via an RF link.

The scanner, reader, and hand-held terminal can either be built into an RFDC device or work as a separate sub-component. Whether hand-held or mounted on a forklift, these devices are always portable (Mullen 1993). The terminal is generally a battery-operated microcomputer with a standard or non-standard keyboard and display screen, which are RF-linked to a controlling computer. While hand-held terminals offer screens displaying one to six lines of text, newer laptop portables for fork lift mounts offer a full-screen display (Teklogix 1993).

The RF link ranges from low to high frequencies in the microwave range, that transmit data from the portable terminal to a host computer up to several miles away. For instance, the hand-held scanner in the RFDC system employed in the warehouse of the Iowa Department of Transportation (IDOT) can relay information up to two miles away via RF, according to IDOT officials (Gray 1993; Lande 1993).

The power sources of the RF-linked portable data collection terminal are typically rechargeable and battery-based.

Modems may link via FM transceiver technology, a telephone line, or a cellular telephone.

The database may receive the collected data via an interfacing computer terminal. However, this step can be circumvented when the hand-held terminal communicates directly with the central controlling computer, as is done with the Iowa DOT warehouse system (Lande 1993).

While operating costs of an RFDC system run relatively low (even for the largest of systems), start-up costs vary widely. Automatic Identification Manufacturers, Inc. (AIM) Technical Manager, Dan Mullen, says the greatest expense for most firms implementing RFDC systems lies in staff-hours spent assessing the system in need of RFDC, and in the planning and designing stages of installation. As for the hardware, Mullen says the cost of equipment depends largely on how many hand-held scanners and interfacing computer terminals will be employed.

Most hand-held laser-based scanners and bar code label printers range from $2,000 to $4,000 per unit. A single battery-recharging station costs $300 to $500. Software packages for RFDC systems now available on the market cost between $300 to $400. A single base-station with the necessary networking technology runs about $5,000. These estimates do not include the cost of additional personal computers which may be needed for the individual needs of any operating system (Mullen 1993).

The payback rate for most RFDC systems today, reports AIM, is 6 to 18 months. This is similar to bar coding technology's average payback rate, perhaps because most RFDC systems are based upon the use of bar code labels for data acquisition. Recent advancements in RFDC systems technology, however, are beginning to handle data captured via other Auto I.D. technologies, including magnetic stripes, optical character recognition (OCR), and touch memory button technologies (Glick 1993; *ID Systems Buyers Guide* 1993; Kilbane 1993; Videx 1993).

Warehouse management tends to be the primary application for RFDC technologies. For simple inventory tracking, RFDC has realized significant savings in operational costs (Jeffress 1993; Mullen 1993; Peters 1993). So far, most RFDC-based warehouse management systems (WMS) use bar code labels for automatic data capturing. The Utilities Industry Group (UIG) is investigating using touch memory buttons in automated warehouse management systems (Kilbane 1993). Applications have also been developed in the areas of construction, power distribution, and medicine (refer to Appendix B for a description of these applications).

The RFDC system must be carefully designed and implemented to be effective and efficient. Most warehousing and plant floor sites involve varying operations between separate buildings, wings, floors, or divisions. Effective communication between remote terminals, base stations, and the central computer is critical. Implementing a RFDC system to accommodate these operations requires that planners have a thorough and realistic knowledge of all operations involved. In addition, vendor skill at compensating for specific operational conditions at each individual facility plays a strong role in the success of a system.

RFDC science becomes involved in this technology's single key performance issue: speed of data communication between remote terminals and base stations. Speed ultimately affects ease of use. The physical environment frequently determines how well the RF-link will work. For example, RF signals might "bounce" and the system's range might be boosted if metal is located nearby. Paper and dense, non-reflecting materials shorten range. Electrical motors, generators, arc welders, wireless Local Area Networks (LANs), cordless phones, vehicle location systems, and other RFDC systems nearby also affect a RF link's performance. In addition, "dead spots" are common problems when using antennae, modems, network technology, counting scales, and scanners.

2.4.2 Electronic Data Interchange (EDI)

EDI is an electronic (computer to computer) exchange of data between two or more companies, using a nationally approved standard data format. In addition, the term "EDI system" is used to explain the total integration of the hardware and software pieces necessary to reach an intra-company computerized process. An important component of an EDI system is the transaction set. This data is an electronic representation of paper transactions, such as a purchase order or invoice. With EDI, a computer sends an electronic purchase order from the customer to one or several of its supplier's computers.

EDI systems symbolize the end of manual preparation and transfer of paper documents. With reduction in paper transactions comes reduction in postage costs, records management overhead, physical storage requirements and errors deriving from illegible handwriting and error-prone manual data entry. EDI allows the storage of vast amounts of information in small devices. For example, about 1,000 short-purchase orders can be saved on a 3.5" diskette. Also, data can be transmitted quickly.

Another benefit of EDI is it frequently improves relationships between companies involved in an EDI project. Since companies and their suppliers must work very closely to determine the terms of the electronic transactions, they will come to a better understanding of what is expected regarding quality, order turn-around, and payment terms.

A study aimed to explore the advantages of electronic data interchange identified several benefits associated with the usage of EDI in a variety of industries. Advantages include improved accuracy of information and reduction in errors, reduced data entry, reduced data transmission time between organizations, reduced inventory and inventory carrying costs, enhanced company relationship with customers and suppliers, improved productivity, reduced paper flow between organizations, standardized programs and procedures, and reduced personnel requirements (Scala and McGrath 1993).

The hardware of an EDI system is either a mainframe or a PC platform. Most companies start with a PC platform, which entails a limited commitment of capital, time, and other resources.

One key software element is the "translation software" which transforms the data into the standard format. This software reformats data generated by a corporate information system, called the application program, into a transaction data set. In the same fashion, a vendor's translator will convert incoming data into his internal applications. The translator's software serves as the connecting point between trading partners with their specific data and ensures that EDI transactions are valid, timely, and accurate. Input comes from either a computer application or from manual keyboard entry. The last piece of software is the data communication software, which serves as the traffic director for the data. It is responsible for establishing the data connection between companies.

Two companies can achieve electronic data interchange by a point-to-point or the value-added network (VAN). With point-to-point systems, companies send and receive electronic transactions directly between their computers. VAN systems provide an electronic mailbox and connect two trading partners.

VAN systems offer additional services, including data translation services, data mapping services, automatic data backup, archival and recovery processes, communication hardware and software, interface capability to a company's communication hardware/software, conversion among different EDI standards, EDI consultation, planning and implementation assistance, multiple levels of security (including data encryption and decryption), and detailed activity reports.

For these reasons, most of the companies using EDI applications use VAN suppliers. Developing the translation software in-house is seldom considered because EDI standards are still evolving (EDI: Concepts and Applications,1993). VAN systems thrive in volume. They can ask for a one-time-only installation fee plus a monthly fee for mailbox "rental." Some charge by document, while others charge a set rate per data character.

Costs depend significantly on the in-house involvement of the trading partners and their computing capabilities. However, the most common approach when implementing EDI is to purchase the software from dedicated companies which track the latest technology and standards changes. Consequently, this report will concentrate on EDI software costs.

EDI software costs range from $700 for simple, limited versions (e.g., they can work with just one or two different standards, are PC-based systems, do not provide technical support, and have other limitations) to $30,000 for complex systems (e.g., those which support most of the EDI standards, provide unlimited technical support, are PC and mainframe based systems, and offer other features). Complex mainframe systems with multiple partner capabilities and extensive technical support can cost more than $50,000.

It is important to stress the variability in prices when acquiring EDI software. Issues such as which standards are supported, operating system compatibility, annual maintenance charges, typical start-up time, customer support services offered, communication protocols supported, special features (e.g., use of templates, error checking, and editing), methods used to update standards, source code, customization, value-added-services, and VAN compatibility must be carefully reviewed.

A partial list of commercial and non-commercial markets now working to adopt industry-wide usage of EDI systems follows: automotive industries, medical health industry, motor carrier industry, and retail. For a more detailed description of these applications, refer to Appendix B.

Choosing a VAN vendor can be a difficult task since most of them offer different services and price arrangements. Other considerations might include connectivity with other VANs, support of the company's specific industry and transaction sets, and data safety guarantees. In addition, Scala and McGrath (1993) identified several disadvantages associated with the usage of EDI: requires high level management commitment to be successful, lacks a common understanding, difficult to quantify the return on investment, requires a high initial capital expense, requires large volumes before benefits are attained, too many vendors providing connectivity, standards are in a state of flux, majority of company's partners do not use EDI, and the impact on the organizational culture.

2.5 PORTABLE COMPUTERS

2.5.1 Pen-Based Computers

Pen-based computers integrate one of the first communication tools, the pen, with the latest microcomputing power. Pen-based computers (PC Notebooks, Tablets, or Slates) use the screen and specialized software to allow direct screen entry of data into a computer (Ellis 1993). Handwriting is entered with a special pen and converted to conventional typed text. Most pen-based computers are similar to notebook portable computers.

This technology does not offer extensive application software from the marketplace, and users must usually develop their own applications from provided development packages. Programming a pen-based computer is comparable to Windows programming, where objects and events are the most important concept. Objects represent figures on the screen, while events are the incidents caused by touching the pen to the screen or by lifting the pen from the screen. Data entry is performed by printing on the screen, by touching and checking off user designed boxes, or by choosing items from a scrolling list. Applications using pen-based computers often resemble the paper forms they are designed to replace. This characteristic of pen-based computers provides easier and faster user training, and decreased aversion to new technologies.

A pen-based interface consists of a digitizer, a pen-like stylus, and an output screen. A recent development has allowed the integration of the digitizer, screen, and computer into a single unit that can measure about 10" x 12" x 1" and weigh less than 5 pounds.

There are four types of pen computers emerging. These are clipboards (having large screens, long battery life, and low prices), tablets (with large screens and high-speed processing), "pen-tops" (pen-reinforced notebooks), and compact hand-held terminals (*The Future of Pen Based Computing 1992).*

A new stream of personal computers is emerging aimed mainly at the executive pen computer market. Distinctly named as personal digital assistants (PDAs), personal communicators, personal intelligent communicators, and personal information processors, these hand-held computers integrate pen input, handwriting recognition, personal organization tools, and state-of-the-art mobile communications.

In general, pen-based computers cost approximately between $2,000 and $4,000 per unit. In some cases, personal digital assistant hand-held computers can cost less than $1,000. Finally, varying software development costs must be considered. Pen-based applications are ideal where low-volume text entry is required. In this sense, check boxes, menus, sliders, and dials offer chances for data entry using pen-based devices. This technology is used extensively in the cargo container shipping industry. Refer to Appendix B for a more complete description of pen-based computing applications.

The main limitation of pen-based computers is lack of accuracy in handwriting recognition. This feature is often used for marketing pen-based devices, but the failure to properly recognize handwritten input can easily frustrate users, consequently delaying the implementation of pen-based applications. Pen-based manufacturers offer a limited solution for this problem. Some computers offer virtual keyboard capabilities (users can tap letters in with the pen using an image of a keyboard on the screen).

3.0 INTEREST LEVEL INVESTIGATION

3.1 METHODOLOGY

Interest in these technologies by Iowa transportation organizations is identified in this portion of the report. The research methodology involved a survey and interview strategy designed to facilitate an understanding of current field data collection systems and to identify the interest level in using advanced field data acquisition technologies. Interviews were conducted to learn more specifically about the needs of each organization. This section provides a description of the survey, sampling plan, analysis technique, and interviews.

3.1.1 Survey

The intent of the survey was to learn more about existing data management procedures used by cities, counties, and the state and to identify any interest in enhancing these procedures using more sophisticated field data collection technologies. To accomplish this goal, a four-part mail-back survey was developed (refer to Appendix D). Part I includes general information regarding the respondent (e.g., name, title, and agency). Part II addresses questions related to the current field data collection approach for nine different programs of importance to the transportation sector: (1) sign management (e.g., field and warehouse inventory), (2) pavement management (e.g., pavement inspection), (3) bridge management (e.g., bridge inspection), (4) traffic management (e.g., signal inspection and accident counts), (5) parking management (e.g., parking lot surveys), (6) surveying (e.g., utility location data collection), (7) safety programs (e.g., accident location identification), (8) maintenance management (e.g., bridges, culverts, and signs), and (9) construction management (e.g., materials, labor, and tool tracking). Respondents identify how data are collected in the field, transmitted, and stored in the office. They also identify specific software applications used for each program both in the field and office. Additionally, respondents provide an inventory of their computer hardware used in the field and office.

Part III indicates the respondent's interest level in using advanced data collection technologies to capture a variety of field data for each of the nine programs. Interest level was measured using the following scale: 1 = Not interested, 2 = Somewhat interested, 3 = Very interested, and I = Implemented. To assist the respondent in filling out Part III, a brief description was provided for each field data collection technology. If questions still existed, the respondent was asked to contact the principal investigator for more information. Part IV identifies the respondent's willingness to share additional information regarding this survey. Respondents were assured that the survey results would be held in the strictest confidence.

3.1.2 Sampling Plan

The survey was sent to directors, engineers, and administrators at the state, city, and county levels who were familiar with their agency's current data collection approach and could best respond to their agency's potential interest in adopting new technologies. At the state level, managers from each major program (e.g., maintenance, construction, safety, and traffic) responded to the survey, and hardware and software types and quantities were provided by the Iowa DOT's computer system information group. Cities with population greater than 5,000 were targeted for the study because of the perceived interest in the use of advanced field data collection technologies compared to smaller cities. Surveys were sent to city engineers, directors, and administrators. County engineers from all 99 counties in Iowa were asked to complete a survey.

About 11 percent of the surveys were completed by both city and county representatives at the American Public Works Association Conference held last spring in Ames, IA. At this conference, the principal investigator provided a description of each technology, answered questions, and had the attendees fill out a survey. This provided the researchers with an opportunity to (1) pretest the survey and (2) explore any possible differences in responses between respondents who were provided with a detailed verbal and graphical description of each technology and ones that were simply provided with a written description.

3.1.3 Analysis Technique

Statistical data analysis techniques were applied to the data to identify significant trends. SAS™ and SPSS (Statistical Package for Social Sciences) are the two statistical packages that were used to analyze the data. Exploratory data analysis was performed using SPSS that showed general trends in current field data collection, transmission, and office manipulation techniques; computer hardware used by transportation agency; and overall interest level in applying these technologies to the various programs. These results are summarized in graphical and tabular format.

Linear regression models were also developed to identify significant trends regarding responses and transportation agency size. This resulted in over one thousand models that were tested using the SAS™ statistical package. Results returned from running the models indicated many significant probabilities using the Student's t-statistic. The significance level for these tests was set at less than or equal to an alpha value (α) of 0.10. This established a level of error of only 10 percent in the results. Statistical trends were established for city and county data. The state data did not lend themselves to statistical analysis because single individuals representing each of the departments responded to their respective program, not allowing for comparative analysis.

Hypothesis tests were also conducted to identify potential differences between the APWA conference respondents and mail-back respondents. This hypothesis was tested using a pooled t-test to determine whether the response means were statistically different. This test was performed to see if there was a difference in interest level by respondents who were provided with a more detailed description of each technology compared to respondents who were provided a brief description on paper.

3.1.4 Interviews

After the survey responses were analyzed, interviews were conducted with a small sample of survey respondents. Interviewees were selected based on several criteria: (1) survey respondents who demonstrated some interest in adopting more advanced field data collection technologies, (2) approximately equal city, county, and state representation, and (3) diversified location in the state of Iowa. The purpose of these interviews was to learn more about how data are collected, transmitted, and stored in the office; the types of data collection forms used by each agency; inefficiencies in their information system; and the types of applications the respondent would like to see developed to improve their current approach. A brief description of each technology was provided if the respondent was interested.

3.2 RESULTS

A total of 155 surveys were received out of approximately 180 that were sent out; this represents approximately an 87 percent response rate (refer to Table 1). There was about an 85 percent response rate for the cities ,and most city respondents were directors, administrators, and engineers. The mean city size was 24,554 and the maximum was 193,187 while the minimum population size was 1,042, despite our goal of surveying transportation agencies greater than or equal to 5,000. Eighty-seven of the 99 counties responded, representing an 88 percent response rate. Most of the county respondents were engineers, assistant engineers, and assistant to the engineers. A 100 percent response rate was obtained from the state. Sixteen of the city respondents and one county respondent had already filled out the survey at the APWA conference.

3.2.1 Current Data Collection, Transmission, and Office Manipulation Approach

3.2.1.1 General Trends

Overall, results show that most Iowa transportation agencies use a manual approach to collect data in the field and hand carry the data to the office (refer to Figures 1 and 2). Figure 1 shows that surveying (Surv) appears to involve the greatest use of computerized field data collection for the cities, counties and state; this is clearly shown by the small number of counts or respondents using this approach. Other programs involved a minimal use of the computer for field data collection. Hand carrying field data to the office is the most widely used data transmission technique (refer to Figure 2). Figure 3 reveals that data is processed using both manual and computer office applications. Sign management and surveying are two programs that have the greatest computer use in-office. The data indicates that the counties use computers more often to process data in the office than cities especially for sign management and surveying (refer to Figures 4 and 5). Cities appear to be more proactive in the use of computers for processing pavement management data compared to the counties.

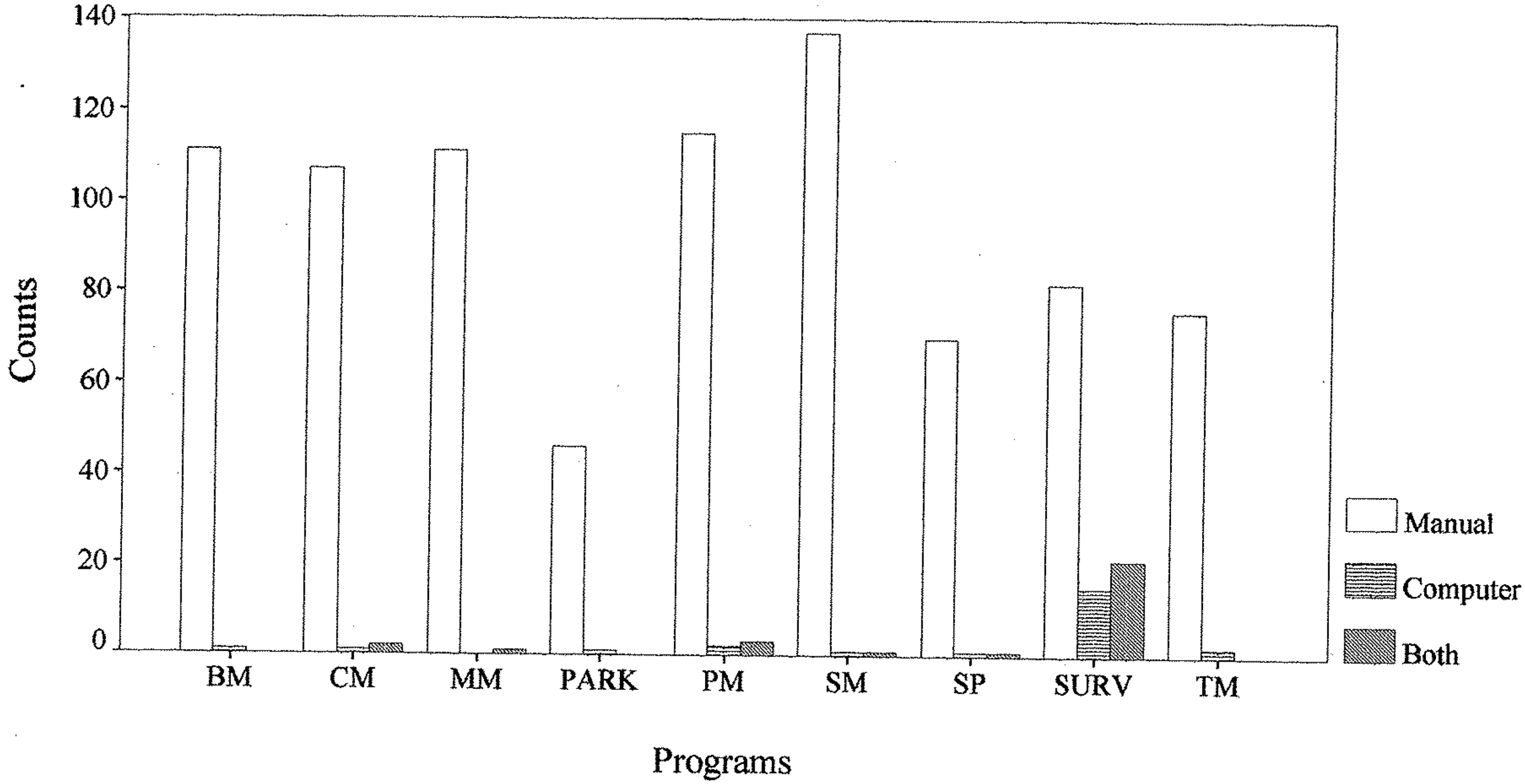
Table 1: Respondent Profile

	Cities	Counties	State	All Respondents
N° Surveys Sent	79	99	1	179
N° Surveys Received	67[1]	87[2]	1	155
% Response Rate	85%	88%	100%	87%
% Representation	43%	56%	1%	100%
Respondents				
Engineer	25.4%	60.9%		
Asst. Engineer	1.5%	16.1%		
Asst. to Engineer	0%	18.4%		
Director	32.8%	0%		
Administrator	28.3%	0%		
Clerk	6.0%	0%		
Other	6.0%	4.6%		
Mean Population	24,554	27,947	N.A.	26,471
Population Standard Dev.	36,067	42,996	N.A.	40,039
Maximum Population	193,187	327,140	N.A.	327,140
Minimum Population	1,042	4,866	N.A.	1,042

[1] Includes 16 additional surveys from the American Public Works Conference held March 18, 1994, Ames, IA.

[2] Includes 1 additional survey from the American Public Works Conference held March 18, 1994, Ames, IA.

Figure 1: Field Data Collection Method for the Cities, Counties, and State

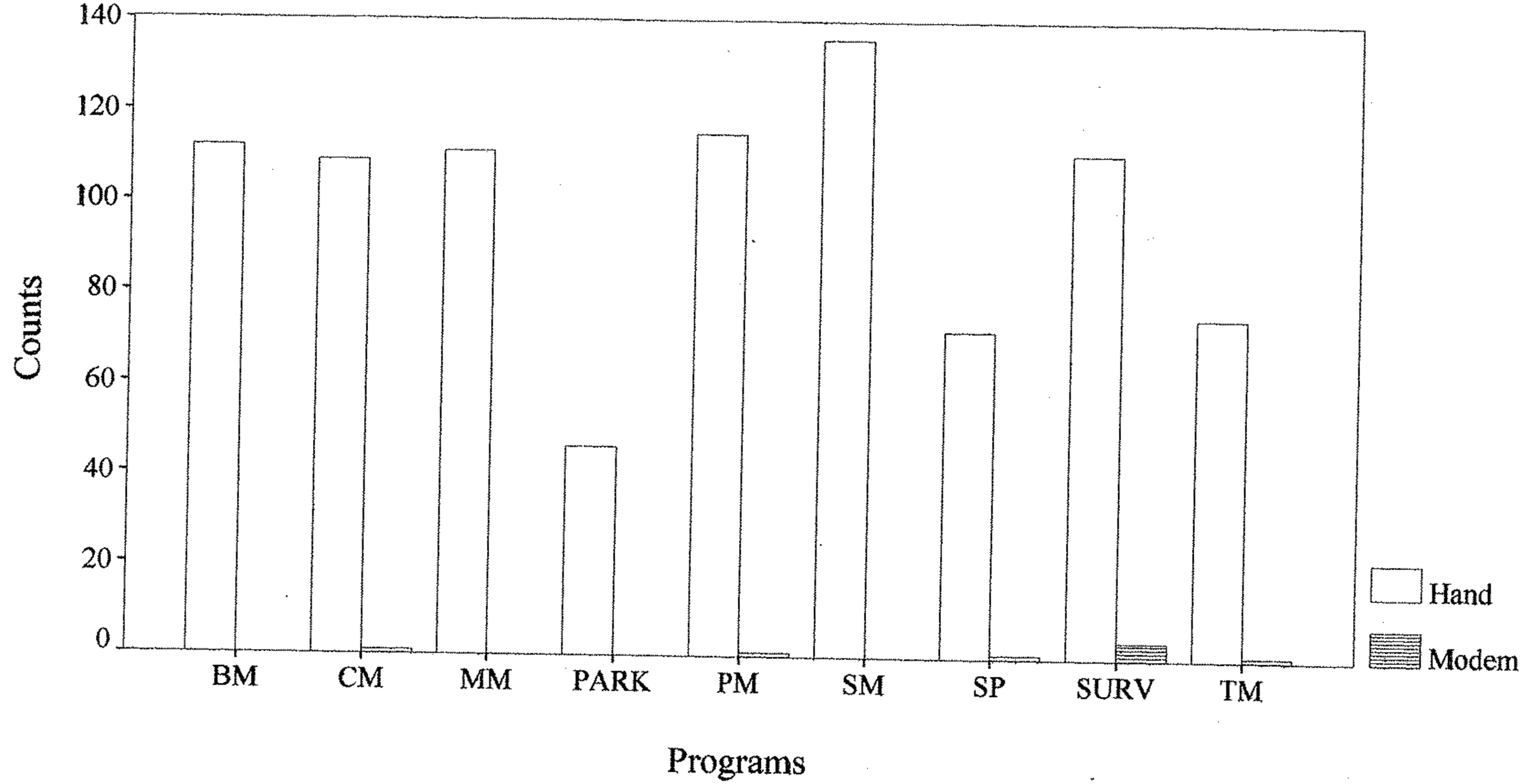


LEGEND

BM: Bridge Management
CM: Construction Management
MM: Maintenance Management
PARK: Parking Management
PM: Pavement Management

SM: Sign Management
SP: Safety Program
SURV: Surveying
TM: Traffic Management

Figure 2: Field Data Transmission Method for the Cities, Counties, and State



LEGEND

BM: Bridge Management
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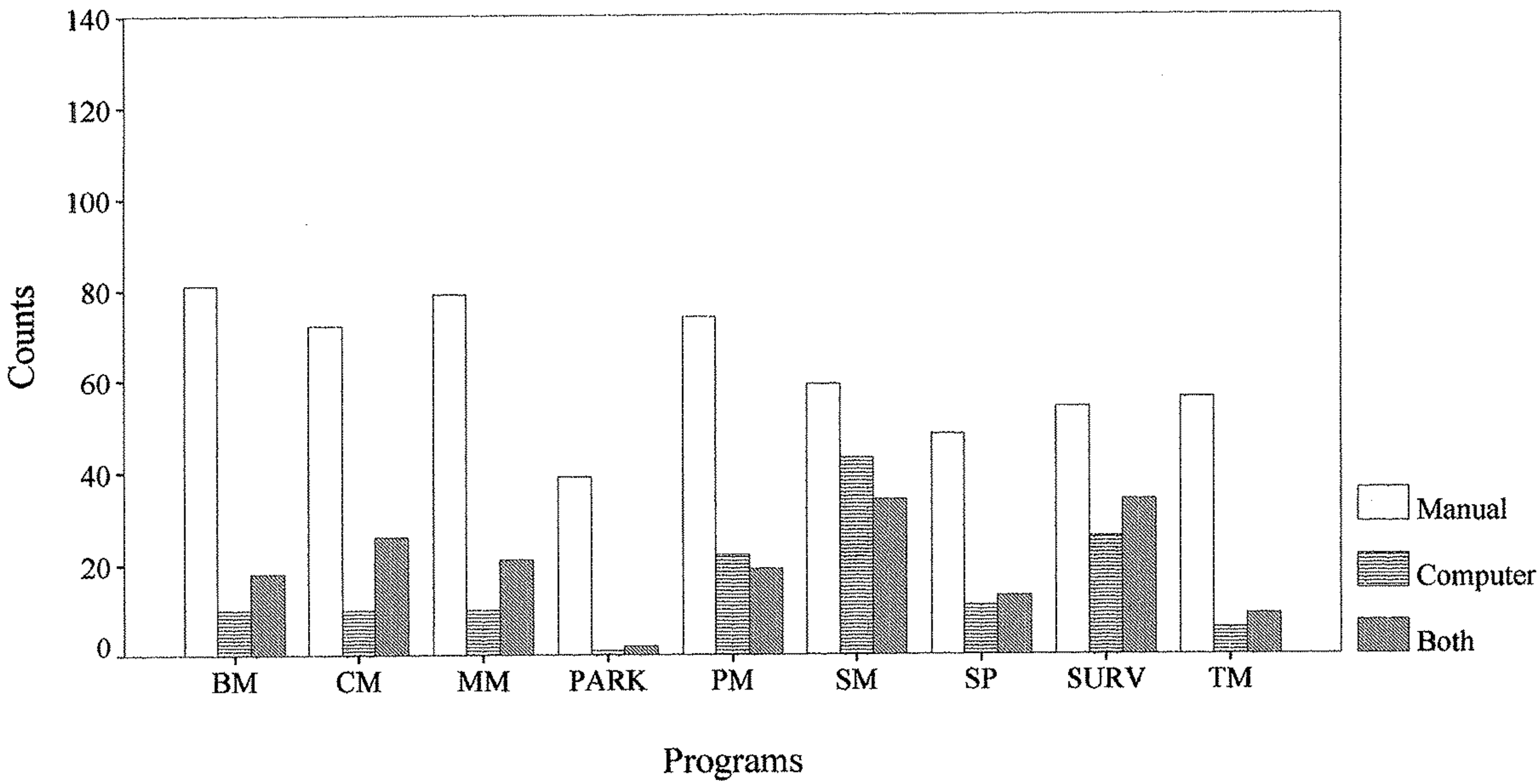
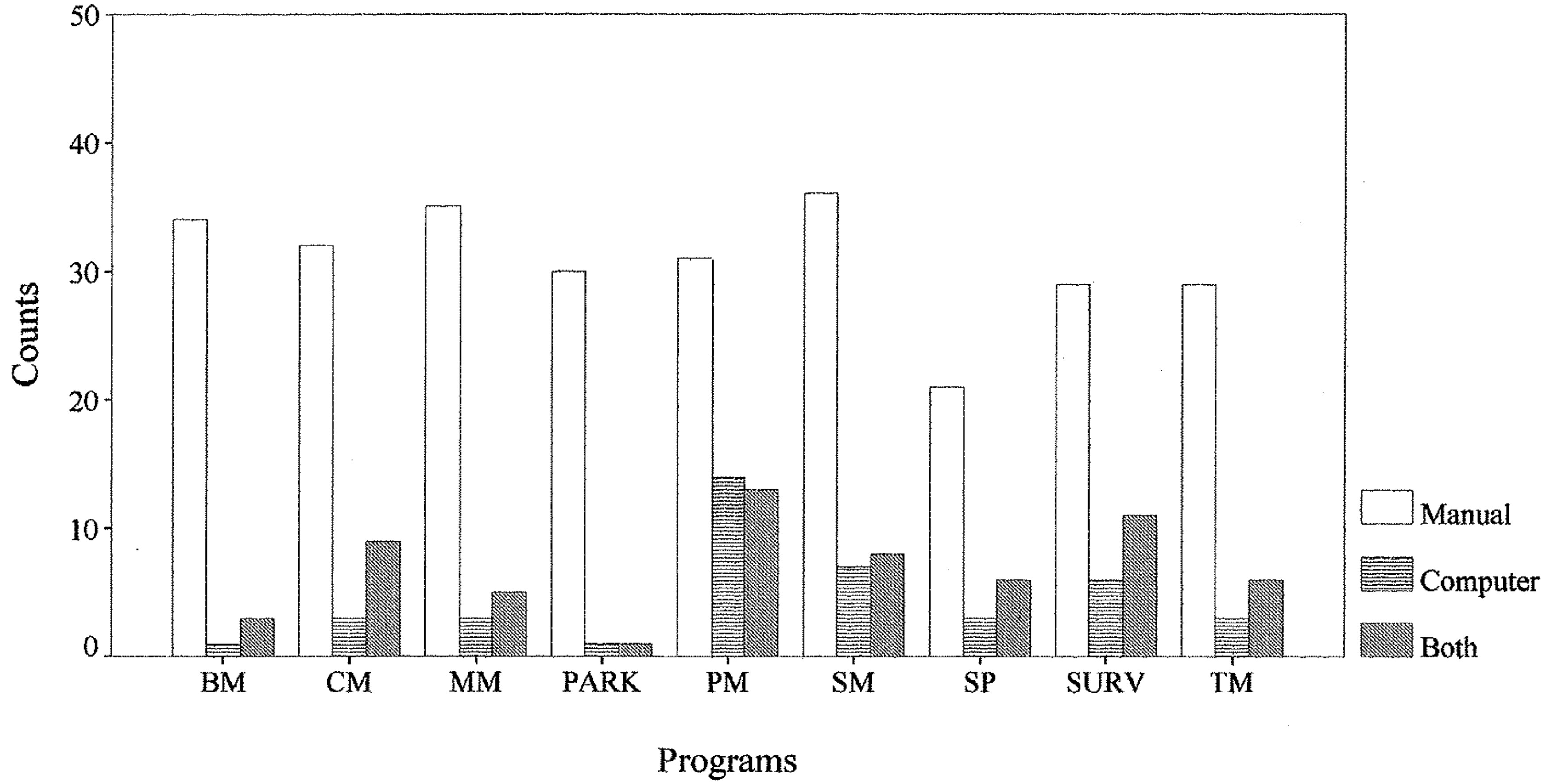
Figure 3: Office Data Manipulation Method for the Cities, Counties, and State



LEGEND

BM:	Bridge Management	SM:	Sign Management
CM:	Construction Management	SP:	Safety Program
MM:	Maintenance Management	SURV:	Surveying
PARK:	Parking Management	TM:	Traffic Management
PM:	Pavement Management		

Figure 4: Office Data Manipulation Method for the Cities



LEGEND

BM: Bridge Management
CM: Construction Management
MM: Maintenance Management
PARK: Parking Management
PM: Pavement Management

SM: Sign Management
SP: Safety Program
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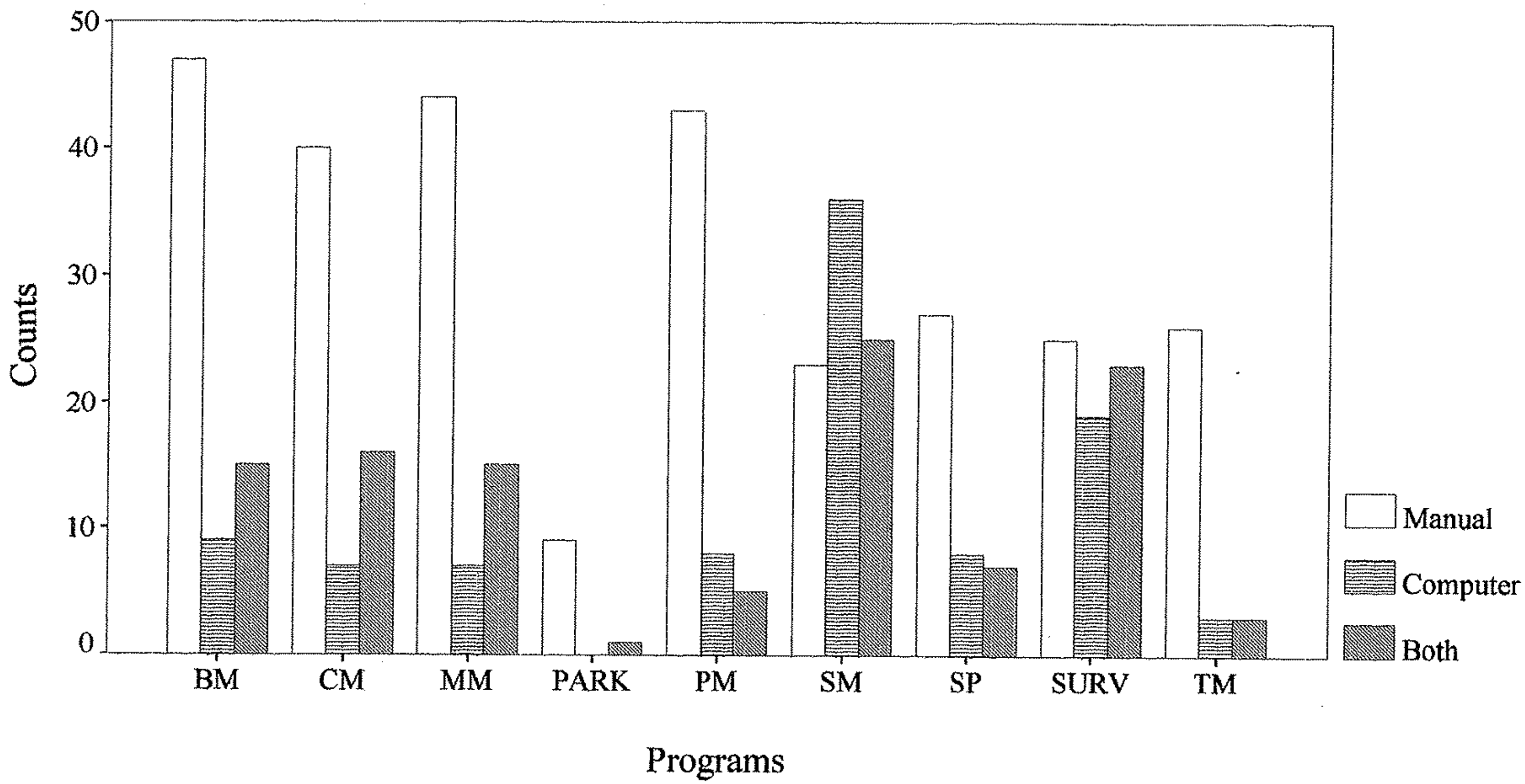
TM: Traffic Management

Figure 5: Office Data Manipulation Method for the Counties



LEGEND

BM: Bridge Management
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PARK: Parking Management
PM: Pavement Management

SM: Sign Management
SP: Safety Program
SURV: Surveying
TM: Traffic Management

3.2.1.2 Influence of Population Size on Data Collection, Transmission, and Office Manipulation

A statistical analysis shows that an inclination to use computers rather than manual means in the field, for transmittal, and in the office is demonstrated by larger transportation agencies related to data collection, transmission, and office manipulation. Table 2 shows this trend for five of the nine management programs investigated in this study. The values in the table reflect the level of significance ($\alpha <$ .10) of population size being an indicator of computer usage. As population size increases for cities, the use of computers to store data in the office increases for sign, bridge, parking, maintenance, and surveying management. Greater usage of computers for field data collection was experienced as population increased for parking management and surveying. As county size increased, the use of computers to store data in the office increased for sign and bridge management. This trend may reflect the need for larger transportation agencies to find more efficient ways to manage the larger amounts of data with proportionally few in-house resources available.

3.2.2 Hardware and Software Currently Being Used

3.2.2.1 General Trends

General trends show that few Iowa transportation agencies use computers in the field (e.g., hand-held, laptops, or pen-based computers), but several agencies do use computers in the office. Table 3 shows that cities and counties have on average about 4.8 and 3.5 computers in the office per all agencies, respectively. PCs appear to be the dominant type of computer hardware for the state as well; however, some agencies use mainframe computers. Cities and counties have on average approximately 0.5 and 0.2 computers for use in field data collection, respectively. Survey stations were the most common field hardware used by both the cities and counties. Table 3 also shows the diversity of hardware usage including hand-held, laptop, Macintosh, and mainframe computers.

Iowa transportation agencies use a variety of software packages from in-house to off-the-shelf. Appendix E provides a listing of the different types of software for each program used in the field and in the office. This appendix also shows how many agencies use each software variety. Notice that many of the transportation agencies develop their own software using both spreadsheets (e.g., Lotus 123 and Excel) and database packages (e.g., DBASE, Paradox, and RBASE). Many also use vendor-developed software packages as well.

3.2.2.2 Population Size Influence on Hardware Used

A statistical analysis was performed to determine the relationship between city and county size (measured in terms of population and area) and the quantity of hardware used by transportation agencies. It was found that the quantity of hardware increased as the population and area increased. This finding was significant at an $\alpha < 10\%$.

Table 2: Computer Usage versus Population Size[1]

		City Population	County Population
Sign Management	Field		
	Transmittal		
	Office	0.0018 (a)	0.0543
Bridge Management	Field	(b)	
	Transmittal		
	Office	0.0280	0.0708
Parking Management	Field	0.0002	
	Transmittal		
	Office	0.0217	
Surveying	Field	0.0071	
	Transmittal		
	Office	0.0030	
Maintenance Management	Field		
	Transmittal		
	Office	0.0003	

[1]Values in this table represent a statistical trend (significance level α of < .10) between population size and use of computers to collect data in the field, transmit data to the home office, and store data in the computer. For example, as city population increases, the use of computers to store data related to sign management increases (significance level of 0.0018--refer to a). No trends were identified in cells left blank (refer to b).

Table 3: Computer Hardware used by Cities, Counties, and State

Cities			Total No. of Surveys:	67
Field				
Type	Total No. of Units	No. of Agencies having Units	Avg. per Agency having Units	Avg. per Agency
HAND-HELD	5	1	5.0	0.07
LAPTOP	9	7	1.3	0.13
PC	2	2	1.0	0.03
SURVEY ST.	18	9	2.0	0.27
Total	34			0.51
Office				
Type	Total No. of Units	No. of Agencies having Units	Avg. per Agency having Units	Avg. per Agency
LAPTOP	3	2	1.5	0.04
MACINTOSH	28	5	5.6	0.42
MAINFRAME	12	12	1.0	0.18
PC	239	54	4.4	3.57
SURVEY ST.	12	4	3.0	0.18
TERMINAL	25	5	5.0	0.37
Total	319			4.76

Counties			Total No. of Surveys:	87
Field				
Type	Total No. of Units	No. of Agencies having Units	Avg. per Agency having Units	Avg. per Agency
LAPTOP	4	4	1.0	0.05
PC	4	2	2.0	0.05
SURVEY ST.	9	9	1.0	0.10
Total	17			0.20
Office				
Type	Total No. of Units	No. of Agencies having Units	Avg. per Agency having Units	Avg. per Agency
LAPTOP	3	3	1.0	0.03
MAINFRAME	22	22	1.0	0.25
PC	262	81	3.2	3.01
TERMINAL	20	7	2.9	0.23
Total	307			3.53

State	Total No. of Surveys: 1
Office	
Type	Total No. of Units
LAP-286	1
LAP-386	49
LAP-486	44
LAP-808X	3
MAINFRAME	1
PC-286	27
PC-386	222
PC-486	28
TERMINAL	54
Total	429

3.2.3 Interest Level in Using Advanced Field Data Collection Technologies

Several advanced field data acquisition technologies were investigated for possible application within the nine transportation programs being investigated in this study. The technologies considered include bar coding (BC), touch buttons (TB), radio frequency identification (RFID), video logging (VL), geographic information systems (GIS), global positioning systems (GPS), optical character recognition (OCR), advanced imaging (AI), hand-held computers (Hand), pen-based computers (Pen), laptops (Lap), radio frequency data communications (RFDC), and electronic data interchange (EDI). Notice that three additional technologies have been included that were not previously discussed in Chapter 2: hand-held computers, laptop computers, and advanced imaging. A brief description of these technologies can be found in Appendix D.

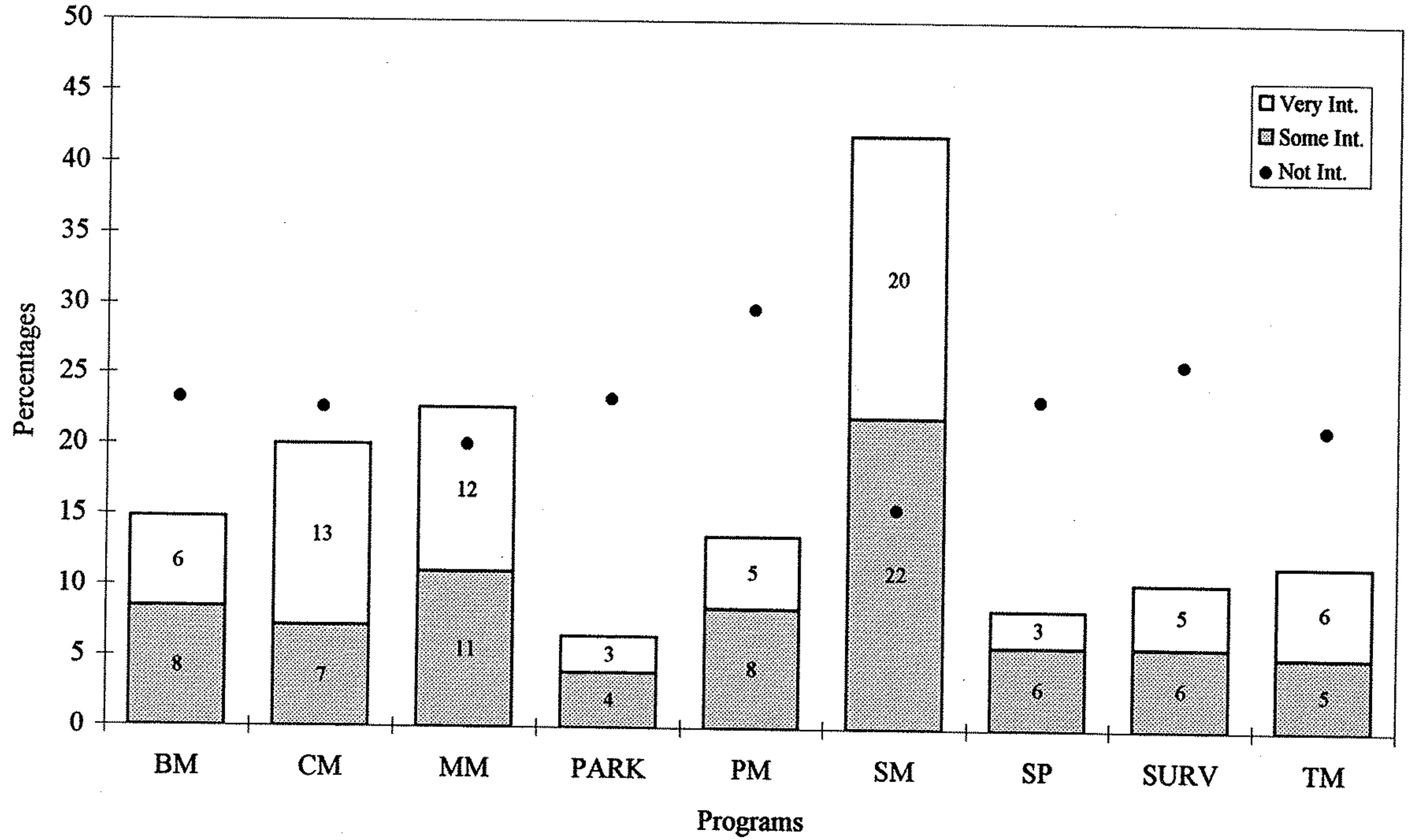
3.2.3.1 All Survey Respondents

Figure 6 shows the interest level in using bar coding for cities, counties and the state. The "dots" reflect the percentage of respondents *not interested* in the technology, the shaded bar reflects those who had *some interest*, and the white bar demonstrates those respondents who were *very interested*. Notice that bar coding held the highest interest for sign and maintenance management programs. Approximately forty-two percent of the respondents were either *very interested* or had *some interest* in using bar coding applications for sign management programs and 23 percent were interested in bar coding applications for maintenance management. It is interesting to note that a large percentage of the respondents did not have an opinion; for example, 69 percent (100 percent – 3 percent *very interested* – 4 percent *some interest* – 24 percent *not interested*) did not respond regarding to bar coding used for parking management. This may be due to the need for a better understanding of how bar coding might apply to enhancing field data collection for parking management or no interest.

Video logging held greater respondent interest compared to those who responded negatively for bridge, maintenance, pavement, sign, safety, and traffic management programs (Figure 7). Pavement and sign management were the two most popular areas (32 percent and 29 percent of the respondents interested, respectively). Bridge and maintenance management were two other areas where respondents expressed a desire to use video logging (26 percent and 27 percent, respectively). It should be noted that a small percentage of the respondents have already implemented a video logging system for pavement, safety, surveying, and traffic management programs.

The interest in using global positioning systems and geographic information systems within transportation agencies is shown in Figures 8 and 9. GPS attracted 38 percent of the survey respondents, while GIS was of most interest for surveying, with approximately 42 percent of the respondents reporting interest. GPS was of some interest for bridge, construction, maintenance, sign, and safety management programs; however, the level of interested respondents almost equaled the level of disinterested respondents. GIS appeared to have broad ranging appeal. Respondents felt that this technology has benefit for all but parking management programs. GPS is

Figure 6: Interest Level in using Bar Coding for Cities, Counties, and State



Total N° of Surveys: 155

LEGEND

BM: Bridge Management
CM: Construction Management
MM: Maintenance Management
PARK: Parking Management
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SM: Sign Management
SP: Safety Program
SURV: Surveying
TM: Traffic Management

Figure 7: Interest Level in using Video Logging for Cities, Counties, and State

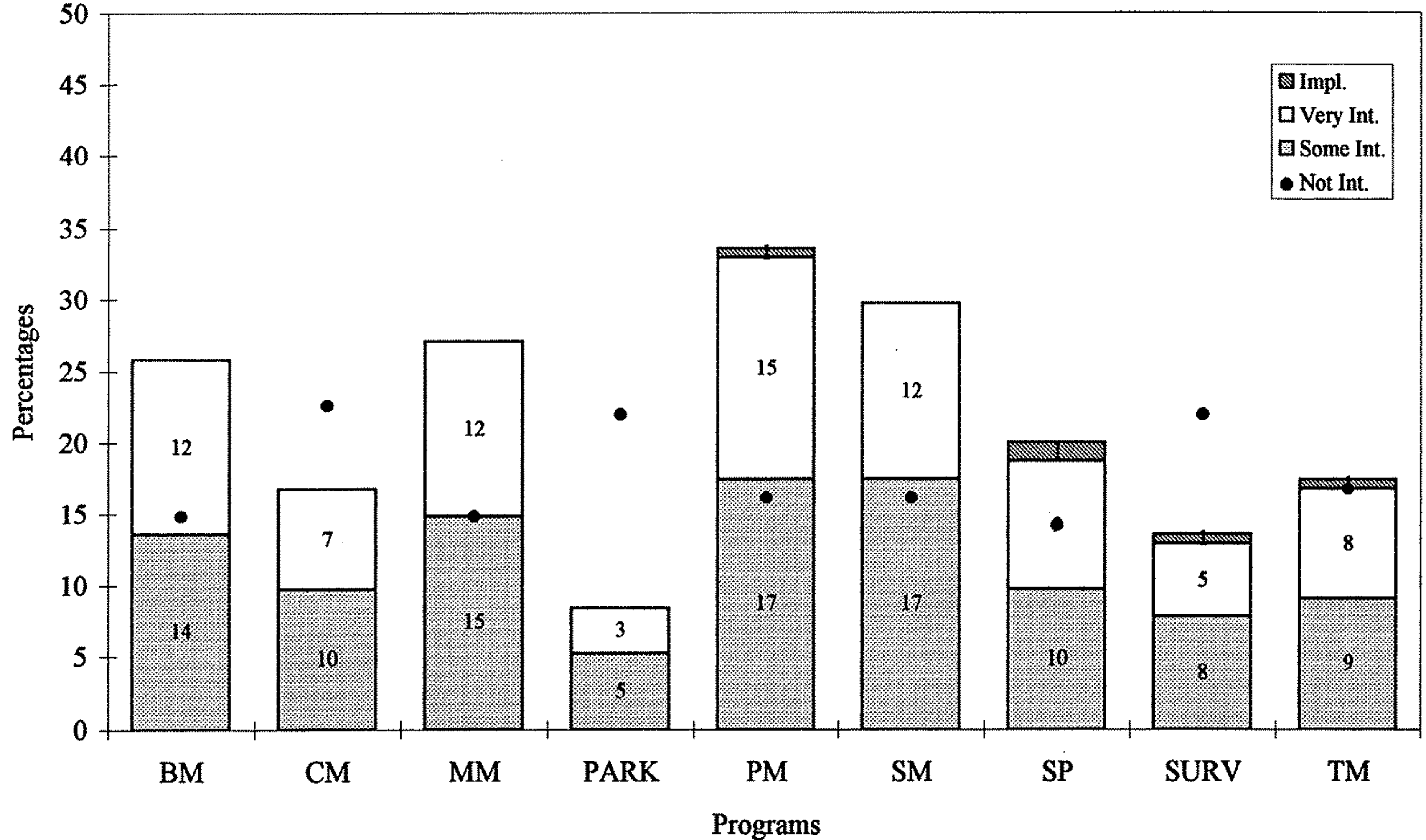

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Figure 8: Interest Level in using GPS for Cities, Counties, and State

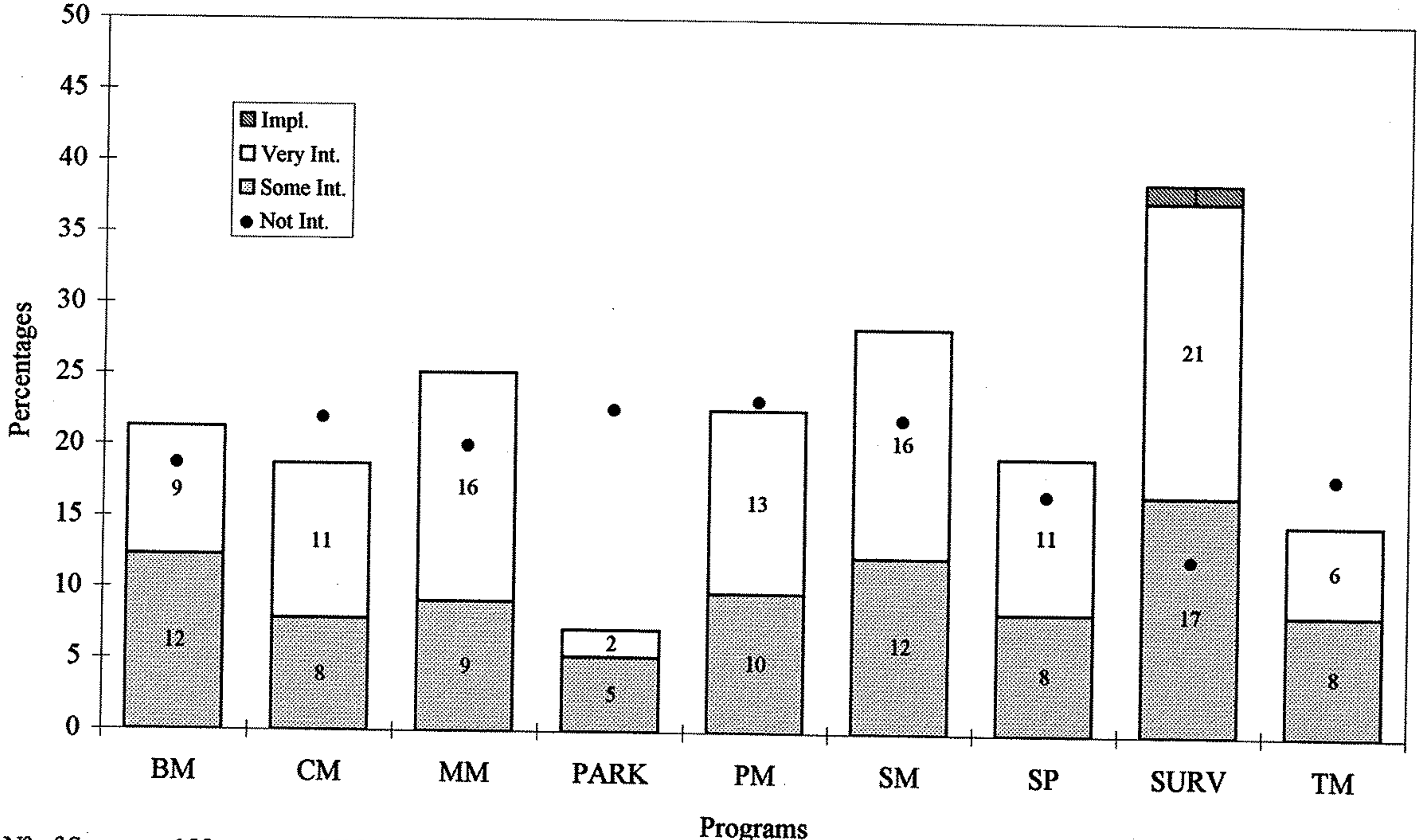

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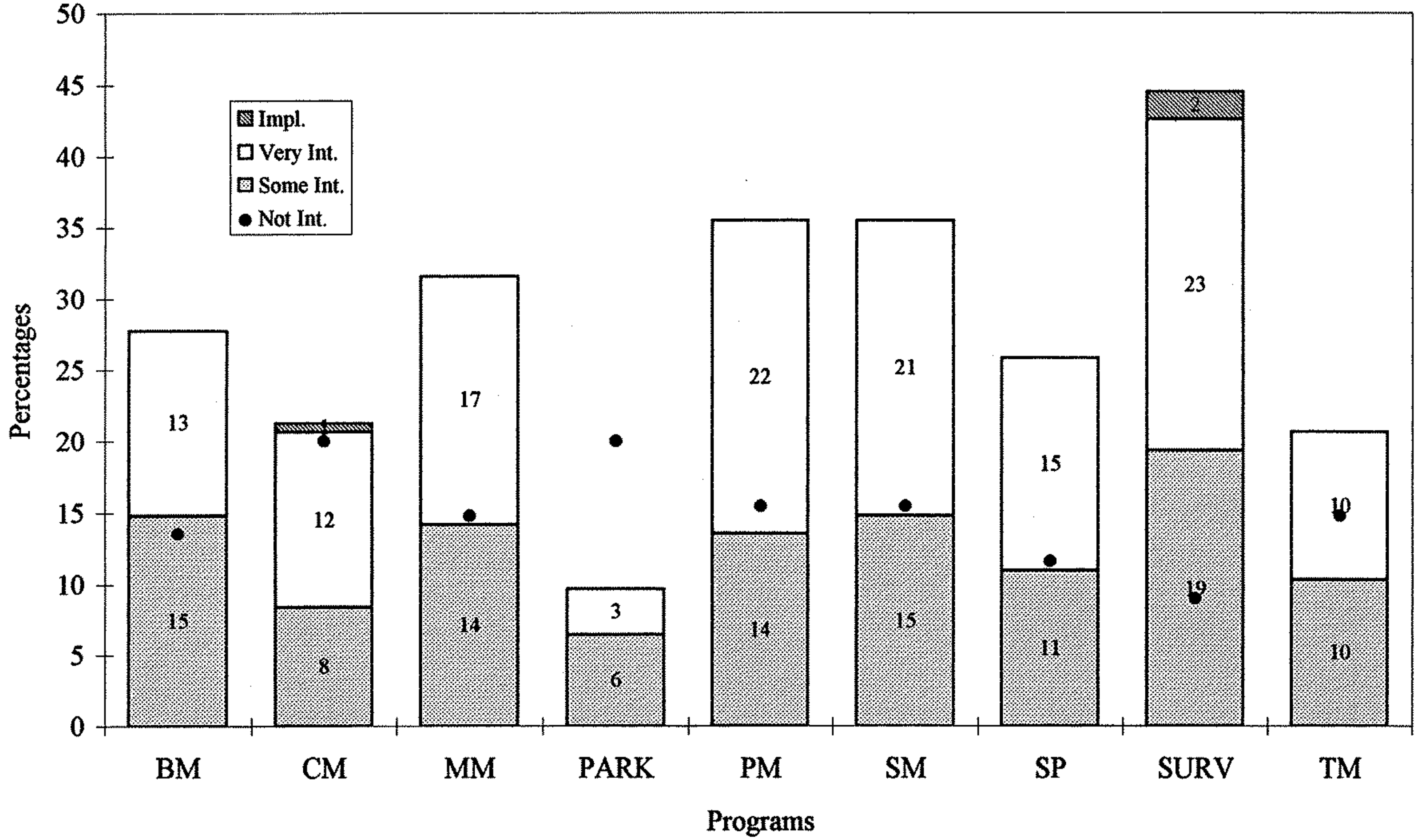
Figure 9: Interest Level in using GIS for Cities, Counties, and State



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currently implemented in surveying, and GIS is being used in both surveying and construction management programs.

The use of portable field computers such as pen-based, laptops, and hand-helds has appeal for the respondents. Many respondents appeared to be interested in using these devices (refer to Figures 10, 11, and 12). It appears from these figures that laptop and hand-held computers are slightly more popular than the pen-based computers. In fact, hand-held computers are already being implemented in surveying and laptops are being used for surveying and pavement management.

Several field data collection technologies appeared to be of less interest to the majority of respondents. Radio frequency identification, touch buttons, magnetic stripes, optical character recognition, voice recognition, advanced imaging, radio frequency data communications, and electronic data interchange held little interest for respondents. As Figures 13 through 20 demonstrate, the majority of replies show a lack of interest in implementing these technologies for management purposes. This disinterest could be due to a lack of understanding of the technologies or their applications. It is interesting to note that touch buttons have been implemented to assist with surveying and that magnetic stripes are being used for parking management. Electronic data interchange is being used by a limited number of respondents for enhancing maintenance, pavement, and surveying programs.

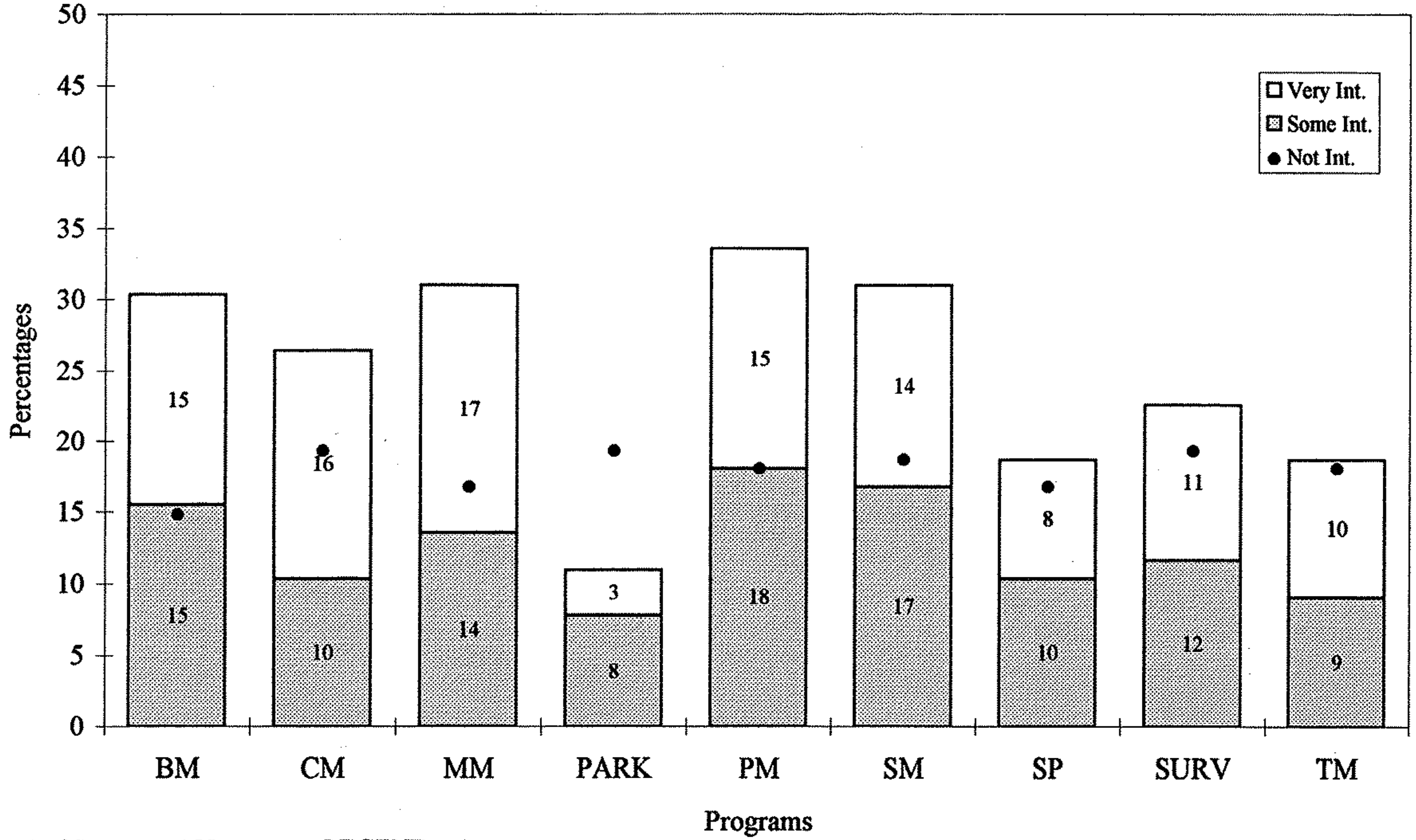
3.2.3.2 Technologies of Interest by Cities, Counties, and State

In order to better understand the interest level of the various technologies for each program, a rating system has been developed showing both the percentage positive responses as well as the ratio of interested to uninterested respondents. Table 4 shows programs and technologies for "all locations," "cities," and "counties." Positive responses greater than 30 percent and interest ratios greater than or equal to 1 were considered likely candidates for an application development.

In general, the survey data show a strong interest in using portable computers for data collection in a variety of management programs. Respondents are most interested in using laptop computers followed by hand-held computers and then pen-based computers. Counties were especially interested in using laptops for sign, bridge, maintenance, pavement, construction, and surveying, and safety management programs. Pen-based computers were of interest for sign, bridge, pavement, and maintenance management programs. Cities were interested in laptop computers for pavement, sign, and traffic management; hand-held computers for pavement, surveying, maintenance, and sign management programs; and pen-based computers for pavement management.

It is interesting to note that both cities and counties have an interest in enhancing data collection procedures for sign management. In general, cities are interested in the use of bar codes with a 43.3 percent positive response rate and 2.6:1 interest ratio.

Figure 10: Interest Level in using Pen-based Computers for Cities, Counties, and State



Total Nº of Surveys: 155

LEGEND

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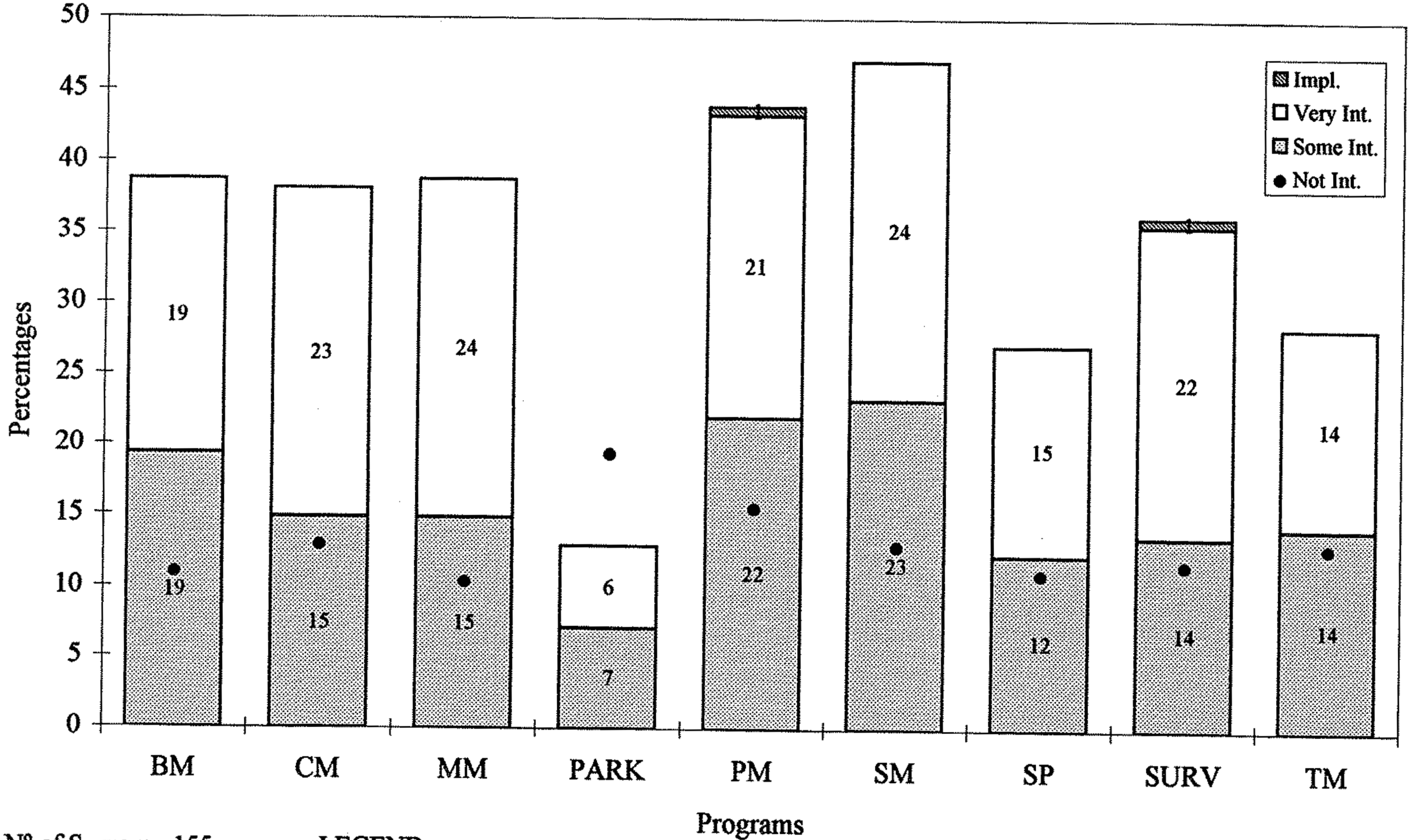
Figure 11: Interest Level in using Laptop Computers for Cities, Counties, and State



Total N° of Surveys: 155

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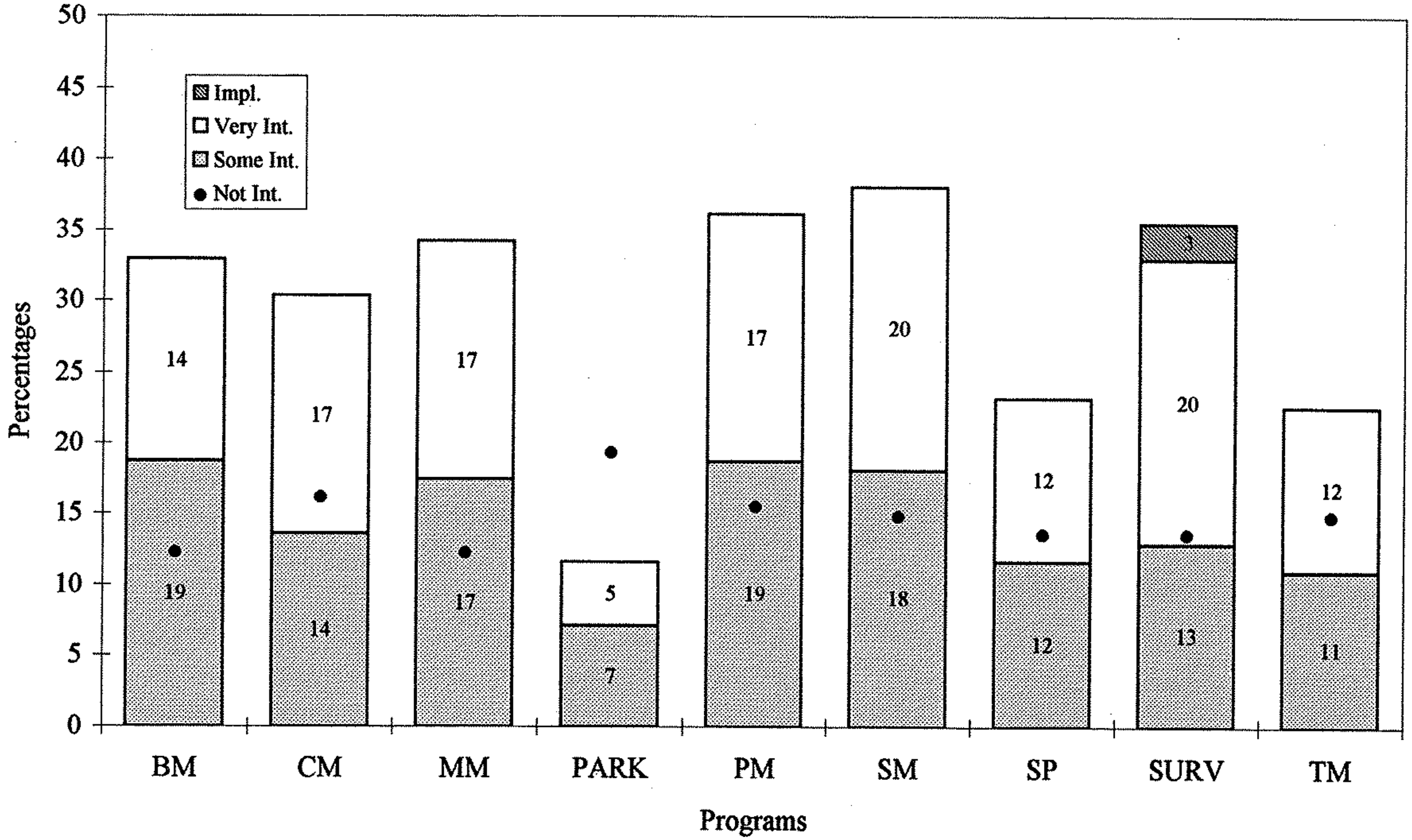
Figure 12: Interest Level in using Hand-Held Computers for Cities, Counties, and State



Total N° of Surveys: 155

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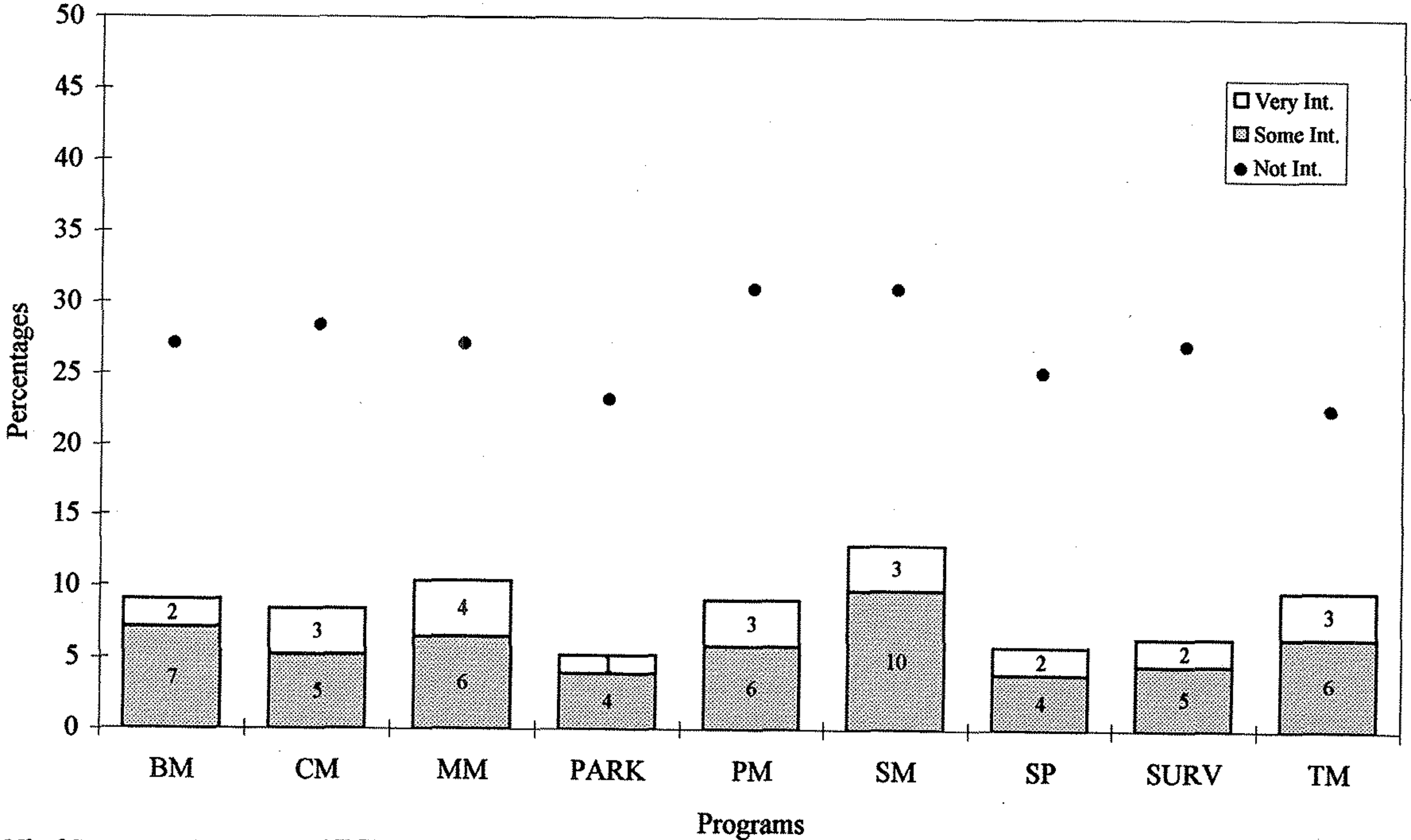
Figure 13: Interest Level in using Radio Frequency Identification for Cities, Counties, and State



Total N° of Surveys: 155

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Figure 14: Interest Level in using Touch Buttons for Cities, Counties, and State

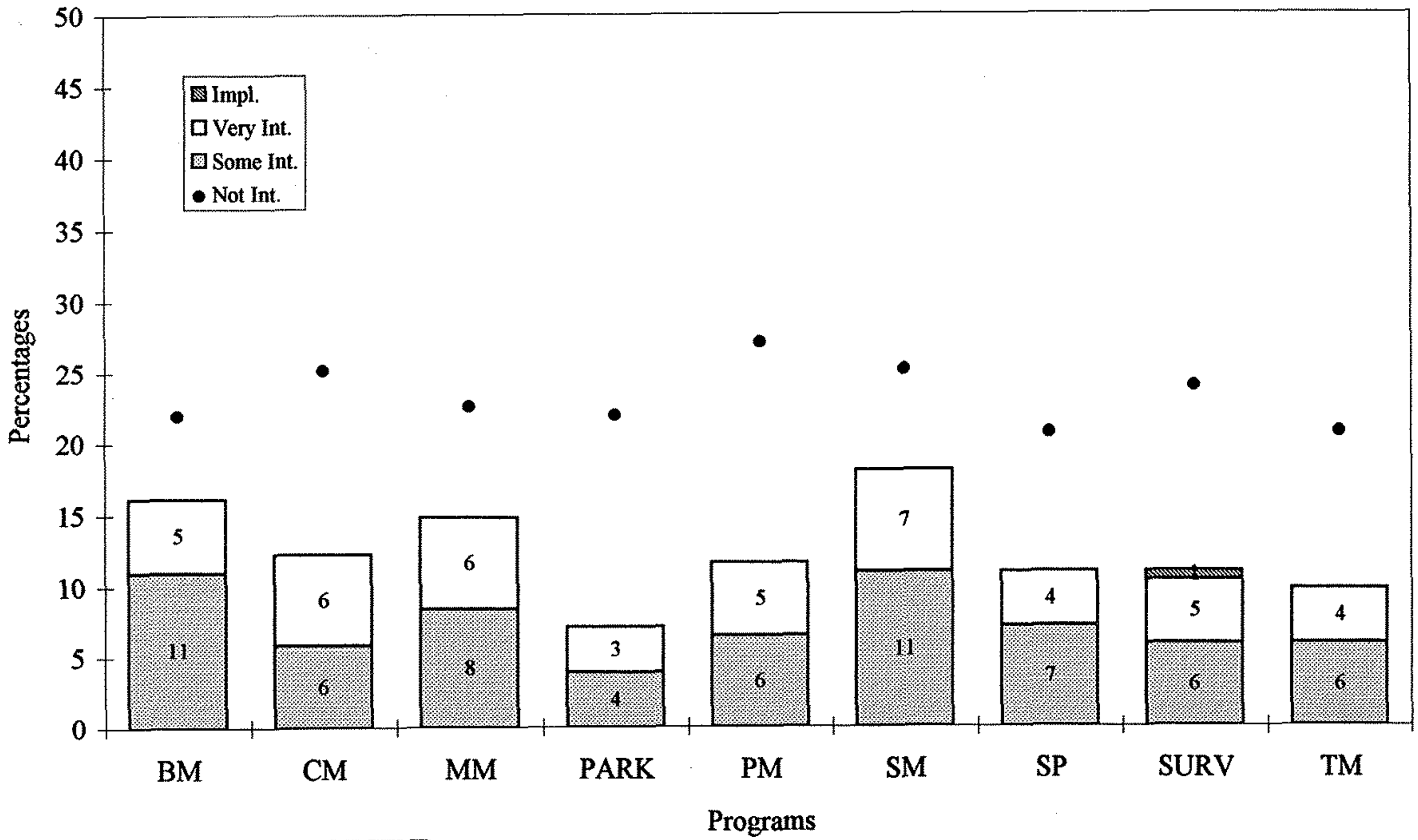

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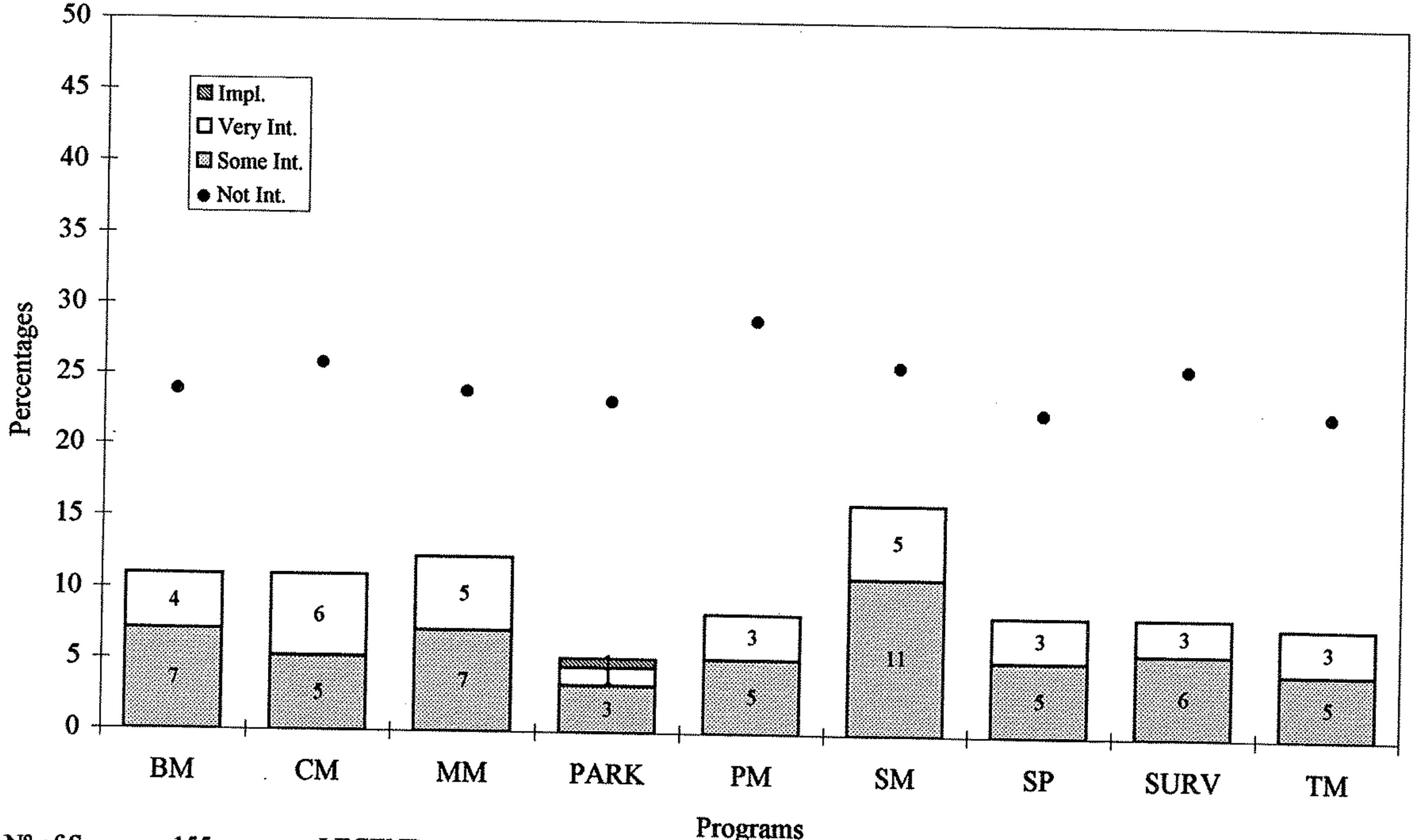
Figure 15: Interest Level in using Magnetic Stripes for Cities, Counties, and State



Total N° of Surveys: 155

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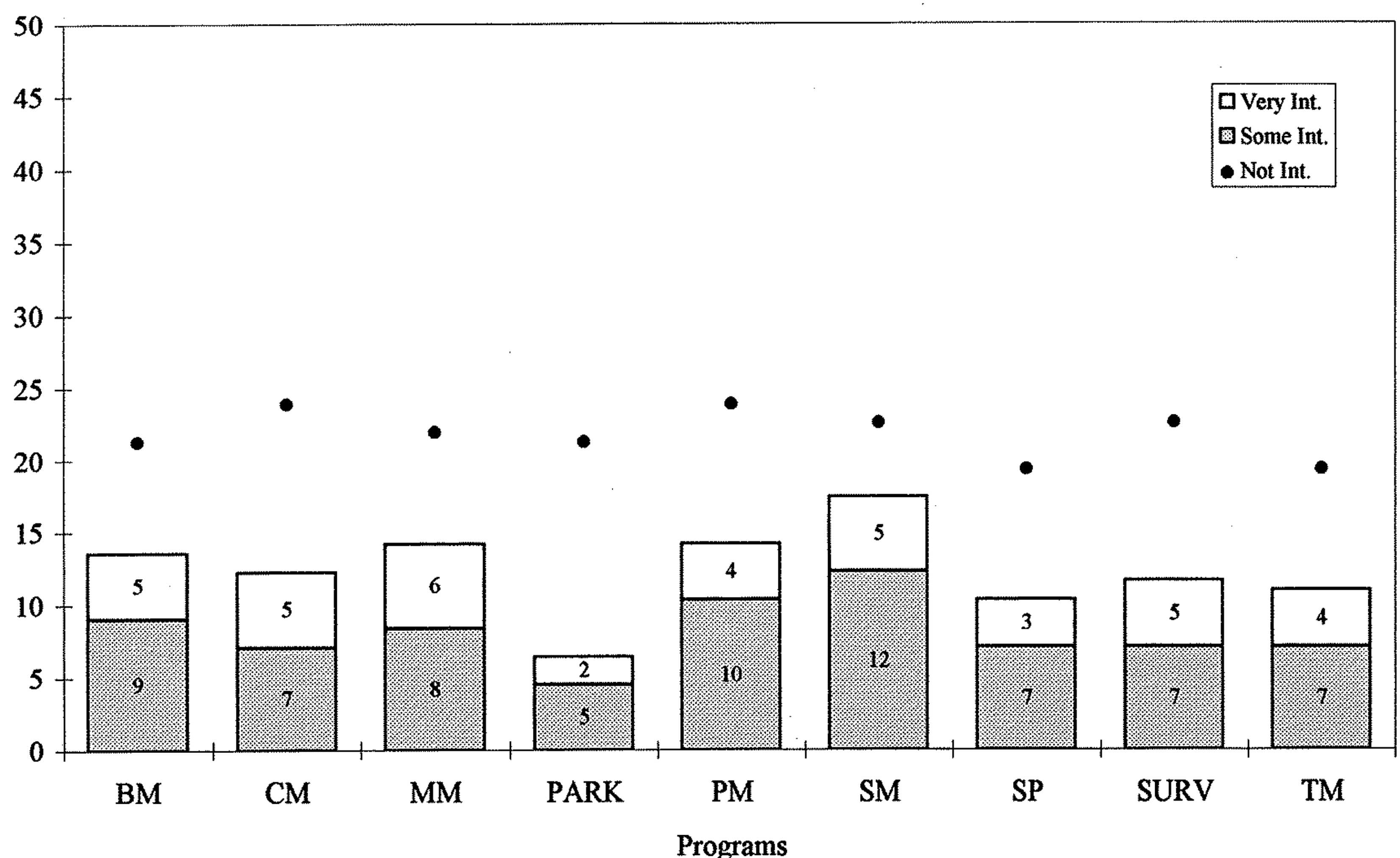
PM: Pavement Management

SM: Sign Management
SP: Safety Program
SURV: Surveying
TM: Traffic Management

Figure 16: Interest Level in using Optical Character Recognition for Cities, Counties, and State



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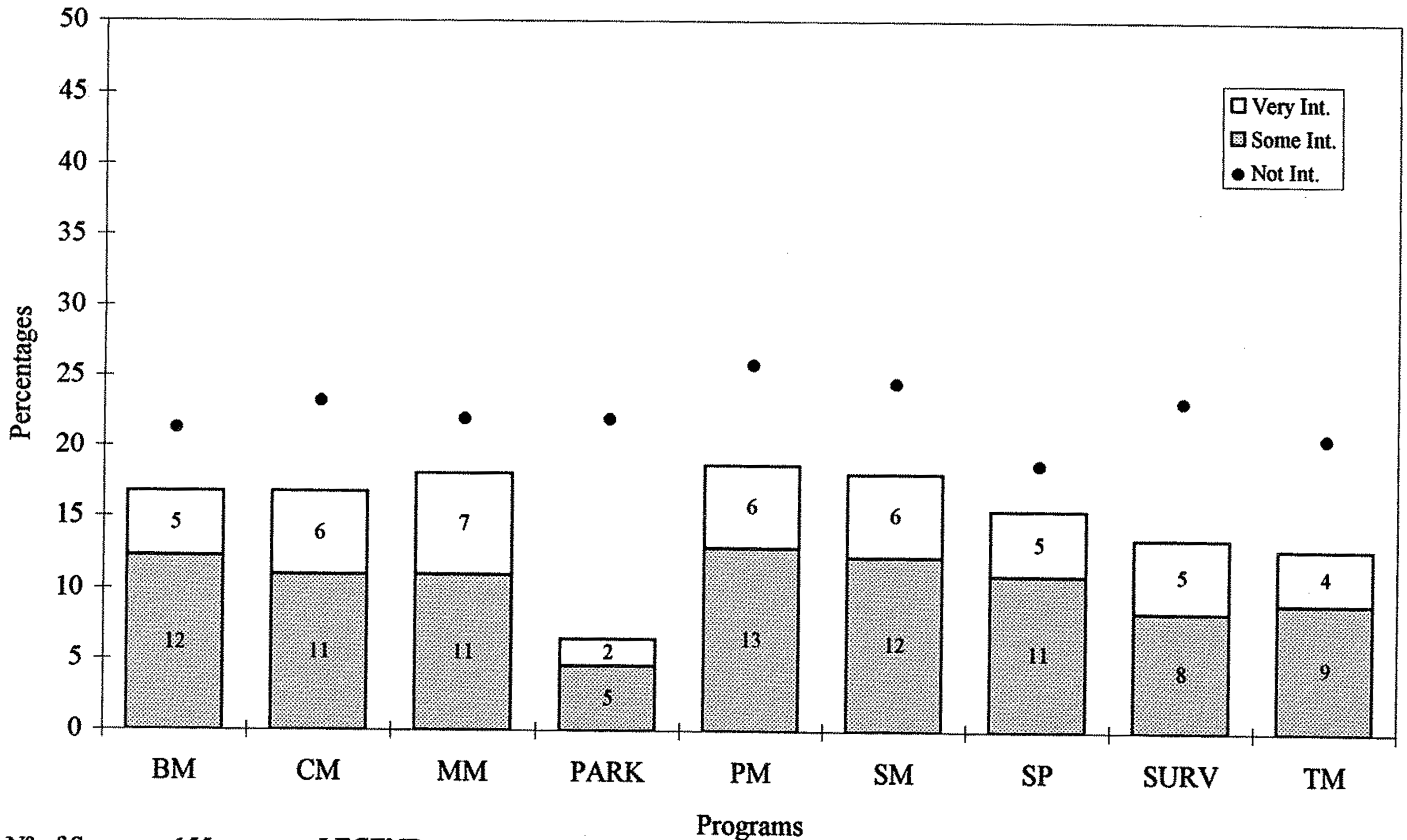
PM: Pavement Management

SM: Sign Management
SP: Safety Program
SURV: Surveying
TM: Traffic Management

Figure 17: Interest Level in using Voice Recognition for Cities, Counties, and State

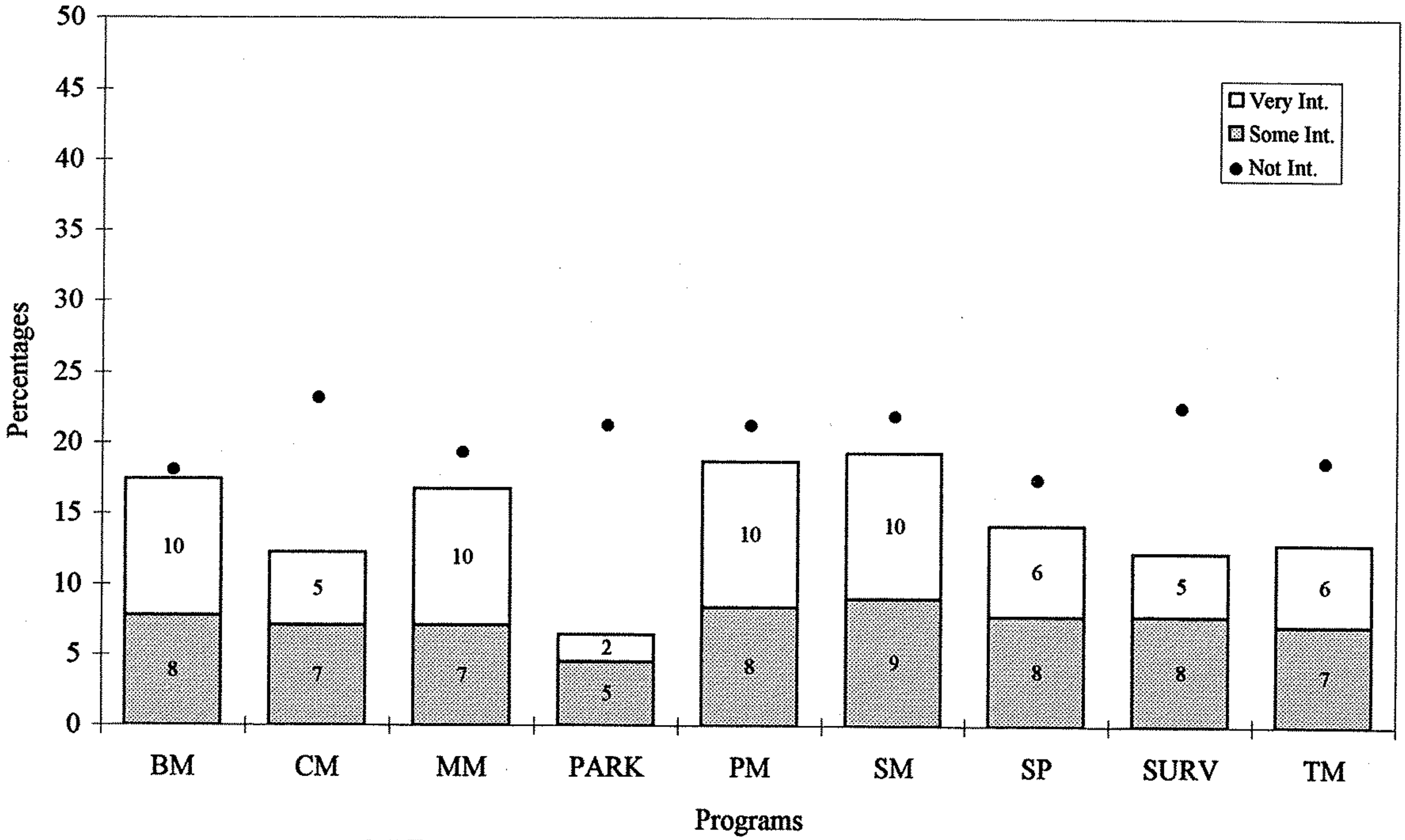


Total N° of Surveys: 155

LEGEND

BM: Bridge Management
CM: Construction Management
MM: Maintenance Management
PARK: Parking Management
PM: Pavement Management
SM: Sign Management
SP: Safety Program
SURV: Surveying
TM: Traffic Management

Figure 18: Interest Level in using Advanced Imaging for Cities, Counties, and State

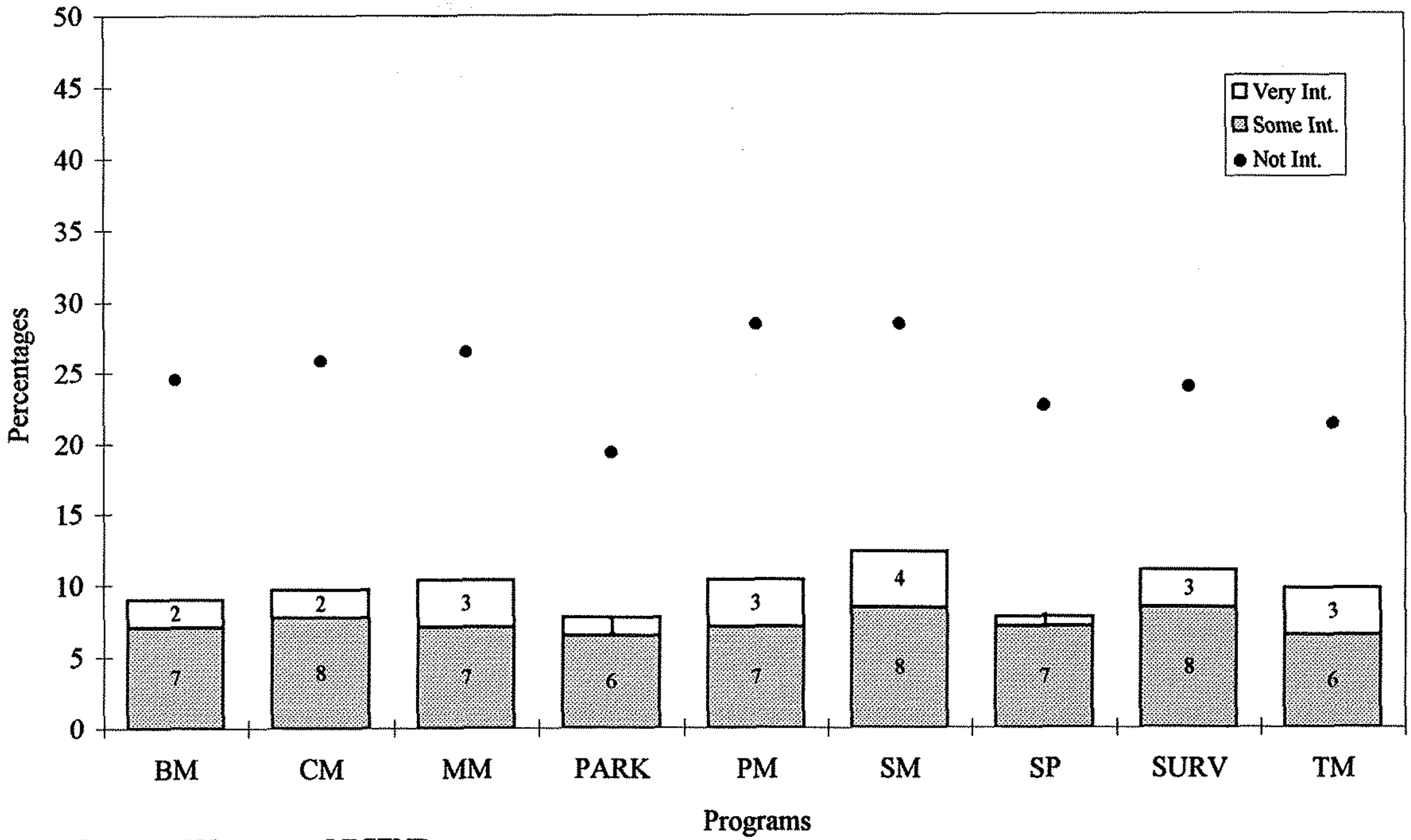


Total N° of Surveys: 155

LEGEND

BM: Bridge Management
CM: Construction Management
MM: Maintenance Management
PARK: Parking Management
PM: Pavement Management
SM: Sign Management
SP: Safety Program
SURV: Surveying
TM: Traffic Management

Figure 19: Interest Level in using Radio Frequency Data Communications for Cities, Counties, and State

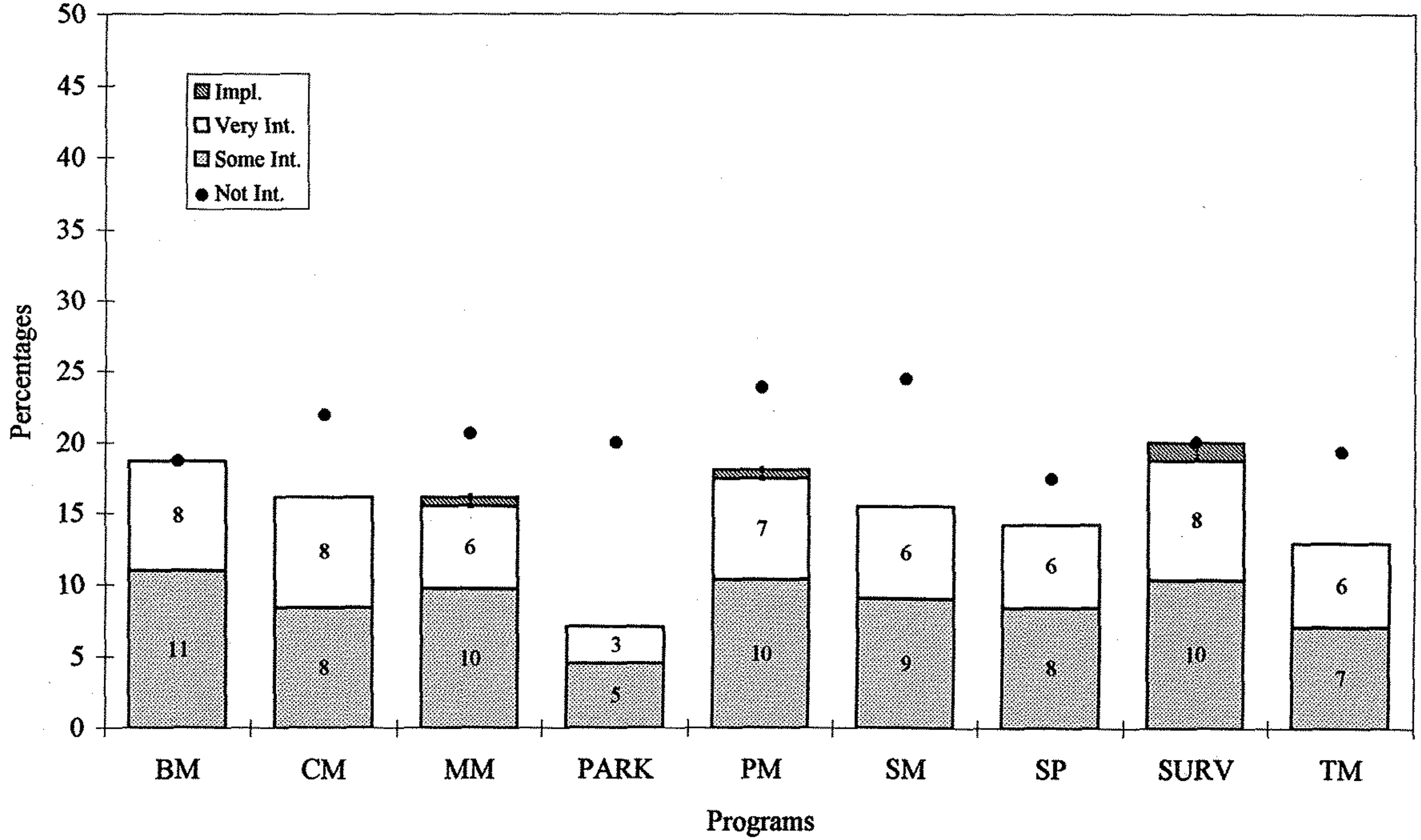


Total N° of Surveys: 155

LEGEND

BM: Bridge Management
CM: Construction Management
MM: Maintenance Management
PARK: Parking Management
PM: Pavement Management
SM: Sign Management
SP: Safety Program
SURV: Surveying
TM: Traffic Management

Figure 20: Interest Level in using Electronic Data Interchange for Cities, Counties, and State



Total N° of Surveys: 155

LEGEND

BM: Bridge Management
CM: Construction Management
MM: Maintenance Management
PARK: Parking Management
PM: Pavement Management
SM: Sign Management
SP: Safety Program
SURV: Surveying
TM: Traffic Management

Table 4: Ranking of Technologies by Program

Sorted by % Pos.

Cities, Counties, and State									n =	155
Program	Tech.	Not Int.	Some Int.	Very Int.	Impl.	Total	% Non Resp.	% Pos.	% Neg.	Int./Not Int.
SM	LAP	20	36	37		93	40.0	47.1	12.9	3.7
SURV	GIS	14	30	36	3	83	46.5	44.5	9.0	4.9
PM	LAP	24	34	33	1	92	40.6	43.9	15.5	2.8
SM	BC	24	34	31		89	42.6	41.9	15.5	2.7
SURV	GPS	19	26	32	2	79	49.0	38.7	12.3	3.2
BM	LAP	17	30	30		77	50.3	38.7	11.0	3.5
MM	LAP	16	23	37		76	51.0	38.7	10.3	3.8
CM	LAP	20	23	36		79	49.0	38.1	12.9	3.0
SM	HAND	23	28	31		82	47.1	38.1	14.8	2.6
SURV	LAP	18	21	34	1	74	52.3	36.1	11.6	3.1
PM	HAND	24	29	27		80	48.4	36.1	15.5	2.3
PM	GIS	24	21	34		79	49.0	35.5	15.5	2.3
SM	GIS	24	23	32		79	49.0	35.5	15.5	2.3
SURV	HAND	21	20	31	4	76	51.0	35.5	13.5	2.6
MM	HAND	19	27	26		72	53.5	34.2	12.3	2.8
PM	VL	25	27	24	1	77	50.3	33.5	16.1	2.1
PM	PEN	28	28	24		80	48.4	33.5	18.1	1.9
BM	HAND	19	29	22		70	54.8	32.9	12.3	2.7
MM	GIS	23	22	27		72	53.5	31.6	14.8	2.1
MM	PEN	26	21	27		74	52.3	31.0	16.8	1.8
SM	PEN	29	26	22		77	50.3	31.0	18.7	1.7
BM	PEN	23	24	23		70	54.8	30.3	14.8	2.0
CM	HAND	25	21	26		72	53.5	30.3	16.1	1.9

Cities									n =	67
Program	Tech.	Not Int.	Some Int.	Very Int.	Impl.	Total	% Non Resp.	% Pos.	% Neg.	Int./Not Int.
SM	BC	11	10	19		40	40.3	43.3	16.4	2.6
PM	LAP	12	15	11	1	39	41.8	40.3	17.9	2.3
SURV	GIS	8	9	16	1	34	49.3	38.8	11.9	3.3
PM	GIS	10	7	18		35	47.8	37.3	14.9	2.5
PM	HAND	11	13	11		35	47.8	35.8	16.4	2.2
SURV	HAND	10	9	13	2	34	49.3	35.8	14.9	2.4
PM	PEN	12	12	10		34	49.3	32.8	17.9	1.8
MM	HAND	8	12	10		30	55.2	32.8	11.9	2.8
PM	VL	12	10	11		33	50.7	31.3	17.9	1.8
SM	LAP	13	10	11		34	49.3	31.3	19.4	1.6
TM	LAP	7	10	11		28	58.2	31.3	10.4	3.0
SM	HAND	12	9	12		33	50.7	31.3	17.9	1.8

Formulas:

Total = Not Int. + Some Int. + Very Int. + Impl.
% Non Resp. = (n-Total)/n
% Pos. = (Some Int. + Very Int. + Impl.)/n
% Neg. = Not Int./n
Int./Not Int. = % Pos/% Neg.

Table 4: Cont.

Sorted by % Pos.

Counties									n =	87
Program	Tech.	Not Int.	Some Int.	Very Int.	Impl.	Total	% Non Resp.	% Pos.	% Neg.	Int./Not Int.
SM	LAP	7	26	25		58	33.3	58.6	8.0	7.3
BM	LAP	9	22	23		54	37.9	51.7	10.3	5.0
SURV	GIS	6	21	20	1	48	44.8	48.3	6.9	7.0
SURV	GPS	8	19	21	1	49	43.7	47.1	9.2	5.1
MM	LAP	7	15	26		48	44.8	47.1	8.0	5.9
PM	LAP	12	19	22		53	39.1	47.1	13.8	3.4
CM	LAP	10	15	25		50	42.5	46.0	11.5	4.0
SM	HAND	11	18	19		48	44.8	42.5	12.6	3.4
SM	GIS	11	17	19		47	46.0	41.4	12.6	3.3
SM	BC	13	23	12		48	44.8	40.2	14.9	2.7
SURV	LAP	10	11	24		45	48.3	40.2	11.5	3.5
BM	HAND	11	20	15		46	47.1	40.2	12.6	3.2
SM	PEN	15	17	15		47	46.0	36.8	17.2	2.1
PM	HAND	13	16	16		45	48.3	36.8	14.9	2.5
BM	PEN	15	16	15		46	47.1	35.6	17.2	2.1
PM	VL	13	17	13		43	50.6	34.5	14.9	2.3
MM	GIS	14	16	14		44	49.4	34.5	16.1	2.1
PM	PEN	16	16	14		46	47.1	34.5	18.4	1.9
MM	HAND	11	15	15		41	52.9	34.5	12.6	2.7
SURV	HAND	11	11	18	1	41	52.9	34.5	12.6	2.7
BM	VL	14	16	13		43	50.6	33.3	16.1	2.1
MM	VL	12	18	11		41	52.9	33.3	13.8	2.4
PM	GIS	14	14	15		43	50.6	33.3	16.1	2.1
SM	VL	14	17	11		42	51.7	32.2	16.1	2.0
BM	GIS	13	15	13		41	52.9	32.2	14.9	2.2
SP	LAP	8	12	16		36	58.6	32.2	9.2	3.5
SM	GPS	19	11	16		46	47.1	31.0	21.8	1.4
MM	PEN	16	12	15		43	50.6	31.0	18.4	1.7

Counties also have an interest in using bar codes with sign management (40.2 percent positive response rate and 2.7:1 interest ratio).

Additionally, larger cities appear to be more interested in the use of bar coding for sign management as compared to the smaller cities. Larger cities (those with a population greater than the median of 9,270) had an interest ratio of 9 to 1 compared to 1.2 to 1 for the smaller cities (refer to Table 5).

Results also show an interest in using a variety of other technologies for different programs. Cities were interested in using GIS software for surveying and pavement management, video logging for pavement management, and different types of portable computers for pavement, maintenance, sign, surveying, and traffic management programs. Counties were interested in GPS for surveying and sign management. GIS for surveying, sign, maintenance, pavement, and bridge management; and bar coding for sign management, video logging for pavement, bridge, maintenance, and sign management.

The state respondents were interested in a variety of technologies for the different programs. Several technologies were of interest for enhancing data management procedures for each program as follows:

Construction Management: bar coding, touch buttons, voice recognition, optical character recognition, advanced imaging, GIS, GPS, EDI, pen-based, laptop, and hand-held computers.

Safety Programs: EDI, GIS, GPS, video logging, advanced imaging, optical character recognition, voice recognition, touch buttons, magnetic stripes, bar codes, laptop computers, and pen-based computers.

Surveying: RFID, bar codes, touch buttons, magnetic stripes, optical character recognition, voice recognition, video logging, advanced imaging, GPS, GIS, RFDC, EDI, pen-based computers, laptop computers, and hand-held computers.

Maintenance Management: EDI, GIS, GPS, video logging, advanced imaging, voice recognition, touch buttons, bar codes, RFID, pen-based computers, laptop computers, and hand-held computers.

Pavement Management: bar codes, RFID, video logging, GIS, GPS, and EDI.

Sign Management: GPS, video logging, voice recognition, magnetic stripes, bar codes, RFID, pen-based computers, and hand-held computers.

Traffic Management: RFID, touch buttons; advanced imaging, GIS, GPS, EDI, pen-based computers, and laptop computers.

Table 5: Ranking of Technologies by Program for Cities

Sorted by % Pos.

Cities with population <= Median (9270)									n =	34
Program	Tech.	Not Int.	Some Int.	Very Int.	Impl.	Total	% Non Resp.	% Pos.	% Neg.	Int./Not Int.
SURV	GIS	5	6	6		17	50.0	35.3	14.7	2.4
PM	HAND	8	9	3		20	41.2	35.3	23.5	1.5
SM	BC	9	4	7		20	41.2	32.4	26.5	1.2
PM	GIS	6	7	4		17	50.0	32.4	17.6	1.8
MM	HAND	7	8	3		18	47.1	32.4	20.6	1.6

Cities with population > Median (9270)									n =	33
Program	Tech.	Not Int.	Some Int.	Very Int.	Impl.	Total	% Non Resp.	% Pos.	% Neg.	Int./Not Int.
SM	BC	2	6	12		20	39.4	54.5	6.1	9.0
PM	LAP	3	8	8	1	20	39.4	51.5	9.1	5.7
PM	GIS	4		14		18	45.5	42.4	12.1	3.5
SURV	GIS	3	3	10	1	17	48.5	42.4	9.1	4.7
SM	LAP	3	6	8		17	48.5	42.4	9.1	4.7
SURV	HAND	4	3	9	2	18	45.5	42.4	12.1	3.5
PM	PEN	3	5	8		16	51.5	39.4	9.1	4.3
TM	LAP	1	4	9		14	57.6	39.4	3.0	13.0
SURV	GPS	4	3	9		16	51.5	36.4	12.1	3.0
MM	PEN	2	3	9		14	57.6	36.4	6.1	6.0
CM	HAND	2	4	8		14	57.6	36.4	6.1	6.0
PM	HAND	3	4	8		15	54.5	36.4	9.1	4.0
SM	HAND	3	3	9		15	54.5	36.4	9.1	4.0
PM	VL	4	3	8		15	54.5	33.3	12.1	2.8
SM	GPS	5	5	6		16	51.5	33.3	15.2	2.2
CM	GIS	3	1	9	1	14	57.6	33.3	9.1	3.7
TM	PEN	2	3	8		13	60.6	33.3	6.1	5.5
CM	LAP	2	4	7		13	60.6	33.3	6.1	5.5
MM	HAND	1	4	7		12	63.6	33.3	3.0	11.0
TM	HAND	2	3	8		13	60.6	33.3	6.1	5.5
MM	GIS	3		10		13	60.6	30.3	9.1	3.3
SM	GIS	4		10		14	57.6	30.3	12.1	2.5
BM	PEN	2	4	6		12	63.6	30.3	6.1	5.0
CM	PEN	3	2	8		13	60.6	30.3	9.1	3.3
BM	LAP	2	5	5		12	63.6	30.3	6.1	5.0
MM	LAP	1	3	7		11	66.7	30.3	3.0	10.0
SURV	LAP	2	3	7		12	63.6	30.3	6.1	5.0
BM	HAND	2	5	5		12	63.6	30.3	6.1	5.0

Formulas:

Total = Not Int. + Some Int. + Very Int. + Impl.
% Non Resp. = (n - Total)/n
% Pos. = (Some Int. + Very Int. + Impl.)/n
% Neg. = Not Int./n
Int./Not Int. = % Pos/% Neg.

3.2.3.3 Influence of Population Size on Interest Levels for Cities and Counties

Population size appeared to have an impact on the interest level in using various technologies. The general trend showed that as population size increased for cities and counties as did the interest level in using advanced field data collection techniques. Table 6 reveals these trends for each of the management programs by transportation agency and are summarized below. Each trend was significant at $\alpha < .10$.

<u>Cities</u>

Sign Management: bar coding, touch buttons, optical character recognition, voice recognition, video logging, advanced imaging, global positioning systems, geographic information systems, RFDC, electronic data interchange, pen-based computers, laptop computers, and hand-held computers.

Pavement Management: bar coding, RFID, touch buttons, OCR, advanced imaging, global positioning systems, geographic information systems, EDI, pen-based computers, laptop and hand-held computers.

Bridge Management: bar coding, video logging, advanced imaging, global positioning systems, electronic data interchange, pen-based computers, laptop computers, and hand-held computers.

Traffic Management: bar coding, radio frequency identification, touch buttons, magnetic stripes, optical character recognition, voice recognition, video logging, advanced imaging, global positioning systems, RFDC, electronic data interchange, pen-based computes, laptop computers, and hand-held computers.

Parking Management: touch buttons and magnetic stripes.

Surveying: touch buttons, global positioning systems, electronic data interchange, pen-based computers, and laptop computers.

Safety Programs: no trends were identified.

Maintenance Management: bar coding, radio frequency identification, touch buttons, magnetic stripes, OCR, voice recognition, video logging, advanced imaging, global positioning systems, geographic information systems, RFDC, EDI, pen-based computes, laptop computers, and hand-held computers.

Construction Management: bar coding, radio frequency identification, touch buttons, magnetic stripes, OCR, voice recognition, video logging, advanced imaging, global positioning systems, geographic information systems, RFDC, EDI, pen-based computes, laptop computers, and hand-held computers.

Table 6: Interest Level versus Population Size[1]

	Sign Management		Pavement Management		Bridge Management	
	City Population	County Population	City Population	County Population	City Population	County Population
Bar Coding	0.0018 (a)	(b)	0.0373		0.0760	
Radio Frequency Identification			0.0418			
Touch Buttons	0.0002		0.0570			
Magnetic Stripes						
Optical Character Recognition	0.0141		0.0106	0.0759		
Voice Recognition	0.0062					
Video Logging	0.0011				0.0394	
Advanced Imaging	0.0009	0.0225	0.0233	0.0275	0.0538	0.0269
Global Positioning Systems	0.0003	0.0611	0.0183	0.0298	0.0365	
Geographic Information Systems	0.0022	0.0859	0.0260	0.0829		
Radio Frequency Data Communications	0.0266					
Electronic Data Interchange	0.0007		0.0386		0.0356	
Pen-Based Computers	0.0013		0.0965		0.0277	
Lap-Top Computers	0.0030		0.0048		0.0807	
Hand-Held Computers	0.0006		0.0078		0.0363	

[1] Values in this table represent a statistical trend (significance level [α] of < 0.1) between population size and interest level in using advanced field data collection technologies for a particular management program. For example, as city population increases the interest level in using bar coding for sign management increases (significance level of 0.0018 -- refer to a). No trends were identified in cells left blank (refer to b).

Table 6: Cont.

	Traffic Management		Parking Management		Surveying	
	City Population	County Population	City Population	County Population	City Population	County Area
Bar Coding	0.0095					0.0364
Radio Frequency Identification	0.0079	0.0326				
Touch Buttons	0.0231		0.0760		0.0162	0.0775
Magnetic Stripes	0.0726	0.0074	0.0476			
Optical Character Recognition	0.0095					0.0619
Voice Recognition	0.0033	0.0029				0.0131
Video Logging	0.0510	0.0506				
Advanced Imaging	0.0104	0.0060				
Global Positioning Systems	0.0043				0.0037	
Geographic Information Systems						
Radio Frequency Data Communications	0.0456					
Electronic Data Interchange	0.0096				0.0169	
Pen-Based Computers	0.0033	0.0549			0.0876	
Lap-Top Computers	0.0115				0.0550	0.0473
Hand-Held Computers	0.0012	0.0254				

Table 6: Cont.

	Safety Programs		Maintenance Management		Construction Management	
	City Population	County Population	City Population	County Population	City Population	County Population
Bar Coding			0.0183		0.0800	
Radio Frequency Identification			0.0031		0.0159	
Touch Buttons			0.0030		0.0159	
Magnetic Stripes			0.0449		0.0526	
Optical Character Recognition			0.0035		0.0220	
Voice Recognition			0.0056		0.0126	
Video Logging			0.0051		0.0262	
Advanced Imaging			0.0096	0.0532	0.0330	
Global Positioning Systems			0.0236	0.0413	0.0146	
Geographic Information Systems			0.0618	0.0477	0.0171	
Radio Frequency Data Communications			0.0041		0.0284	
Electronic Data Interchange			0.3270		0.0050	
Pen-Based Computers			0.0104		0.0499	
Lap-Top Computers			0.0155		0.0099	
Hand-Held Computers			0.0212		0.0191	

Counties

Sign Management: advanced imaging, global positioning systems, and geographic information systems.

Pavement Management: optical character recognition, advanced imaging, global positioning systems, and geographic information systems.

Bridge Management: advanced imaging.

Traffic Management: radio frequency identification, magnetic stripes, voice recognition, video logging, advanced imaging, pen-based computers, and hand-held computers.

Parking Management: no trends were identified.

Surveying[1]*:* bar coding, touch buttons, optical character recognition, voice recognition, and laptop computers.

Safety Programs: no trends were identified.

Maintenance Management: advanced imaging, global positioning systems, and geographic information systems.

Construction Management: no trends were identified.

3.2.3.4 Conference Versus Mail-Back Survey Respondents

Hypothesis tests were conducted to identify potential differences between the survey responses at an American Public Works Association Conference (APWA) during the Spring of 1994 held in Ames, Iowa and the mail-back responses. The principal investigator provided a conference audience, mostly consisting of city engineers and public works directors with a description of each technology, showed a video tape entitled "Field Demonstrations for Advanced Field Data Acquisition Technologies," and answered specific questions related to these technologies. After the presentation, a survey was distributed to everyone in the audience and 17 filled out the survey. This test was performed to see if there was a difference in interest level by respondents who were provided with a more detailed description of each technology compared to respondents who were provided a brief description on paper.

Results show that the conference did have an effect on the interest level. Conference respondents tended to rate several of the technologies higher compared to their mail-back survey counterparts. This was especially true for voice recognition, video logging, GPS, GIS, electronic data interchange, pen-based computers, laptop computers, and hand-held computers. Table 7 shows which technologies and programs were rated more favorably by the conference respondents. An "X" has been

[1]Based on county area

Table 7: APWA Conference versus Mail Back Responses

	Programs							
Technologies	Sign Management	Pavement Management	Bridge Management	Traffic Management	Surveying	Safety Programs	Maintenance Management	Construction Management
Bar Coding								
Radio Frequency Identification								
Touch Buttons								
Magnetic Stripes								
Optical Character Recognition								
Voice Recognition	X	X						X
Video Logging	X						X	
Advanced Imaging								
Global Positioning Systems								X
Geographic Information Systems								X
Radio Frequency Data Communications								
Electronic Data Interchange	X	X	X	X				X
Pen-Based Computers		X					X	X
Lap-Top Computers		X						
Hand-Held Computers							X	X

The "X's" represent areas where there was a statistical difference ($\alpha < .10$) between the interest level in survey responses from APWA conference attendees and mail back survey respondents regarding their desire to implement advanced field data collection technologies. Conference respondents were provided with approximately a one hour presentation on the technologies versus mail back survey respondents who were provided a brief written description of each technology as part of the survey.

placed in the table where there was a statistical difference between the mean responses ($\alpha < .10$).

Technologies that did not show a difference in interest level were bar coding, radio frequency identification, touch buttons, magnetic stripes, optical character recognition, advanced imaging, and radio frequency data communications. This means that the conference respondents felt similarly compared to the mail-back respondents on the use of these technologies.

It should be noted that these results are only for cities and do not include counties. It should also be noted that there were only 16 city surveys from the conference.

3.2.4 Survey Comments

Comments from the survey varied from respondents who were very interested to those who were not interested and did not have time to fill it out (refer to Appendix F). Some were also unsure of the type of equipment they would need. Some respondents stated that they did not know their needs at this time or were lacking in knowledge to complete the survey. Some respondents offered suggestion for beneficial applications that could be developed.

3.3 INTERVIEWS

As a follow up to the mail-back survey responses, interviews were conducted with several transportation agency representatives. The purpose of these interviews was three-fold: (1) describe technologies in more detail, (2) develop a better understanding of each agency's data management techniques, and (3) identify potential areas of improvement using some form of advanced data capture. In all, a total of thirteen interviews with nineteen interviewers were conducted with city, county, and state representatives (refer to Appendix G for list of interviewees). Most of the people interviewed had filled out the survey or had knowledge of its existence.

Several points came out of the interviews: (1) several agencies use their own unique paper forms to collect data indicating a lack of standardization, (2) office data entry was manually performed by different types of office support staff, (3) there is an overall interest in improving field data collection using appropriate technologies, and (4) resource constraints prohibited several agencies from adopting innovative technologies.

Almost all interview respondents use some type of paper form to collect data. In many cases, this was a preprinted form that the user was to fill out in the field and bring back to the office where someone would key in the data. Others used nothing more than a pad of paper to collect the data. Appendix H shows a sample of some of the forms used by the various transportation agencies. It was apparent that each transportation entity had their own form and that there was not a great deal of standardization. As an example, three different forms for sign management were collected on the interviews. Data collected in the field were typically hand carried to the office and keyed into the computer or stored in its original form on file for future reference.

Interviewees, in general, were interested in improving their field data collection efforts and sensed the benefits of computerized data entry at the source. Several of the technologies were of interest to them. For example, Michael Koch, public works director, City of Dubuque, had an interest in improving Dubuque's sign and pavement approach using laptops. GIS applications were of particular interest for mapping locations.

Jim Brachtel, traffic engineer for Iowa City, was interested in enhancing their current sign management approach which currently involves collecting data on a standard form on about 35,000 to 40,000 signs. His criteria for an improved sign management system were as follows: (1) mobile sign management systems (SMS); (2) link to distance device; (3) operate in the cab; and (4) use of a laptop computer. Jim was in favor of using pull-down menu options or other information gathering techniques that are simple and foolproof.

Rick Fosse, city engineer from Iowa City, had several concerns related to using field computers to collect data. One concern related to the learning curve effect whereby it will take workers time to learn the system and become productive (he cited an example of the two-year training curve to learn AutoCad and some of its add-ons for efficiently using the total work station). Rick said that he will wait for others to develop, implement, and debug the technologies before he will be willing to try them in his organization.

Furthermore, he preferred the idea of having an Iowa DOT team of inspectors come to Iowa City and provide an assortment of inspections using advanced field data collection technologies. This way the team is always up on the learning curve and each city will not need to purchase new hardware and software every 2 years (the duration of time between pavement inspections). The Iowa DOT would be a reputable organization that could be trusted to help develop and implement the guidelines.

Donald Pool, Van Buren County assistant to the engineer, said that most of the field data are collected manually in Van Buren County. Data collection technology they own consists of a 15-year-old total work station and the SMS program which they have not had a chance to use. Donald thought that using the paper forms is a hassle and that he would like to see a portable computer used. He also thought that $2,000 seemed excessive. It would be better if the portable computer could also be used for a variety of applications. Some of the particular areas of interest in using advanced information technologies related to bridge replacements, sign management, and pavement management. He thought that improving the sign management system would be most critical. Donald liked the concept of using bar code labels to track sign inventory from the time it is purchased until it has reached its useful like and is discarded. He favored the use of bar code labels on signs.

Bill Cox, Wapello County assistant engineer, was interested in improving his county's parts inventory system and was particularly interested in the use of bar codes. They have recently begun to consider using bar code labels on signs. Their new Sokkia survey equipment has been very beneficial as it now takes a half day for developing a design that usually took three days. Bill also liked the idea of using video logging to perform surveys. In general, Bill was interested in any technologies that will improve inventory management in the following order of interest: (1) parts, (2) yard inspection, and (3) signs. Bill also thought that introducing a reflectivity meter along with bar codes would be a good application to develop for sign management.

Robert Bailey, city manager, and Stephanie Hussamn, administrative assistant, said that Clarinda, Iowa is doing some very innovative work in the area of water meter reading using touch buttons as a result of their water supervisor's efforts. Robert said that their city is currently developing a program in Lotus 123 for sign inventory. He would like an ongoing sign management system that would be tied to traffic accident reports.

George Parris, Audubon County engineer, and Tom McGovern, data specialist, were interested in several different technologies that could be used for improving timekeeping, mapping, and inventory/parts. George thought that the use of bar codes and laptop computers would enhance their current sign management approach.

Randall Schlei, Emmet County engineer, Jack Weber, Emmet County assistant to the engineer, and Steve Timmons, summer intern, of Estherville, IA, indicated that Emmet County uses manual approaches to collect data using their own forms. They are particularly interested in reducing the amount of paper work required to computerize their data. Data are stored in custom made computerized databases. Randall appeared to be interested in some of the technologies as they might be used to reduce paperwork for maintenance and fueling of vehicles and being able to track gravel from production to placement.

Jon Ranney, Iowa DOT Photogrammetry, uses laptop "calculators" connected to a Geodemeter GeoDat to collect surveying data. He would prefer having the "calculators" at the rod instead of at the GeoDat unit to simplify communications between the rod person and the GeoDat operator. The information collected in the field is currently processed in the office. Ranney was interested in the tagging attributes of bar coding, and also thought that touch buttons and RFID might be useful because they would store more data. He also indicated an interest in the use of hand-held, laptop, and pen-based computers but did not name a specific application.

Fred Walker, Iowa DOT Safety, was interested in the use of GPS to locate accident sites and GIS as a tool to assist in data analysis. He would like to use these technologies to help pinpoint probable accident locations. He mentioned that this would probably be more viable in a highly populated area because accidents in more densely populated regions tend to occur in the same locations repeatedly.

Dwight Stevens, IDOT Traffic Management, and Fred Walker, outlined some areas related to traffic safety that could be addressed using more advanced data collection technologies. For example, speed monitoring of 55 mph/65 mph zones for the federal government involves taking vehicle speed samples from 32 different sites in Iowa using magnetic loops. Speed data are recorded and saved into memory at the site and are later transmitted by telemetry (phone lines) to the office. Both individuals feel that improved methods of data collection and dissemination could be developed to enhance this monitoring of federally mandated speeds.

Sign management procedures could be significantly improved. Currently, they do not have a complete sign inventory because it is so labor intensive. Both Fred and Dwight feel that they need a convenient, reliable way to keep data up-to-date and keep replacement/maintenance history logged into the system. Additionally, they would like a better way to record materials, date of installation, message, and other pertinent information about a sign. They said that this is going to take a lot of personnel, time, and investment and questioned whether this would be a cost effective use of funds. They also mentioned that there might be possible GPS and GIS applications for enhancing sign management. Furthermore, they need to check the reflectivity of the signs every so often and would like to have a history so that they can take a long-term look at the lessening of reflectivity of the various reflective materials. At the moment, standards are being worked on by the federal government for sign reflectivity. The only way they currently have of measuring sign reflectivity is either night inspections, which are subjective, and a hand-held retroreflectometer device. They would prefer to have a more mobile device that is not so labor intensive because they have so many signs to check.

Pavement markings are basically the same as signs, only pavement markings deteriorate more quickly (a year or less). They want to study the performance of the materials they use for pavement markings—supposedly there is a system that will currently perform this operation. They do have a way of measuring marking reflectivity, but it is labor intensive as well and this results in a small sample for their tests. They once again have to face federal standards and would like to have histories of deterioration for each area.

In the area of congestion in construction work zones, they would like to see message signs to warn or reroute motorists that are automatically triggered for certain conditions. Furthermore, they need a way to measure/monitor capacity, queue lengths, speed, etc., all of which are indicators of the level of congestion.

They are also interested in an automated way to collect data from pavement friction tests. Presently, these tests are performed by the materials section following appropriate ASTM (American Society of Testing Materials) standards for pavement friction requirements. This is periodically done all over the state with the frequency depending on the class of the highway.

Another area for improvement relates to identification of roadway features such as culverts, horizontal curves, and vertical curves. Currently, this information is not reported because it is too labor intensive. They are currently able to track the number of curves within a certain section, but not the specific location of each curve unless they consult the roadway plans (an action that is quite labor intensive). A similar concern relates to no passing zones. Even though the zones are currently set up, they may have to be changed in the future if federal standards are changed and this would take quite some time unless they had a way of testing the distances other than their current method. Currently, they have to take a measured length of line out into the field, string it along, and test each curve, both vertical and horizontal. They would like to have a more automated system to resurvey the curves.

Brian McWaters, Iowa DOT Pavement Management, was really interested in using GPS in such a manner that his inspectors could drive down the road and not have to enter the location data into a computer or onto paper. They are currently tied to mile sections for their locations and this does not allow for locating items that are of interest other than within those mile sections. Brian expressed an interest in dynamic segmentation. They also are somewhat interested in tying coordinate locations into a GIS system, but the GIS system needs to have the ability to analyze data and show it on the map.

Brian liked the idea of using pen-based computers because data could be directly entered bypassing the need to use a paper form and using a keyboard to type information into the computer (Brian felt like a laptop computer would be difficult to use in the field). He also had an interest in using video logging but expressed a concern related to the picture quality for their purposes. They need adequate resolution to be able to determine stresses on pavements covering approximately 27,000 miles of state, city, and county roads to analyze. Brian is fairly sure that the accuracy and precision of video logging is not sufficient for his purposes. They also would like automated reduction of the images for quickness of analysis. This means that the computer would be able to analyze the pictures and determine the size of the cracks and flag potential problem areas. An ideal system would allow data to flow through it from beginning to end without human intervention. Furthermore, they are interested in comparing as-built drawings with original plans and the pavement history to see what maintenance was performed in the past. Perhaps a computer-aided design and drafting software package could be used to efficiently compare the original plans to the actual.

John Smythe, Iowa DOT Construction Program, expressed interest in using advanced field data collection technologies to enhance the data gathering process. Donna Buckwald, Iowa DOT Construction Program, provided the research team with several paper forms that are used by field inspectors. Donna is currently responsible for developing a strategic plan to better understand the information flow within the construction area and is in the process of distributing pen-based computers to field inspectors for more efficient data capture operations. John mentioned that he is an AASHTO committee member responsible for developing the system requirements for a comprehensive Construction Management System (CMS) that would integrate five areas: (1) project record keeping and daily work reports, (2) estimate processing and finalization, (3) materials management, (4) project-oriented civil rights requirements, and (5) construction administration. CMS would conceivably be used by all the state departments of transportation to better manage the reporting process for construction-related information. John expressed an interest in developing appropriate "front-end" technologies for capturing data and inputting them into the CMS program.

4.0 TECHNOLOGY IMPLEMENTATION ASSESSMENT

This section provides a brief summary of the study results and discussion of technology needs and potential applications for future development. Overall, results showed that most of the field data are collected manually in the state of Iowa and either hand entered into a computer or simply filed in the office. Also, most transportation agencies had office computers, but lacked portable computers for field data collection. Additionally, results showed that an interest exists in using advanced field data collection technologies to enhance current field data collection techniques; interest in specific technologies varied depending on the type and size of the transportation agency as well as the particular program (e.g., maintenance and bridge management).[1] Survey results were confirmed through the interviews where respondents provided more insight into their current data management procedures, problem areas, and specific interest in developing applications using advanced data acquisition technologies. This information has helped the research team prioritize technology needs and provide insights into beneficial applications for the Iowa transportation agencies.

4.1 PRIORITIZATION OF TECHNOLOGY NEEDS

The greatest priority, in terms of enhancing field data acquisition techniques, relates to streamlining the data collection approach using computerized data entry and reporting procedures. Technologies should be implemented to reduce the amount of paperwork related to collecting field data. For efficient operations, data should be collected directly into some type of portable computer that can be connected to the office system. This may involve developing "computerized" data collection forms as well as computerized analysis and reporting procedures. Using electronic data capture techniques will reduce the overall amount of effort expended to produce higher quality reports in a shorter period of time; this may assist transportation managers and planners in making more informed and timely decisions.

4.2 POTENTIAL APPLICATIONS

Several potential applications are suggested based on the interest level shown in the survey as well as the interviews. These applications are categorized by the county, city, and state levels.

4.2.1 Counties

Very few counties have actually implemented GPS and GIS (refer to Table 4 surveying program). There appears to be some interest in utilizing GIS in the areas of sign (41.4 percent positive response rate; 3.3:1 interest ratio), maintenance (34.5

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[1]Researchers were still able to identify general trends regarding technology interest level despite numerous missing data from Table 2 in the survey.

percent positive response rate; 2.1:1 interest ratio), bridge (32.2 percent positive response rate; 2.2:1 interest ratio), and pavement (33.3 percent positive response rate; 2.1:1 interest ratio) management (refer to Table 4).

County respondents, in general, expressed an interest in using portable computers to collect field data. Laptops were of greatest interest (percent positive response rate > 30 percent) for sign (58.6 percent), bridge (51.7 percent), maintenance (47.1 percent), pavement (47.1 percent), construction (46 percent), surveying (40.2 percent), and safety (32.2 percent) management programs (refer to Table 4). There was also interest in using pen-based computers for sign, bridge, pavement, and maintenance management programs (percent positive response rate greater that 30 percent but less than 40 percent—refer to Table 4).

Video logging was a technology of interest for enhancing pavement, bridge, maintenance, and sign management programs with percent positive responses in the range of approximately 32 percent to 35 percent (refer to Table 4).

The use of bar codes for sign management was also of interest to county respondents as 40.2 percent of the respondents responded favorably (refer to Table 4).

Additionally, the interest level in using advanced data collection technologies increased as the county population size increased. Several technologies followed this trend especially for traffic and pavement management and surveying (refer to Table 6).

Personal interviews with county representatives confirmed some of the findings of the written survey revealing an interest in implementing more advanced data collection approaches in their organizations. Areas indicated are as follows (not in any particular order): sign management, parts and yard inventory, time-keeping, mapping, maintenance and fueling of vehicles, tracking gravel from production to placement, bridge replacement, and pavement management. Bar coding, portable computers, and video logging were a few of the technologies specifically mentioned as holding the greatest interest. Concern was raised by one individual regarding the cost of implementing such approaches.

4.2.2 Cities

Larger cities (population greater than 9,270) exhibited a strong interest in applying bar coding techniques to their sign management programs (54.5 percent positive response rate and a 9:1 interest ratio—Table 5). GIS was of interest for pavement (42.4 percent positive response rate and a 3.5:1 interest ratio), surveying (42.4 percent positive response rate and a 4.7:1 interest ratio), construction (33.3 percent positive response rate and a 3.7:1 interest ratio), maintenance (30.3 percent positive response rate and a 3.3:1 interest ratio), and sign (30.3 percent positive response rate and a 2.5:1 interest ratio) management programs. GPS was of particular interest for sign management (33.3 percent positive response rate and a 2.2:1 interest ratio) and surveying (36.4 percent positive response rate and a 3:1 interest ratio). Video logging was of interest for pavement management (33.3 percent positive response rate and a 2.8:1 interest ratio). A variety of portable computers (i.e., laptop, hand-held, and pen-based) were of interest for pavement, surveying, traffic, sign, construction, maintenance, and bridge management programs (refer to Table 5 for the actual percentage of positive response rates and interest ratios).

Additionally, the interest level in using advanced data collection technologies increased as the city population size increased. Several technologies followed this trend especially for sign, pavement, bridge, traffic, surveying, maintenance, and construction management (refer to Table 6).

Smaller cities (population less than or equal to 9,270) expressed some interest in using GIS for surveying (35.3 percent positive response rate and a 2.4:1 interest ratio) and pavement management (32.4 percent positive response rate and a 1.8:1 interest ratio). The use of hand-held computers were of greatest interest collecting data related to pavement and maintenance management (35.3 percent and 32.4 percent positive response rates, respectively). Bar codes were also of interest for sign management (32.4 percent positive response rate and a 1.2:1 interest ratio).

Personal interviews revealed an interest in enhancing field data collection using portable computers, GIS, and bar coding technologies for sign and pavement management. Concerns regarding cost, technology obsolescence, and training requirements were mentioned by a few respondents. Additionally, some respondents were interested in a tie between programs such as sign management and accident reporting.

4.2.3 State

It was difficult to select specific applications that were of interest for state respondents because they seemed to be interested in applying several of the technologies to their particular programs. Personal interviews with several state representatives revealed a diverse interest in using advanced field data collection technologies. Jon Ranney's interest in enhancing Iowa DOT surveying procedures involved having the "calculators" at the rod instead of at the GeoDat unit and tagging locations with a choice of bar codes, touch buttons, or radio frequency identification tags. Fred Walker, Iowa DOT Safety, was particularly interested in the use of GPS to locate accident site and GIS as a tool to assist in data analysis. Both Dwight Stevens, Iowa DOT Traffic Management, and Fred Walker feel that improved methods of data collection and dissemination could be developed to enhance monitoring of federally mandated speeds. They also felt that sign management could be improved by using GPS and GIS. Other areas for improvement included measuring sign and pavement marking reflectivity, identifying areas of congestion and posting proper warnings for motorists, collecting data from pavement friction tests, and identifying roadway features such as culverts and curves. Brian McWaters, Iowa DOT Pavement Management, expressed an interest in using GPS in such a manner that his inspectors could drive down the road and not need to hand enter the coordinate locations. He also liked the use of pen-based computers since they could be used to bypass the use of paper forms. Furthermore, Brian would like to see a better approach to determine pavement stress involving the use of advanced imaging and computer aided design. John Smythe, Iowa DOT Construction Program, expressed an interest in using appropriate field data collection technologies for more efficient data capture as part of the "front end" portion of the future Construction Management System.

5.0 STUDY LIMITATIONS

Although the response rate was quite satisfactory, several people did not identify their interest level in using all of the technologies for each program. Comments from respondents revealed that this was because they did not feel adequately knowledgeable to comment or simply felt indifferent for one reason or another. This may indicate that further education is necessary to make people more familiar with these advanced technologies. Responders with greater familiarity to the technologies would probably have been even more interested, as was evidenced by the American Public Works Association Conference (APWA) respondents.

State survey results are based on responses from individuals responsible for each of the management programs. These respondent individuals may have a different opinion regarding the application of various technologies than those who actually perform the field data collection. Additional sampling for field employees may be necessary.

6.0 SUMMARY, RECOMMENDATIONS, AND CONCLUSIONS

A substantial amount of knowledge was gained from this study regarding state-of-the-art field data collection technologies, current field data collection approaches, interest level in applying these technologies, and potential applications for future development in the state of Iowa. A multitude of technologies suited for field data collection exist; and the capabilities of these technologies are changing rapidly. Most field data are collected manually in the state of Iowa and either hand entered into a computer or simply filed in an office. Most transportation agencies had office computers (e.g., PCs and mainframes), but very few portable computers that could be used for field data collection. There appeared to be sufficient interest by Iowa transportation agencies (city, county, and state) to use some of the technologies described in this report; it was noted that the interest level varied depending on the type and size of the transportation agency and specific management program. Several application areas were identified for future development based the findings from the survey and personal interviews.

As a result of this study, recommendations are made to enhance the use of advanced field data acquisition technologies in Iowa transportation agencies.

(1) Appoint a statewide task group to coordinate the effort to automate field data collection and reporting within the Iowa transportation agencies. Subgroups representing the cities, counties, and state should be formed with oversight provided by the statewide task group. Automation efforts should consider the interest level results from this study and take into account the differing needs between the various agencies (e.g., cities versus counties, large cities versus small cities, and state versus counties). Additionally, the task group should address the need to efficiently integrate data and electronically capture data at the source. To accomplish this goal, more standardized data entry forms can be computerized and shared by all agencies and the number of field portable computers should be increased.

(2) Educate employees at different levels of an agency so that they become familiar with the various field data acquisition technologies. This will assist in identifying potential applications and ease the transition as new technologies are implemented.

This study has provided information on current technologies and critical insights into the interest levels of various transportation agencies in implementing these technologies. It is hoped that this research will be carefully reviewed and used in planning and executing more efficient data collection procedures for Iowa transportation agencies.

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APPENDIX A
STEERING COMMITTEE MEMBERS AND MEETING AGENDA

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STEERING COMMITTEE MEETINGS FOR "FIELD DATA ACQUISITION TECHNOLOGIES FOR IOWA TRANSPORTATION AGENCIES" IDOT CONTRACT # H-366

Date	Agenda
August 26, 1993	Kick-off meeting (introductions, brief review of project, discussion, and demonstration of voice recognition).
September 30, 1993	Review progress-to-date (weekly team meetings, trip to AIM Upper Midwest Data Collection Systems Expo at the Minneapolis Convention Center on September 21, and detailed schedule for accomplishing first interim report), discussion of bar coding technology (brief overview, demonstration of an enhanced labor and material reporting system using bar coding techniques, and brainstorming session on bar coding applications in the transportation industry).
October 28, 1993	Demonstration on radio frequency data communications (RFDC) by Fred Lande, brainstorm other RFDC applications for the transportation sector, review progress on first interim report.
December 20, 1993	Review first interim report (description of advanced field data collection technologies for Iowa transportation agencies).
January 28, 1994	*First interim report presentation to the Iowa Highway Research Board.*
February 18, 1994	Discuss interim report presentation to the Highway Research Advisory Board, review survey, discuss sampling plan, touch button demonstration, and discussion of applications for thetransportation industry.
April 29, 1994	Discuss survey results, review project schedule, and discuss next phase possibilities.
May 20, 1994	*Second interim report presentation to the Iowa Highway Research Board.*

June 13, 1994	Discuss comments from May 20 meeting and provide schedule for contract completion by August 31, 1994.
August 25, 1994	Review draft of final report.
September 30, 1994	*Final Report Presentation to the Iowa Highway Research Board.*

APPENDIX B
FIELD DATA ACQUISITION TECHNOLOGY APPLICATIONS

B.1 BAR CODING

In the military, bar codes have been used for about two decades. The U.S. Department of Defense (DOD) implemented the use of bar codes in the 1970s. Bar code usage was spearheaded by the Joint Steering Groups for Logistics Applications of Automated Marking and Reading Symbols (LOGMARS), who conducted pilot projects for many different bar code applications. The results of LOGMAR efforts led the DOD to implement bar codes for depot level maintenance, ammunition inventory, service store inventory/issue, wholesale receiving and shipping, retail receiving, wholesale inventory/location audit, and whole sale disposal. By the early 1980s, the DOD projected it would realize a savings of $113.9 million due to bar code usage instead of conventional data entry methods (Bell and McCullouch 1988).

The U.S. Army Corp of Engineers Construction Engineering Research Laboratories (CERL) has been developing and using bar coding technologies for tracking materials and equipment since the early 1980s. CERL Public Affairs Specialist Dana Finney now reports those types of applications are in use throughout the entire U.S. Army (Finney 1993a, 1993b). CERL has recently developed new bar coding systems for use in quality assurance inspection programs, scheduling functions, and labor tracking (U.S. Army Corp of Engineers, Construction Engineering Research Laboratories 1993a, 1993b, 1993c, 1993d, and 1993e). Nearly one dozen Army post maintenance departments employing 200 or more workers are using CERL's newest Automated Labor and Equipment Card (ALEC) system for combined time-keeping and tool-tracking functions. After the completion of this pilot project, officials hope to install ALEC in all Army post maintenance shops employing 58 to 200 workers. Army experts estimate ALEC systems will save each maintenance shop $60,000 yearly in clerical work for data entry, plus save 20 minutes per worker per day normally spent recording times spent doing individual tasks and in checking in and out tools. On average, ALEC systems are expected to pay for themselves in about six months (Finney 1993b).

Several years ago, the Marine Corps needed an efficient system for better asset management upon the return of troops from the Persian Gulf region after Operation Desert Storm. The accuracy and efficiency of operations were significant when using bar coding to help with the deployment of 40,000 pieces of equipment onto 26 ships. Benefits included faster response to deployment and additional data is now available to aid decision-making for similar operations in the field (McCauley 1992).

In plant manufacturing processes, bar coding continues to make a profound impact. For example, a paper manufacturer streamlined manufacturing flow, inventory, and shipping by implementing a customized version of a bar code and labeling software system. This system has produced higher levels of accuracy in the company's computer system. Immediate information on product flow and on product location is available, saving time and reducing overhead costs (Zaiger 1991).

In the automotive industries, Ford Motor Company and a Mazda plant implemented a bar code system as a part of a "Just-In-Time" project between the two companies. The Ford Motor Company supplied automobile parts identified by standardized bar code labels to the Mazda plant. To avoid parts shortages and expensive idle time, the collaborative program demanded shipping/receiving and production data be timely and accurate. The use of bar coding reduced shipping/receiving errors, reduced the need for shipping and production count reporting, and increased record-keeping efficiency (Mazurkiewics 1991).

In keeping time and attendance records, the benefits of bar coding are widely realized. Time and attendance applications usually provide companies the first exposure to automatic data collection technologies, and these applications are considered the easiest projects to justify with dollar savings. Other benefits are commonly reported; paybacks in less than a year, greater accuracy, less time for payroll processing, and smoother payroll operations (Sharp 1993).

A food processing company reduced payroll processing effort by 80 employee-hours per week with the use of bar coding. This company, with more than 1,800 employees in 28 locations, reported a major overhead expense for tracking time and attendance. The company developed a bar code system that gathered information directly from the working environment and delivered it to the data processing system. This reduced data inaccuracy, out-of-date information, and payroll errors inherently attached to the previously employed manual system (Navis 1992).

A bar code system for time keeping and cost control processing was developed by Iowa State University and the Weitz Company, Inc., a general contracting firm located in Des Moines, Iowa. Previously, daily time sheets were consolidated and entered in the centralized payroll application using manual data collection and entry procedures. This approach involved many people, was mistake-prone, and time consuming. An automated process was developed with the aid of bar coding and a template book containing information related to worker's names and cost accounts for work performed. The new automated system is cutting job site payroll processing costs by approximately 75 percent, and the $22,000 system will have a payback in less than a year (Anderson 1993; Jaselskis 1993).

In transportation, the Iowa Department of Transportation central warehouse uses bar coding along with radio frequency data communications for faster and more accurate receiving, storing, and delivering of supplies from the central warehouse to other locations within the state. In addition, this technology can be used to better manage the infrastructure at the city, county, and state level—a sign management system that uses bar code labels to identify sign inventory, for example.

Vehicle scanning has streamlined parking and relieved traffic congestion at the Orlando International Airport. Shuttles take employees to work from remote parking places, alleviating the need for lots and docks surrounding the main terminal. These shuttles, along with all airport-access-licensed vehicles (e.g., cabs, rental cars, etc.), have attached bar code labels that are read by scanning gates, eliminating the need to have dedicated personnel to approve passage into the airport's very active traffic. Benefits include recouping lost revenues from magnetic card sharing (the old system), reduction of access lanes, higher turnover of curb spaces, and a better and more sophisticated report generation and billing system (Raith 1993).

A truck-stop supply firm cut order entry time from hours to minutes for its route salespersons with the use of a hand-held computer equipped with a bar code light pen scanner. In the past, salespeople were routinely flooded with paperwork. Written orders were sent via fax or phone to the home office every night, which included errors from transcribing messages from answering machines, unreadable faxes, and key-entry mistakes. Under the new system, a particular sales representative connects directly to the main office's personal computer, where ordering, availability, and other useful information are exchanged automatically. This automated data collection and transmission of sales orders has increased the accuracy and speed of orders, increased customer satisfaction, and resulted in faster shipping (McClelland 1992).

In retail, the Wal-Mart Store is considering using 2-D bar codes for improving receiving operations. Information about a shipment can be coded and placed by the supplier, which would be scanned and uploaded into the store's computer system upon arrival. The Wal-Mart strategy manager for Retail Link (a technology platform Wal-Mart shares with its suppliers free of charge, allowing vendors to handle all communications with a particular store and to access daily point-of-sale electronically) thinks this new system will give the company and its trading partners an original opportunity for redefining the way merchandise flows to the selling floor. Tracking of this flow will also eliminate unnecessary costs or time delays ("Wal-Mart Studies 2-D Codes" 1993).

B.2 RADIO FREQUENCY IDENTIFICATION (RFID)

Transportation-related uses include standards that have been set for railroads, trucking, and cargo containers. The Association of American Railroads, for example, mandated the use of a universal RFID system for freight carriers in 1991. Railroad cars and locomotives, with RFID transponders attached to them, are tracked by readers installed along tens of thousands of miles of track. Other potential future applications for RFID in transportation systems include tracking hazardous cargo state-to-state and sign identification on highways.

In law enforcement, RFID tags are being used to track convicted criminals, racing dogs, and vehicles enrolled in crime-prevention programs (David 1993; Krause 1993; Kilbane 1993; Mead 1993; Quinn 1993a). When manufacturing motorcycles and cars, some tags (originally embedded in parts to track a vehicle in the assembly line) are left inside the parts and are then used to provide law enforcement agencies with tracking capabilities in case of theft. These embedded tags also can be used to collect warranty information (Floyd 1993; Mead 1993).

In hazardous work-place safety markets, RFID systems are being implemented—particularly in underground work environments such as mining operations (Bernell 1993). To improve safety conditions, the RFID antennae and tags are used to monitor the miners, the props that support mine roofs and walls, and the carts and conveyors which carry coal to crushing machines. In addition, RFID tags record the duration each miner spends below ground for time and attendance, payroll operations, and as a means of adding critical safety features to their mining operations.

In one mine, Texas Instrument's TIRIS tags are affixed to pit props to permanently and accurately identify each vital component being used in mining operations. Maintenance records have also been improved.

By using passive tags, common accidents involving underground workers and automated carts with attached readers have stopped. When these readers sense a miner within range, the cart halts. A German mining company's system features another safety feature, involving a transponder capable of transmitting on different frequency bands. In the case of a mine collapse, the high frequency band would be used to locate miners caught below ground (Bernell 1993).

In home and business security systems, RFID technology has a growing market. Hughes Identification Devices is developing a security card called "RFID cards" to provide a hands-free access control system. With an embedded computer chip that will actually act as the "key" to apartments and homes, the card opens the door when it passes within close proximity, eliminating the need for fumbling with keys or tricky locks. Other companies developing or selling RFID cards include Rancom Systems and Texas Instruments (Kilbane 1993; "New Products" 1993; "RF/ID Cards May Soon Unlock House Doors" 1993).

Agricultural fields may be considered the birthplace of RFID technologies. This technology grew in a large part out of government-sponsored programs in the early 1970s to manage livestock. Animal tagging remains a large part of the business and it is the one industry farthest advanced in the development of international standardization (Kachmar 1992).

Perhaps the most widely publicized example of RFID livestock applications involves the TIRIS system, first introduced by Texas Instruments in 1991 ("Breeders Track Ostriches" 1993; "Farmers to Get RFID" 1993; "TI Enters RF/ID Market with TIRIS System" 1991).

B.3 TOUCH BUTTONS

1. Access Control	
a) Badges	Attaches to an ID badge using an adhesive pad or a locking retainer.

b) Keys	Serves as an "electronic key" (often when affixed to a personnel ID badge) which triggers electronic access upon contacting a wall plate touching the probe. Can be affixed to and/or collaborate with mechanical keys for boosting security.
c) Door Monitoring	Stores location of the door frame to which the button memory is attached.
d) Door locks	Identifies person at door when an electric door lock is fitted with touch pen electronics. Matches name on access list with name in the touch or and checks time-of-day criteria before latch for entry is released.
e) Easy Proximity Information Exchange Badges	Responds automatically to touch/proximity chip affixed to personnel ID badge within 15 meters of a 132 KHz source with data transmission.
2. Medical	
a) Veterinary Medicine	Logs medical and ownership records of livestock in button which is attached to ear tag.
b) Patient Bracelets	Identifies patient when hand-held meter is touched to touch hospital bracelet.
c) Diagnostic Reagent Labels	Insures accurate test results by touching button affixed to a reagent vial of specimen to a probe built onto the medical meter used for calibrating lab tests.
d) Medical Laboratory Work	Fits to button of sample tubes for storing patient name, hospital ID code, and time and date of sample collected. Adds information automatically to memory as sample is processed in the laboratory.

3. Container and Container Handling Equipment	
a) Mail Processing	Extends "probable" surface of button via conductive tape or foil strapped along bottom and sides of mail tray. Contacts between toucher and button enables identifying trays and sorting mail according to destination and other information programmed in button memory.
b) Automated Conveyers	Enables exchange of information between buttons attached to containers on conveyer belts and "fingers," or rollers (probes) that wipe the button's surface or its extended surface.
c) Warehouse Functions	Identifies pallets (and its contents) whenever being moved with a touch memory wire or button mounted on the front of the pallet. Keeps records of activities both in the pallet and in the forklift truck's reader automatically. Contents, dates, codes, and date of last movement can be stored.
d) Parts Reels	Logs information regarding part's type and number dispensed when attached to part's reel. When free standing, reel can be probed with a hand-held computer. When mounted, the button transfers information through the axle to the dispensing machine, even while rotating.
e) Carts with Automatic Check-In/Out	Enables computers to automatically inventory tagged work trays and the work carts upon which they are carried.
f) Truck Cargo Logs	Logs identification and cargo information in button memory attached to truck trailer without driver involvement. Stand-alone or loading dock probes can read or modify this information.

4. Systems Interfaces	
a) Microprocessor Interface	interfacing with microprocessors is possible with the DS2404-001 touch memory chip which has two serial ports: the traditional one-wire that supports touch protocol and a 3-wire for higher speed interface.
b) Other Electronic Information Management Interfaces	Interfacing is also possible with other automatic data capturing systems. In particular, bar coding, radio frequency data communications, and radio frequency identification systems can be compatible with *touch memory buttons technologies.*

(*50 Ways to Touch Memory* 1993; Glick 1993; Kilbane 1993; *TouchPath: The Low Cost Data Path for Touch Memory* 1993)

In warehousing operations, touch button technology is being investigated by the Utilities Industry Group (UIG) association (Kilbane 1993). Touch buttons are being considered for work site or infield applications where high information storage is important, while non-contact readability is of less consequence.

In security systems, touch memory buttons are being used by the largest security company on the Australian continent. Wormald Security now uses 19 hand-held Videx, Inc. touch probes and 500 button memories to account for the guards and mobile patrol units it employs for patrolling commercial sites. Wormald had been using bar code security assurance systems at its client sites for nearly seven years and had found the labels to be too limited when in hazardous environments frequently encountered by guards. On average, Wormald reports, its bar code labels exposed to the elements needed replacement every six months.

Now Wormald is phasing in touch memory buttons for checking in and out its guards and recording their shift activities. The benefits of the touch button system supersede the automated security management system's bar coding component in several ways. Touch buttons are more reliable in harsh environments. The Videx, Inc. hand-held touch probe costs far less than the customary hand-held bar code scanner and the probes are powered with a lithium battery, lasting up to 5-years and eliminating the need for recharging. The probes are automatically reset by the PC system after uploading, while the previous bar code readers had to have their memories and clocks reset manually (Quinn 1993b).

B.4 VOICE RECOGNITION

In the automotive industry, Saturn Automobile Corporation uses a voice recognition system for tracking paint quality in real-time to achieve the high quality standards of Saturn automobiles. This voice recognition system allows workers to have their hands and eyes free for inspection and rework. Workers can identify and log paint non-conformities, identify the causes, and prevent paint non-conformities from leaving the plant. Benefits include better paint quality, increased productivity, faster information, and higher accuracy (Hackmeister 1992).

In transportation, a road inspection system using voice recognition technology is used by Main Roads in Western Australia. Laptop computers are used and workers enter voice commands related to road conditions as they drive along an established route. The information is saved into a diskette and transferred to the office personal computer. This computerized system has helped the Australian agency to provide efficient, reliable, and timely information for road maintenance. Historical data can be analyzed and trends can be established (*Voice Recognition Technology in Field Data Capture* 1993).

In the lumber industry, one Pacific Northwestern company uses a voice recognition system in an extremely noisy environment. In this application, real-time collection of grading and tally data in the lumber mill is accomplished. Data gathered through the voice recognition system is automatically entered into the main cost-accounting system and into the inventory and sales forecasting applications. Workers increased their productivity and a safer environment was produced (King 1993).

In the pharmaceutical industry, a manufacturer implemented a voice recognition system for processing returned goods with a payback of three months. The difficult task of controlling returned goods was overcome by providing a portable voice computer to workers in the shipping and receiving sections. A portable computer enables the worker to go about his or her tasks by using context-sensitive prompts to enter spoken attributes such as quantity and condition of the returned items. The data is uploaded into a personal computer and, at the end of each shift, into the mainframe. This system improved customer service and resulted in quicker price "look ups" (Quirk 1993).

B.5 OPTICAL CHARACTER RECOGNITION (OCR)

Traffic control: As mentioned in a prior example, OCR systems could be used in transportation control situations. The scanner would need to be either a video camera or a charged coupled device (CCD) camera with an auto-iris zoom and a suitable aperture and focal length (D'Agostino 1992). The preprocessing of data would involve software that would locate the license plate number and prepare it for recognition.

This project application could cut down on the need for police officers, the mileage traveled by state patrol vehicles, reduce the number of speeding violators, and provide safer highways for the general public.

PC-Based Car License Plate Reader: An application of OCR has been developed to allow a system to identify license plates. The system reads license plates and checks with a central database for stolen vehicles. It takes the system 0.7 seconds to recognize a car license plate using a PC-based computer with 80486/50 CPU (control processing unit). The recognition rate of the system is about 97 percent; the system is also used in vehicle flow statistics.

Contrast Enhancement of Mail Piece Images: Researchers at the State University of New York at Buffalo have developed a simple image processing technique for enhancing the contrast of mail piece images. This technique processes a stream of mail piece images and extracts destination address blocks. Using an assembly line design, with a set of image-processing tools, the system achieves an effective throughput of 1/12 of a second per mail piece in the letter stream.

Cornell Documents Restoration Project: Nearly one-third of all library holdings across the country are in brittle or near-brittle condition. In some cases, it is impossible to reproduce these documents because they are too old and irreplaceable. Recently, electronic imaging has been used to solve this problem. Cornell University is one of the first schools to implement this technology. Cornell researchers have been using electronic imaging to digitize, scan and capture text and image. This provides easy, on-line access to the material, and the data can be used for high-quality laser prints (Webster 1993).

DARPA High Resolution Display Technologies: The military's need to increase weapons systems effectiveness and durability has encouraged them to use a DARPA (Defense Advanced Research Projects Agency) program. The two major aspects of the DARPA program are the development of a display processor that involves data compression and the development of a video work station that can manipulate digital video information. This advanced-imaging application provided the military with a visual interface between user and machine, offering more efficient and accurate information transfer and processing.

Visualization to Predict a Child's Skull Growth: Another application for advanced imaging has been developed at Johns Hopkins University. The project combines scientific and statistical methods to develop a three-dimensional study of skull growth with clinical image data, visualization tools, and network capabilities. The ultimate goal of the project is to predict future skull development of patients, based on empirically derived growth patterns and specific database images.

B.6 GLOBAL POSITIONING SYSTEMS (GPS)

In Agriculture, Erny's Fertilizer Service, Inc., Walton, IN, uses GPS-guided yield sensors to increase the sales of "CornFacts." Erny's will use information from the yield monitors to generate electronic yield maps using Agmap software from RDI, Inc. These maps will then be overlaid on a computer with other electronic maps containing soils and drainage information. This will allow contractors to analyze the data, providing the basis for improved and more site-specific recommendations to their customers. Erny's customers are willing to pay extra for site-specific yield data and recommendations (Farris 1993).

In shipping and navigation, an emergency response system provides real-time navigation information using a global positioning system to assist rescue ship crews in an emergency. This system is used in conjunction with geographic information system (GIS) technologies . Optimum path information can be obtained from a loaded Land Use-Transportation System (LUTS), a network that uses specialized computer simulation models to compute trip generation and distribution, model split - analysis, and path-building traffic assignment analysis. When these three components of the LGG system are integrated, GPS determines the real-time coordinates of the vehicle and GIS places the data as a point on a digital transportation network map. This allows the vehicle to be tracked on a video monitor. When the third part of LGG is linked, the optimum path (minpath) can be determined, minimizing the expected travel time of a trip (Saka 1993).

In a mapping application, the Los Angeles Department of Water and Power planned a comprehensive first-order, area-wide horizontal and vertical geodetic survey control throughout the Owens Valley-Mono Basin to create a system-wide GIS. During a three-week period in 1990, a detailed field investigation was conducted, including a check for skyward obstructions, station location sketches, and the creation of a comprehensive project map (which included a plot of 90 critical points). Six dual-frequency GPS receivers were used for a two-hour observation. These plans resulted in the development of a GPS scheme for the Los Angeles Department of Water and Power (Crossfield 1991).

In another mapping application, the need to establish a stable geodetic network for major federal, state and county engineering projects (including transportation, flood control and land development), prompted the conversion of the Orange County, California, horizontal control system to the North American Datum of 1983 (NAD 83). The geodetic network was completed using GPS. The Orange County geodetic primary control network was developed in two phases. The first was field procedure (planning and reconnaissance, elevation determination, data acquisition, and documentation), followed by office procedure (data preprocessing, relative positioning computations, adjustment processing, and documentation). Orange County was able to finish their primary control network in the record time of only 16 days of field work. The computerization of field and office procedures required fewer technical and clerical hours. A few years ago it would have taken five people working all day for six months to complete this task. The primary control network, which consisted of 21 stations, was established at a cost of $20,000. Orange County undertook later projects that consisted of surveying 111 additional points at a cost of $69,000 and 137 points at a cost of $165,800 (Canas 1990).

In Transportation Management, base mapping in a timely manner is of crucial importance. The California Department of Transportation District 7 developed a method of compiling digitized two-dimensional (2D) mapping with horizontal data using aerial photos. Compared to the full three-dimensional (3D) mapping, digitized 2D mapping resulted in a 60 percent savings. The primary control network for this project consisted of a GPS network to obtain adequate ties to the existing National Geodetic Survey (NGS) control stations and a GPS network linking all new monuments along the corridor. The use of GPS and total station data provided control along a 17.1 mile section of the Santa Monica freeway in California. There were 54 primary stations positioned with GPS, along with 203 secondary stations that were positioned with a total station. The primary purpose for completing the survey control was to digitize the traveled edges of the freeway, facilitating better transportation management in terms of pavement rehabilitation, stripping, and congestion programs (Launen 1993).

An Automatic Vehicle Location and Navigation System (AVLN2000) was developed at the University of Calgary, Canada. This was a prototype system designed to coordinate the positioning of a vehicle, locate the vehicle in relation to a digital road map database, provide an optimal path through the network, provide dynamic coordinate determination of the vehicle, and route guidance through the network (Harris 1989). It consisted of a GPS receiver, a pair of Nu-Metrics odometers, a map-matching module, and a portable IBM compatible microcomputer, used for real-time computation and display.

B.7 GEOGRAPHIC INFORMATION SYSTEMS (GIS)

In transportation management, the Iowa Department of Transportation is now working to interface a GIS system with its operating GPS system for positioning tower sites. (Lande 1993; Whited 1993).

GIS can also be used to perform transportation hazard analysis and incident management. Concerns addressed by transportation hazard analysis include dynamic routing, emergency preparedness for accidental release of hazardous materials while in transit, comprehensive risk assessment, and planning for evacuation. Incident management concerns involve rerouting to bypass an affected area and deployment of emergency response systems (Lepofsky et al. 1993).

In the construction industry, GIS has been proposed for problem solving applications where it is necessary to integrate large volumes of spatial and descriptive data from several sources (Jeljeli et al. 1993).

In urban storm water management models, GIS aids in modeling a city's storm sewer system. Drainage-network verification and sizing are two applications that have been researched (Djokic and Maidment 1993).

In watershed hydrologic modeling, GIS utilizes a geomorphic approach for modeling watersheds, calculating the travel time of a drop of water landing in the watershed to the watershed outlet. A GIS has been used in integrated hydrologic modeling to provide for increased evaluation detail, decreased parameter bias caused by user subjectivity, and reduced costs of analysis through time savings. The GIS provides a spatial/analytical function and performs geo-referencing and spatial overlays to quickly develop the inputs. The GIS also links different codes written with disparate spatial discretations (Bhaskar et al. 1991)

In long-term regional water-resources planning, GIS may calculate potential deficits or excesses in the water supply over an extended period of time with given data about the current water-supply and forecasts for future demand. GIS may also suggest alternatives for developing additional water supplies in the event of a forecast deficit (McKinney et al. 1993).

In uplands, wetlands, and submerged ecosystems analysis and management, GIS aids in the mapping and analysis of these ecosystems so they may be managed efficiently. A system is currently being developed by the National Oceanic Administration and the Environmental Protection Agency to satisfy immediate needs of their respective Coastwatch Change Analysis Program and Environmental Monitoring and Assessment Program (Klemes, et al. 1992).

In education, institutions are teaching the use of GIS to create more interest in the research and development of GIS. At Iowa State University several groups have ongoing projects involved with instruction and research of GIS capabilities and possibilities. Jim Majure, Director of the ISU GIS facility, teaches a variety of GIS classes as well as chairing the GIS curriculum committee. He programs some research in GIS and runs a GIS lab in the Durham Computer Center. Dr. Kandiah Jeyapalan, a professor in the Civil Engineering department, also sits on the GIS curriculum committee as well as teaching GIS and GPS in his advanced surveying courses. Dr. Reginald Souleyrette, Associate Director of the Iowa Transportation Center and a professor in the Civil and Construction Engineering Department, has an ongoing research project for the Iowa Department of Transportation (DOT) involving GIS. The overall project mission is to develop a functioning GIS at the Iowa DOT (Souleyrette 1993).

B.8 RADIO FREQUENCY DATA COMMUNICATIONS (RFDC)

Warehouse management tends to be the primary application for RFDC technologies. For simple inventory tracking, RFDC has realized significant savings in operational costs (Jeffress 1993; Mullen 1993; Peters 1993). So far, most RFDC-based warehouse management systems (WMS) use bar code labels for automatic data capturing. The Utilities Industry Group (UIG) is investigating using touch memory buttons in automated warehouse management systems (Kilbane 1993). A few examples of RFDC systems used for warehouse management are listed below.

In the Iowa Department of Transportation central warehouse, an on-line real-time radio frequency order processing system is an important component of the Iowa DOT's inventory system. This system tracks nearly 7,000 materials, supplies, and parts in 160 store rooms and garages throughout the state. It serves 730 users at 320 "ordering stations" at 175 different locations and communities throughout Iowa. This two-year-old Ames-based centralized system has reduced the number of warehouse workers from nine to seven without decreasing the number of picks, packs, and shipments made there. In addition, turn-around time on orders improved by two days for orders placed from Ames staff, and by up to five days for orders placed from the field. In addition, the system's real-time stock status reports, combined with on-line links to Iowa DOT storerooms statewide, provide for more accurate and quicker decision-making in response to stock shortages.

The Iowa DOT's central inventory system runs on the mainframe computer (an IBM ES-9000) at the Iowa DOT headquarters and communicates through remote processors in maintenance garages, driver license stations, and regional offices across the state. Stock transfers, issues, and returns are entered on-line at these terminals. These "electronic documents" are proofread by the computer and corrected by the end-user. The supply orders or reports of taken items are submitted for immediate processing by warehouse personnel.

While real-time accounts of stock status throughout the state is possible using this on-line system, the interfacing RFDC system in the central warehouse paves the way for quick responses. In fact, once orders submitted by agencies 200 miles away are sent to the warehouse, workers can respond within seconds. After supply orders entered on-line from across Iowa are officially approved, they are relayed from the mainframe by a RF-link to the warehouse.

Warehouse parts workers, using hand-held terminals equipped with bar code scanners, are instructed with the system's "pick" functions. Each item retrieved is scanned to verify picks. To avoid redundant steps in the warehouse, workers are directed from one order to the next via messages displayed on the hand-held screen.

When a worker's cart is full, it is taken to a staging area where individual boxes are packed for delivery to various locations. Here, the system's "pack" function tells the worker which items on the cart to pack for specific deliveries. Each item and box is scanned to verify the packing process was done correctly.

Other activities utilizing RF-linked terminals are receiving, storing, transferring, cycle-counting, and breakdowns in the Iowa DOT warehouse (Lande 1993).

In the construction industry, the Helmkamp Construction Company Illinois-based firm is using RFDC applications to help track all of its tools valued at $100 or more.

In the utilities industry, bar code-based RFDC is moving into warehouse operations for real-time reporting, especially in automated warehousing operations. Because of recent changes in government regulations, the competition between the power suppliers of the nation is fierce. To withstand the pressure, utility companies are now struggling to keep their overhead as low as possible and are investigating how RFDC and other Auto I.D. technologies can help them do so (Kilbane 1993).

In the medical industry, hospitals and clinics are notorious for acquiring high-tech equipment used to detect and help cure human illness. However, the industry is far less advanced in its adoption of automated record keeping systems (Jeffress 1993). RFDC is gaining ground in this marketplace, as medical facilities look to electronic data management systems for economic answers.

St. Mary's Hospital in Grand Rapids, Michigan, has already benefited from RFDC record keeping. Hospital administrators decided to implement a $400,000 RFDC system for keeping an inventory of pharmaceutical and medical supplies. The system paid for itself within two months by uncovering $200,000 in unnecessary medical supplies purchased each month (Bergerson 1993; Norand Corporation 1993).

Washoe Medical Center in Reno, Nevada, is planning to purchase a $125,000 Teklogix system for assisting materials management personnel and respiratory therapists with inventory, process, and personnel control (Jeffress 1993). The system involves 24 wireless portable terminals and 27-ounce hand-held terminals. Materials management will use the terminals, measuring 10" x 3" x 4" and featuring 16 line by 32 character screens and wand-readers.

In-field tracking and record-keeping appears to be gaining strength as a RFDC market. Industries interested in using RFDC for tracking materials, equipment, operations, and in-field labor include construction, utilities, defense, and transportation industries (Allemeirer 1993; Bell and McCollouch 1988; Glick 1993).

UIG is investigating affixing touch memory buttons to utility poles in-field. Possibly the items' maintenance and other pertinent information will be read by a hand-held scanner which relays the data via RF back to an interfacing terminal. Already, RFDC terminals are being used to relay information from bar coded poles.

B.9 ELECTRONIC DATA INTERCHANGE (EDI)

In the automotive industries, EDI is a growing technology with extensive applications for automotive manufacturers, dealers and suppliers. Initially, all production parts suppliers were directed to accommodate the Just-In-Time (where parts deliveries are taken directly from the trucks to production lines, notably reducing inventories, and creating zero-error settings) environment of the auto industry.

Non-production suppliers are beginning to use EDI. Following the latest statement, a large distribution center in the United States was asked by the major automakers to begin using EDI for its packaging products. Product-related documents, including purchase orders, production releases, advance ship notices, request for quotes, blanket orders, and receipt advises are now being electronically exchanged. Benefits of the EDI system include reduction of order processing by three days, the ability to meet the business transactions needs of their customers, and improved efficiency.

The company, Zellerbach, started using AIAG (Automotive Industry Action Group) standards to communicate electronically computer-to-computer with the auto plants. The PC-based system allows Zellerbach Detroit to exchange information with Ford, General Motors, and Chrysler. Future expansions include the link with the Honda, Toyota, and Mazda (domestic) plants.

In the medical health industry, the U. S. Department of Health and Human Services (HHS) started a nationwide effort to establish an electronic health care information network focusing on electronic billing and claims processing. This EDI-intense system, along with the proposed health insurance card, will conserve an estimated $114 billion between now and the year 2000. The new standardized billing form will be mandatory for medical services by March 31, 1994. This year, electronic billings are paid two weeks faster than manual-paper Medicare claims. In this initiative, ASC X12 EDI standards would be mandatory by the fourth quarter of 1994.

One of the first hospital groups to implement health care electronic payment was St. Joseph Health System in northern California and Texas. Here, the explanation of benefits (EOB's) documents are sent electronically via diskette or modem to hospitals from several reimbursement documents. That information is put directly into the hospital's accounts receivable system. Further enhancement allows the consortium of Catholic hospitals to work on several transaction sets for additional applications. Benefits include the elimination of redundant keypunching, simplification of reconcilement procedures, and simplification of secondary billing procedures.

In motor carrier industries, EDI and bar coding economically solve time-consuming logistical problems. For example, Lindend Motor Freight Co., a freight carrier that delivers goods for J.C. Penney, uses its 486 PC computer to interact with the J.C. Penney central computer located in Dallas, Texas. Information related to shipping and receiving is handled electronically, producing exemption reports and other important documents. After the initial investment, Linden experienced a 18 percent increase in distribution productivity.

In retail, a candy maker uses EDI for automatic stock replenishment. Quick Candy monitors inventory levels of its products at 12 K-mart distribution centers with one on-line EDI system. Sales information is sent electronically from the point of sale to the back room computer at any K-mart store. This information is then transmitted to the regional K-mart distribution center, and to the candy maker when necessary. Finally, sales reports are printed, and it is determined which distribution center needs more of the product. This system has allowed the candy maker to make rapid inventory assessment, and provide the company with raw data for sales projection estimates (Quinn 1993c).

In interfacing with other Auto I.D. systems, EDI is most frequently used today in conjunction with bar coding. Bar code labels provide the data needed for the company's application. Then EDI is used to communicate that data and other related information (e.g., billings and shipping notices) from one company's computer to its trading partner's computer system.

B.10 PEN-BASED COMPUTERS

The United Parcel Service (UPS) use of pen-based computers for digitized signature collection has helped make this technology familiar. Rather than collecting signatures by paper, UPS delivery persons use a pen-based scratch pad to instantly digitize signatures. Then, these signatures are transferred to databases where they are available within hours of delivery (Seideman 1993).

The cargo container shipping industry was introduced to pen-based systems thanks to Sea-Land, the world's largest company in the industry. Sea-Land needed to reduce its turn-around time for moving containers from shore to ship to minimize waiting time for trucks and trains off-loading their cargoes and prevent delays in the ships' departure times. Automating cargo inspection (a paper-based process) was the key. Paper-based cargo inspection involved several steps, each requiring its own paperwork. Inspectors checked each container for physical damage, recorded and verified the container's assigned number, checked customs seals, and routed the containers to the appropriate ship. The process was significantly simplified by Sea-Land's customized application program using hand-held pen-based terminals, each of which was either RF-linked or hard-wired. Inspections now consist mostly of clicking buttons (handwriting-recognition provided high error rates in pilot testing) and Sea-Land has cut its data processing and improved its turn-around, minimizing the trucks' waiting times .

In transportation, the Florida Department of Transportation provides its highway construction inspectors with pen-based computers to report on work activity. Florida bridge inspectors are also testing pen computers to fill out annual forms on about 12,000 bridges, allowing information to be transmitted to central computers at the main office the same day, rather than up to 45 days later if manual processing is used (Gapay 1993).

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APPENDIX C
VENDOR LISTS

Bar Coding:

Husky Computers Inc.
18167 U.S. Highway #19 North
Suite 285
Clearwater, FL 34642
Phone: (813)530-4141
Fax: (813)536-9906
Manufacturer of rugged, MS-DOS, hand-held computers used in a range of integrated field applications.

Intermec Corp.
6001 36th Ave W
PO Box 4280
Everett, WA 98203-9280
Phone: (206)348-2600
Fax: (206)355-9551
Manufactures and sells automated data collection technologies, software & services for information management, including bar coding and RFDC. Products include readers, printers, input devices, and software.

Metalcraft
149 Fourth St SW
Mason City, IA 50401
Phone: (800) 437-5283
Fax: (515) 423-8898
Manufacturer of blank labels, custom metal tags, harsh environment labels, laminated labels, photocomposed labels, preprinted labels, and sequentially numbered labels.

Metrologic Instruments Inc.
PO Box 307
Bellmawr, NJ 08099
Phone: (609) 228-8886
Fax: (609) 228-6673
Manufacturers laser bar code scanning equipment designed to increase efficiency and productivity in every application.

Norand Corp.
550 Second St SE
Cedar Rapids, IA 52401
Phone: 1-(800)-221-9236
Fax: (319) 369-3453

Manufacturer and marketer of portable, computerized data collection systems and hand-held radio frequency terminals used in a wide range of applications.

Panasonic Communications & Systems Co.
2 Panasonic Way, #7B-3
Secaucus, NJ 07094
Phone: (201) 392-6714
Fax: (201) 392-4897

Manufacture a line of wireless hand-held data collection computers.

PSC Inc.
770 Basket Rd
Webster, NY 14580
Phone: 1-(800)-828-6489
Fax: (716) 265-6400

Designs, manufactures, and sells bar code scanning and verification products through a reseller channel consisting of VARs, OEMs, distributors, and dealers.

Seagull Scientific Systems, Inc.
15127 NE 24th, Ste 333
Redmond, WA 98052
Phone: (800) 758-2001
Fax: (206) 451-8982

Manufacturers of bar code reading hardware and printing software for MS-DOS and Windows PCs.

Symbol Technologies
116 Wilbar Place
Bohemia, NY 11716
Phone: (516) 722-6234
Fax: (516) 244-4645

Manufacture & market bar code data capture systems.

Timekeeping Systems Inc.
1306 E 55 St.
Cleveland, OH 44103
Phone: (216) 361-9995
Fax: (216) 361-0030

Manufacturer of the EZBarcode product line of bar code readers, decoder and printing software.

TPS Electronics
2495 Old Middle Field Way
Mountain View, CA 94043
Phone: 1-(800)-526-5920
Fax: (415) 998-0289

Manufacturer of automatic identification equipment, bar code and magnetic stripe readers.

Videx Inc.
1105 NE Circle Blvd.
Corvallis, OR 97330
Phone: (503) 758-0521
Fax: (503) 752-5285
Manufactures portable data collectors, peripherals and software.

RFID:

Advanced Data Collections, USA.
7740 Schrader Rd., Ste. E.
Richmond, VA 23228
Phone: (804) 672-1212
Fax: (804) 672-2020
A system integrator, value-added reseller, and consultant which also sells low frequency RFID systems, RF active and passive, read-only and read/write transponder tags, and active replaceable batteries.

Allen-Bradley
Industrial Control Group
1201 S. Second St.
P.O. Box 2086
Milwaukee, WI 53201
Phone: (414) 382-2000
Fax: (414) 382-2507
A manufacturer and distributor of low and high RFID systems technologies, including active and passive, read-only and read/write transponder tags, and fixed data collection terminals. Also manufactures industrial controls including circuit breakers, coils, contactors, and switches.

Amtech Corp.
17304 Preston Rd., Bldg.. E-100
Dallas, TX
75252
Phone: (214) 733-6600
Fax: (214) 733-6699
A manufacturer of low frequency RFID tags.

Austin Consulting
9801 W. Higgins Rd.
Rosemont, IL 60018
Phone: (708) 696-0500
Fax: (708) 698-6359

A systems integrator and consultant which also sells low frequency RFID systems, RF active and passive, read-only and read/write transponder tags, and active replaceable batteries.

Aztech America
P.O. Box 43200
Detroit, MI 48243
Phone: (313) 963-2048
Fax: (313) 963-2263

A systems integrator, consultant, and software developer, which also handles EDI and bar code labeling systems.

BALOUGH T.A.G.
3990 Varsity Drive
Ann Arbor, MI 48108
Phone: (800) 252-RFID
Fax (313) 971-9007

A manufacturer of passive, read-only or read/write industrial RF tags, positioning systems, proximity sensors, and process control systems.

CardPro Services, Inc.
135 W. 61st
Westmont, IL 69559-2617
Phone: (708) 960-5640
Fax: (708) 960-5631

A distributor, dealer, consultant and manufacturer which also sells low frequency RFID systems, RF active and passive, read-only and read/write transponder tags, and active replaceable batteries.

Compunetics, Inc
Bar Code Division
3863 Rochester
Troy, MI 48083
Phone: (800) 544-6386
Fax: (313) 524-6374

A distributor, value-added reseller, and manufacturer which also sells low frequency RFID systems, active and passive, read-only and read/write transponder tags, and active replaceable batteries.

HTI Corp. (HTIC)
High Technology USA Div. 1210 18th St. NW
Washington, DC 20036
Phone: (800) 648-1641
Fax: (800) 328-2188

Dealer, distributor, system integrator, value-added reseller.

Indala Corp.
711 Charcot Avenue
San Jose, CA 95313
Phone: (408) 7010
Fax: (418) 7057

Manufacturer of RFID products for identification, tracking, control, detection and position of a wide range of objects.

Micron Communications, Inc.
2805 E. Columbia Road, MS: 272
Boise, ID
Phone: (208) 368-4239
Fax: (208) 368-42286

Manufacturer of RFID components and systems with a specialization in large and minute tags of various frequencies.

Texas Instruments Inc.
34 Forest St.
Attleboro, MA 02703
Phone: (508) 699-3800
Fax: (508) 699-3647

A manufacturer of low frequency RFID active and passive, read-only and read/write transponder tags.

QED Systems
P.O. Box 2524
Cedar Rapids, IA 52406-2524
Phone: (319) 364-0202
Fax: (319) 364-8814

A systems design, education, and consulting firm focusing on RFID, bar coding, and EDI technologies.

Rydex, Ltd
118 Center Ave. North
Mitchellville, IA 50169
Phone: (515) 967-0294
Fax: (515) 967-2207

A manufacturer of low frequency RFID tags complete with tamper proof screw tag and installation system.

Touch Buttons:

Control Module Inc.
380 Enfield Street
Enfield, CT 06082
Phone: (800) 722-6654
Fax: (203) 741-6064

A third-party developer which markets IBM-compatible, fixed-station, intelligent time and attendance terminals which reads magnetic stripe cards and bar codes in addition to touch buttons.

Cansec Systems Ltd.
8260 NW 27th Street, Suite 405
Miami, FL 33122
Phone: (305) 477-5267
Fax: (305) 477-4083

A third-party developer which markets stand-alone, programmable readers and writers called "SmartKey," which enable variable door unlock times, changeable commands regarding public or employee-specific access privileges, by-pass features, anti-return passage access, and anti-return passage over-ride privileges.

CSI Control Systems International
1625 W. Crosby RD., Suite 100
Carrolton, TX 75006
Phone (214) 323-1111
Fax: (214) 242-0026

A third-party developer which markets fixed-station touch readers for processing local controllers and door processing units for security systems and "retrofitting" applications.

Dynasys Technologies, Inc.
800 Belleair Road
Clearwater, FL 34616
Phone: (813) 443-6600
Fax: (813) 443-4390

A value-added reseller and third-party developer which markets touch memory probes, communication ports, touch memory keyboards and accompanying software in addition to memory buttons. Also manufactures and resells barcode interfaces, wedges, wands, CCD and laser scanners, hand-held terminals, barcode and receipt printers.

Dynamic Analysis, Inc.
3313 bob Wallace Avenue
Suite 103
Huntsville, AL 35805
Phone: (813) 443-6600
Fax: (813) 443-4390

A third-party developer which markets touch identification tag/keys and tag/key access controller-box supports for door security.

RE Electronics
200 No. Francis Suite 214
P.O. Box 792
Terrell, TX 75160
Phone: (214) 563-2996
Fax: (214) 563-2997

A distributor which sells touch technologies for security, medical, fleet maintenance, and asset tracking systems. Also manufacture and act as a 2nd-party distributor for bar codes, magnetic stripes, and access control technologies.

TEK Electronics
6 Progressive Drive
Manchester, CT 06040
Phone: (203) 647-8738
Fax: (203) 649-7735

A third-party developer which markets a portable, lithium battery-powered touch pen.

Time Data Systems
1113 Military Street
Port Huron, MI 48060
Phone: (313) 984-1313
Fax: (313) 984-5518

A third-party developer which markets a *time and data collection terminal* which performs a multitude of data collection tasks using a built-in magnetic stripe or bar code reader, integral keypad, and touch memory readers in addition to memory buttons. Also develops software.

Videx, Inc.
1105 N.E. Circle Blvd.,
Corvallis, OR 97330
Fax: (503) 752-5285

A third-party developer which markets hand-held 128K touch probes, editors, and accompanying software as well as memory buttons.

Vindicator
3001 Bee Caves Road
Austin, TX 8746
Phone: (512) 314-1200
Fax: (512) 314-1270

A third party developer which sells electronic microprocessor lock systems for safes. Also sell security systems for critical asset protection and intrusion detection.

Magnetic Stripes:

Identification Badges of America
9100 35 W South
Bloomington, MN 55431
Phone: (612) 881-0634
Fax: (612) 888-0304

Produces custom designed magnetic stripe and bar code badges using the exclusive DFII polyester coating.

Cardpro Services
135 West 61st St.
Westmont, IL 60559-2617
Phone: (708) 960-5640
Fax: (708) 960-5631

Manufactures and sells a full line of readers, encoders, and cards.

Card Imaging
760 N. Frontage Rd., Suite 102
Willowbrook, IL 60521
Phone: (708) 325-9099
Fax: (708) 325-9105

Sells encoders, magnetic stripe cards, photo ID equipment, and bar code cards.

Magtek
20725 S. Annalee Ave.
Carson, CA 90746
Phone: (310) 631-8602
Fax: (310) 631-3956

Manufactures and sells readers and encoders.

Northern Computers, Inc.
5007 S. Howell Ave.
Milwaukee, WI 53207
Phone: (414) 769-5980
Fax: (414) 769-5989

Specializes in access control and security systems and includes readers and software for magnetic stripe cards.

Pannier Marking Systems
207 Sandusky St Pittsburgh, PA 15212
Phone: (412) 323-4900
Fax: (412) 323-4962

Manufacturers magnetic stripe encoders.

IdentoGraph Corp.
40 Elm St.
Dryden, NY 13053
Phone: (607) 844-9306
Fax: (607) 844-8031

Manufactures and sells badges, magnetic stripe cards, encoders, readers, photoidentification equipment, printers, slot scanner/reader, smart card products and services, and bar coding and bar code label software.

Identicard Systems
630 E. Oregon Rd.
Lancaster, PA 17601
Phone: (717) 569-5797
Fax: (717) 569-2390

Manufactures and sells badges; magnetic stripe: cards, media, and readers; scanners; and software. Also video imaging and access control technologies.

Identatronics, Inc.
425 Lively Blvd.
Elk Grove Village, IL 60007-2082
Phone: (708) 437-2654
Fax: (708) 437-2660

Manufactures and sells badges; magnetic stripe: cards, encoders, media; maintenance, printers, and software. Customized ID card including magnetic stripes, bar codes, and video imaging. Also sells cameras, photo cutters and laminators; assorted laminating supplies; provides maintenance.

Video Logging:

Mandli Communications Inc.
2211-D Parview Road
Middleton, WI 53562
Phone: (608) 836-3344
Fax: (608) 836-8176

Develops, manufactures, and markets complete video logging systems.

Roadware Corporation
1 Roadway Drive
Box 209
Kylertown, PA 16487
Phone: (814) 345-6938
Fax: (814) 345-6943

Develops, manufactures, and markets complete video logging systems including specialty vans.

GPS:

AT & T Bell Labs-Global Product Compliance Laboratory 101
Crawford Corners Rd.
P.O. Box 3030
Holmdel, NJ 07733-3030
Phone: (908) 834-1800

Garmin International
9875 Widmer Road
Lenexa, KS 66215
Phone: (913) 599-1515
Fax: (913) 599-2103

Magnavox Nav-Com, Inc.
9 Brandywine Drive
Deer Park, New York 11729
Phone: (516) 667-7710
Fax: (516) 667-2235

Motorola, Inc.
1303 E. Algonquin Rd.
Schaumburg, IL 60196
Phone: (708) 397-5000
Fax: (708) 576-3258

Panasonic Industrial CO.
1 Panasonic Way
Secaucus, NJ 07094-2917
Phone: (201) 348-9090
Fax: (201) 392-4010

Collins Avionics and Communications Division
Rockwell International Corp.
350 Collins Road NE
Cedar Rapids, IA 52498
Phone: (319) 395-2789
Fax: (319) 395-3775

Trimble Navigation
675-J Tollgate Rd.
Elgin, IL 60123
Phone: (708) 931-0076
Fax: (708) 931-0166

Voice Recognition:

CompuSpeak Laboratories
15095 W 116 St.
Olathe, KS 66062-1098
Phone: (913) 491-3444
Fax: (913) 491-9399

Developer and manufacturer of systems solutions specializing in voice recognition, imaging and other data input technologies.

Covox, Inc.
675 Conger St.
Eugene, OR 97402
Phone: (503) 342-1271
Fax: (503) 342-1283

Manufactures and sells speech processing and voice recognition hardware and software systems for IBM PC and compatible computers. Also sells listen for windows, which allows users to use Microsoft Windows applications via voice commands.

Verbex Voice Systems, Inc.
1090 King George's Post Rd., Bldg. 107
Edison, NJ 08837
Phone: (908) 225-5225
Fax: (908) 225-7764

Manufactures and sells continuous speech recognition products. These products are available as full turnkey integrated solutions or as PC boards, portables, and stand-alone models.

Vocollect
664 Linden Ave
East Pittsburgh, PA 15112
Phone: (412) 829-8145
Fax: (412) 829-0972

Provides products for the real-time collection and dissemination of information in factories and warehousing using computer-based voice input/output technology.

Voice Connexion
17835 Sky Park Circle, Ste C
Irvine, CA 92714
Phone: (714) 261-2366
Fax: (714) 261-8563

Manufacturer of voice recognition and synthesis products. Also provides research and development and systems integrations.

OCR:

Ban-Koe Systems, Inc.
9100 W. Bloomington Freeway
Minneapolis, MN 55431-2200
Phone: (612) 888-6688
Fax: (612) 888-0304

System integrator, value-added reseller, distributor, dealer; also has a bar code division.

BCE Technologies, Inc.
620 Ware BLVD.
Tampa, FL 33619
Phone: (813) 621-8128
Fax: (813) 620-1206

Manufacturer for food manufacturing products, groceries, raw materials processing, warehousing/distribution. Sells applications in inventory control, order entry, production control, warehouse management, and work-in-process.

Character Technologies, Inc. (CTI)
8 Fourfield Crescent
West Coldwell, NJ 07006
Phone: (201) 882-6433
Fax: (201) 575-7879

Manufacturer, system integrator, value-added reseller. Asset management, document management, inventory control, time and attendance, and warehouse management.

CIE America
2515 McCabe Way
Irvine, CA 92714
Phone: (800) 877-1421
Fax: (714) 757-4488

Manufacturers optical character recognition printers, inventory control, package tracking/delivery, production control, shipping and receiving, and warehouse management.

Computer Recognition Systems, Inc.
639 Massachusetts Ave..
Cambridge, MA 02139
Phone: (617) 491-7665
Fax: (617) 491-7753

Manufactures, develops, and sells OCR systems and applications which include speed limit control, traffic counts, traffic management, among others.

Dataflo Corporation
11126 Q St.
Omaha, NE 68137
Phone: (402) 592-5517
Fax: (402) 592-9245

System Integrator, consultant, and distributor of data entry devices, including OCR technologies, bar code scanners, and printers. Primary applications are sold in asset management, inventory control, item tracking, shipping and receiving, and time and attendance. Mainly markets to distribution and manufacturing industries.

Digi Postal Corp.
11135 W. 79th St.
Lenexa, KS 66214
Phone: (913) 492-3444
Fax: (913) 541-1683

Distributor, system integrator, manufacturer, and value-added reseller. Applications in item tracking, labor reporting, package tracking/delivery, point-of-sale, and shipping and receiving.

Effective Management Systems, Inc. (EMS)
12000 West Park Place
Milwaukee, WI 53224-3026
Phone: (414) 359-9800
Fax: (414) 359-9011

Value-added reseller, distributor, dealer, and consultant dealing with applications in factory floor data collection, inventory control, job costing, labor reporting, and time and attendance.

Entry Technology, Inc.
Cream Ridge Professional Ctr.
PO Box 139
Cream Ridge, NJ 08514
Phone: (609) 758-0900
Fax: (609) 758-0602

System integrator, manufacturer, consultant, and value-added reseller which deals with applications in inventory control, lot tracking, production control, and warehousing/distribution, and primarily turnkey label verification systems.

Fargo Electronic, Inc.
7901 Flying Cloud Drive
Eden Prairie, MN 55344
Phone: (612) 941-9470
Fax: (612) 941-7836

Develops applications in asset management, inventory control, package tracking/delivery, shipping & receiving, and warehouse management.

Monarch Marking Systems
PO Box 608
Dayton, OH 45401
Ph. (800) 543-6650
Fax (513) 865-6605

Manufacturer of labels and bar code equipment. System integrator for applications in inventory control, point-of-sale, production control, shipping and receiving, and work in process.

QED Systems
PO Box 2524
Cedar Rapids, IA 52406-2524
Phone: (319) 364-0212
Fax: (319) 365-8814

Consultant and system integrator for applications in factory floor data collection, inventory control, shipping and receiving, and warehouse management.

Tharo Systems, Inc.
2967 Nationwide Pkwy. #5
P.O. Box 798
Brunswick, OH 44212
Phone: (216) 273-4408
Fax: (216) 225-0099

Develops and sells application hardware and software mainly in inventory control.

Zebra Technologies, Inc.
333 Corporate Woods Pkwy.
Vernon Hills, Il 60061
Phone: (708) 634-6700
Fax: (708) 913-8766

Manufacturer of applications in factory floor data collection, inventory control, package tracking/delivery, shipping and receiving, and warehouse management.

GIS:

Byers Engineering Company
6285 Barfield Road
Atlanta, GA
Phone: (404) 843-1000
Fax: (404) 843-1004

Consulting engineering firm which offers computer graphics service.

Caliper Corporation
1172 Beacon St., Suite 302
Newton, MA 02161
Phone: (617) 527-4700
Fax: (617) 527-5113

Transportation consultants who do software development and offer customization services.

Decision Images, Inc.
9 Charlton Street
Princeton, NJ 08540
Phone: (609) 683-0234
Fax: (609) 683-4068

Develops and sells software, does consulting, offers digitizing and spatial analysis packages.

Enghouse Systems, Ltd.
80 Tiverton Court, Suite 800
Markham, Ontario, Canada L3R OG4
Phone: (905) 477-1212
Fax: (905) 477-1466

Provides automated mapping systems, does software development in automated mapping facility management, and provides consulting services.

Environmental Systems Research Institute (ESRI)
380 New York Street
Redlands, CA 92373
Phone: (909) 793-2853
Direct Sales: (909) 793-2853 ext. 1375
Fax: (909) 793-5953

Provides computers, peripherals, and software for GIS systems and natural resource research services.

Facility Mapping Systems, Inc.
38 Miller Ave., Suite 11
Mill Valley, CA 94941
Phone: (800) 442-3674
Fax: (415) 381-9604

Software development, strategic developers, consulting as part of a sale, sell through resellers and through above office.

Genasys II, Inc.
2629 Redwing Rd., Suite 330
Ft. Collins, CO 80526
Phone: (800) 447-0265
Fax: (303) 226-0869

Develops UNIX-based GIS systems, complementary products for GIS software. Provide training, support, and consulting.

IBM Corporation
Old Orchard Road
Armonk, NY 10504
Phone: (914) 765-1900
Fax: (518) 274-6066

Develops mainframe computers, minicomputers, personal computers (microcomputers), typewriters and parts, computer peripheral equipment, computer printers, computer storage devices, computer terminals, application computer software, GIS software, operating systems computer software.

Information and Graphics Systems, Inc.
2511 55th Street, Building C
Boulder, CO 80301-9692
Phone: (800) 447-4630
Fax: (303) 449-1298

Computer software development.

Intergraph Corporation
One Madison Industrial Park
Huntsville, AL 35894-0001
Phone: (205) 730-2000
Fax: (205) 730-3300

Provides computer integrated systems design, computer-aided design (CAD) systems service, computer-aided engineering (CAE) systems service, computer-aided manufacturing (CAM) systems service, electronic computers, computer peripheral equipment, GIS software.

MapInfo Corp.
One Global View
Troy, NY 12180-8399
Phone: (800) 552-2571
Direct Sales: (800) 327-8627
Fax: (518) 285-6070

Provide data visualization and analysis software.

RJN Group, Inc.
202 W. Front St.
Wheaton, IL 60187
Phone: (800) 227-7838
Fax: (708) 682-4754

Provides software that may be integrated with CAD/GIS related to facilities management, engineering documents management, scheduled maintenance, inspection and testing, hydraulic modeling, pavement management, parks and recreation management. Perform software development, system integration, consulting, infrastructure rehabilitation, and maintenance management.

Strategic Mapping, Inc.
3135 Kifer Road
Santa Clara, CA 95051-0804
Phone: (800) 442-8887
Fax: (408) 970-9999

Software developers of mapping and GIS, accumulate databases related to demographics and specific industries.

System Dynamics, Corp.
151 Esna Park Dr.
Markham, Ontario, Canada L3R 3B1
Phone: (905) 475-5155
Fax: (905) 475-9378

Offers software development and support.

Westinghouse Electronic Systems Ventures, Inc.
Subsidiary of Westinghouse Electric Corp.
11 Stanwix Street
Pittsburgh, PA 15222-1384
Phone: (412) 244-2000
Fax: (412) 642-3404

Provide computers, business oriented computer software.

RFDC:

AccuScan, Inc.
1540 Highway 138
P.O. Box 80037
Conyers, GA 30208
Phone: (800) 950-0101
Fax: (404) 922-0368

A systems integrator, manufacturer, value-added reseller, and consultant which also sells fixed and portable RFDC software, antennas, terminals, modems, network technology, and scanners—both fixed-station (diode laser, helium neon laser, and omnidirectional) and hand-held (contact wand, diode laser, and helium neon laser).

Advanced Data Systems USA
7740 Shrader Rd., Ste. E
Richmond, VA 23228
Phone: (804) 672-1212
Fax: (804) 672-2020

A system integrator, value-added reseller and consultancy which also sells RFDC software, antennas, modems, network technology, and scanners—both fixed-station (combined OCR and bar code, CCD, diode laser, helium neon laser, and omnidirectional) and hand-held (combined bar code and OCR, contact wand, CCD, diode laser, helium neon laser).

Automated Dimensions, Inc.
268 W. Hospitality Lane
Ste. 200
San Bernadino, CA 92408
Phone: (909) 889-3838
Fax: (909) 889-2630
A value-added reseller, system integrator, consultant, distributor, and dealer which also sells RFDC software, antennas, modems, network technology and scanners—both fixed-station (LED contact, combined OCR and bar code, CCD, diode laser, helium neon laser, and omnidirectional) and hand-held (combined bar code and OCR, contact wand, CCD, diode laser, helium neon laser).

Avery Dennison Corp.
Soabar Systems Div.
7722 Dungon Rd.
Philadelphia, PA 19111
Phone: (215) 725-4700
Fax: (215) 725-4717
A manufacturer and systems integrator which also sells data collection terminals including hand-held computers, EDI products and services, smart card products and services, label applicators, converters and services, and harsh-environment label technologies as well as RFDC scanners—both fixed-station (combined bar code and OCR and diode laser) and hand-held (combined bar code and OCR, diode laser).

AT&T
Network/Manufacturing Systems
2 Oak Way
Berkeley Heights, NJ 07922
Phone: (800) 253-2346
Fax: (908) 771-3180
A manufacturer, systems integrator and consultancy which also sells RFDC software, network technology, and scanners—both fixed-station (badge type slot-scanner readers) and hand-held (combined bar code and OCR).

Barcode Data Systems, Inc.
19100 Detroit Rd.
Cleveland, OH 44116
Phone: (216) 333-9080
Fax: (216) 333-8288
A systems integrator, value-added reseller, manufacturer, consultant, dealer and distributor which also sells RFDC software, antennas, modems, network technology, scanners—both fixed-station (LED contact type, badge type slot/scanner reader, CCD, diode laser, and omnidirectional) and hand-held (combined bar code and OCR, contact wand, CCD and diode laser).

Data Collection Systems, Inc.
5959 Baker Rd.
Minnetonka, MN 55345
Phone: (612) 938-6461
Fax: (612) 938-2944

A systems integrator, value-added reseller and consultant which also sells RFDC software, antennas, modems, network technology, counting scales and scales systems, and scanners.

Easy Software Systems, Inc.
8 Lee Park Ave.
Wikes-Barre, PA 18702
Phone: (717) 823-5152
Fax: (717) 823-7998

A manufacturer, systems integrator, value added reseller, and consultant which also sells RFDC software, antennas, modems, network technology and scanners—both hand-held and fixed.

Hand Held Products
8008 Corporate Center Dr.
Charlotte, N.C. 28226
Phone: (704) 541-1380
Fax: (704) 541-1333

Manufactures lightweight integrated RF scanners including field upgradable contact and non-contact scanners.

Motorola
Wireless Data Group
11411 Number Five Rd.
Richmond, British Columbia
V7A 4Z3, Canada
Phone: (604) 241-6126
Fax: (604) 241-6042

Manufacturer, value-added reseller, and distributor. Product line includes communications processors, data communication terminals (radio linked portable, radio frequency data communications, and modems).

Norand Corp.
Radio Frequency Division
550 2nd St. S. E.
Cedar Rapids, IA 52402
Phone: (800) 553-5971
Fax: (319) 369-3453

A manufacturer and marketer of portable computerized data collection systems and handheld radio frequency terminals used in a wide range of applications.

Teklogix
U.S. Headquarters
7914 Tanners Gate
Florence, Kentucky 41042
Phone: (800) 633-3040
Fax: (606) 371-6422

A manufacturer which sells RFDC antennas, modems, network technology, and hand-held scanners. Also sells RFID systems technology.

Peak Technologies Group, Inc.
315 West University Drive
Arlington Heights, IL 60004
Phone: (800) 950-6372
Fax: (708) 255-8856

A national distributor and integrator of bar code data collection systems. Peak sells equipment from major manufacturers and is able to combine it with software and services to solve data collections problems.

QED Systems
P.O. Box 2524
Cedar Rapids, IA 52406-2524
Phone: (319) 364-0212
Fax: (319) 365-8814

System integrator of biometric identification and communication processors; consultants on data collection terminals (e.g., clipboard/graphic data entry devices, handheld computers, and radio linked products).

Telxon Corporation
5929 Baker Road Suite 430
Minnetonka, Minnesota 55345-5955
Phone: (612) 933-1450
Fax: (612) 933-3177

Manufacturer, system integrator, and consultant for biometric identification, communications processors, and data collection terminals.

United States Data Corporation (USDATA)
2435 N. Central Expressway
Richardson , TX 75080
Phone: (214) 680-9700
Fax: (214) 669-9557

Full-service distributor and system integrator of Auto ID products, software and systems offering nationwide sales, service and support. Products include Symbol, Norand, PSC, Zebra, SATO, Printronix, and others.

Universal Data Inc.
7183 M-15
Clarkston, MI 98346
Phone: (810) 625-3763
Fax: (810) 625-3764

Marketing firm which deals with data collection terminals, antennas, modems, network technology, and software applications

EDI:

ABC-American Business Computer
24 Frank Lloyd Wright Drive, Lobby B, PO Box 305
Ann Arbor, MI 48106-0305
Phone: (313) 930-3200
Fax: (313) 930-3201

Provides DOS- or UNIX-based EDI software to over 1000 automotive customers.

Advantis
3407 W. Dr. M.L. King, Jr. Blvd
Tampa, Fl 33607
Phone: (800) 284-5849
Fax: (813) 878-5298

Provides a full range of e-mail and EDI services and software including translation software, trading partner communications, and installation services.

American Custom Software
2420 Fisk Rd.
Cookeville, TN 38501
Phone: (615) 537-6516
Fax: (615) 537-6519

Provides advice and assistance to companies implementing EDI or bar coding systems; provides programming services.

Aztech America
P.O. Box 43200
Detroit, MI 48243
Phone: (313) 963-2048
Fax: (313) 963-2263

Systems integrator/software developer. Work with EDI communications and data collection, consulting, installation, programming, support, and training.

The EDI Group, Inc.
221 Lake St.
Oak Park, IL 60302
Phone: (708) 848-0135
Fax: (708) 848-0153

Provides education, publications and research to the EDI marketplace.

Telink Systems Inc.
19650 Club House Rd.
Gaithersburg, MD 20879
Phone: (301) 670-0811
Fax: (301) 590-9284
Provides EDI translation software and services, mapping applications for DOS and Unix. Provide training, education, consulting, and customizing services.

EDI, Spread the Word!
3331 Towerwood, Ste 304
Dallas, TX 75234
Phone: (214) 243-3456
Fax: (214) 243-7265
Publishes EDI Yellow Pages International and EDI Bookstore and offers consulting, research and executive search in EDI and quick response.

EDS
750 Tower Drive
Troy, MI 48098
Phone: (313) 265-9273
Fax: (313) 265-9253
Leading provider of information technology services world-wide, includes both auto - ID and non-Auti ID, GPS, GIS, others.

Harbinger EDI Services
1055 Lenox Park Blvd.
Atlanta, GA 30319
Phone: (404) 841-4334
Fax: (404) 841-4399
Provides PC-based EDI software, VAN services, implementation services and consulting services for businesses.

Management Information Systems Group (MISG)
10 Laboratory Dr., PO Box 13966
Research Triangle Park, NC 27709-3966
Phone: (919) 549-8700
Fax: (919) 549-8733
Provide EDI network services, software and support.

Oakland Software Corporation
7031 Orchard Lake Rd., Ste 303
W. Bloomfield, MI 48322
Phone: (810) 855-6155
Fax: (810) 855-6195
Provide EDI network services, software and support. Introducing EDI software for Microsoft Windows.

Sterling Software
Network Services Division
4600 Lakehurst Ct., PO Box 7160
Dublin, OH 43017-0760
Phone: (614) 793-7000
Fax: (614) 793-7092

Leading supplier of EDI network services and software, and also offers EDI implementation programs, database services, communications software, consulting and EDI education.

St. Paul Software, Inc.
754 Transfer Road
St. Paul, MN 55114
Phone: (612) 641-0963
Fax: (612) 641-0609

Service supplier of EDI-UNIX and PC products/services.

Supply Tech, Inc.
1000 Campus Drive
Ann Arbor, MI 48104
Phone: (313) 998-4000
Fax: (313) 998-4099

Provide EDI and barcoding software for IBM PC and IBM mainframes.

Pen-based Computers:

Apple Computer, Inc.
20525 Mariani Ave.
Cupertino, CA 95014
Phone: (408) 996-1010
Fax: (408) 974-9974

AT&T/EO
800A E. Middlefield Rd.
Mountain View, CA 94043
Phone: (800) 458-0880

AST Research
7 Village Circle
Westlake, TX 76262
Phone: (817) 491-5200
Fax: (817) 491-5983

Inforite
1670 S. Amphlett Blvd., Ste. 100
San Mateo, CA 94402
Phone: (800) 366-4635
Fax: (415) 571-7547

NEC Technologies, Inc.
1414 Massachusetts Ave.
Boxborough, MA 01719
Phone: (508) 264-8000
Fax: (508) 264-8673

APPENDIX D
COVER LETTER AND SURVEY

April 25, 1994

«title» «firstname» «lastname»
«position»
«address»
«city», «state» «zip»

Dear «title» «lastname»;

Iowa State University has been funded by the Iowa Highway Research Board to investigate the use of advanced field data acquisition technologies such as bar coding, voice recognition, and pen-based computers to assist the state, cities, and counties in more efficiently collecting field data. It is hoped that these technologies will improve management programs in such areas as signs, pavement, bridges, traffic, and maintenance.

The purpose of the attached survey is to understand your current field data collection approach and your interest level in using advanced techniques to enhance your field data collection process. Ideally, this questionnaire should be filled out by someone who has knowledge about your organization's current data collection approach. Please fill out the survey and return it to me as soon as possible. Information will be held in the strictest of confidence. As a token of our appreciation, a copy of the results will be sent to you.

Thank you for your participation. If you have any questions or would like additional information, please call me at (515) 294-0250.

Sincerely,

Edward J. Jaselskis
Assistant Professor

enc.

Field Data Acquisition Technologies For Iowa Transportation Agencies Survey

Iowa State University has been funded by the Iowa Highway Research Board to investigate the use of advanced field data acquisition technologies such as bar coding, voice recognition, and pen-based computers to assist the state, cities, and counties in more efficiently collecting field data related to such programs as signs, pavement, bridges, traffic, and maintenance. This survey consists of four parts: Part I includes information regarding the respondent, Part II addresses questions related to your current field data collection approach, Part III indicates your interest level in using advanced data collection technologies to capture a variety of field data, and Part IV identifies your willingness to share additional information regarding this survey. Ideally, this survey should be filled out by someone who has knowledge about your organization's current data collection process. Information that you provide will be held in the strictest of confidence. Please return your completed survey in the pre-addressed envelope provided by March 20. If you have any questions please contact:

Professor Edward J. Jaselskis
450 Town Engineering Building
Iowa State University
Ames, IA 50011
Telephone: (515) 294-0250
Fax: (515) 294-8216

Part I: Respondent Information

Name: ____

Title: ____

Agency: ____

Address: ____

Telephone: ______________________ Fax: ______________

Part II: Current Field Data Collection Approach

1. **Directions:** Please place a (√) next to the management programs listed in Table 1 that are the responsibility of your agency. Under the "Field" heading, place an "M" if the field data is manually collected using paper forms, a "C" if the data is entered into a computer in the field, or "B" for both. Under "Transmittal", please indicate the method by which you deliver the field data to your office. The following are a list of possible choices: "Fax", "Phone", "Modem", or "Hand carry." Under "Office", please place an "M" if the data for that program is stored in paper format in your office, or a "C" if the data is stored in a computer, or "B" for both. Under "Software", please indicate the

name of the software used for each management program. Please feel free to add any other programs not included in this list.

Table 1. Current Field Data Collection Approach

✓	Program	Field	Transmittal	Office	Software	
					Field	Office
	Sign Management (e.g., field and warehouse inventory)					
	Pavement Management (e.g., pavement inspection)					
	Bridge Management (e.g., bridge inspection)					
	Traffic Management (e.g., signal inspection and accident counts)					
	Parking Management (e.g., parking lot surveys)					
	Surveying (e.g., utility location data collection)					
	Safety Programs (e.g., accident location identification)					
	Maintenance Management (e.g., bridges, culverts, and signs)					
	Construction Management (e.g., material, labor, and tool tracking)					
	Others?					

Field and Office	Transmittal
M=Manual; **C**=Computer; **B**=Both	**H**=Hand carry; **F**=Fax; **P**=Phone; **Mo**=Modem

2. Please describe the type and quantity of computer hardware used by your agency.

Field Computer Hardware (e.g., PCs, lap tops, and pen-based computers):

Total Quantity: ______________________________

Type(s) and Quantity(ies): ______________________________

____

____

Office Computer Hardware (e.g., PCs, mainframe and minicomputers, and portables):

Total Quantity: ______________________________

Type(s) and Quantity(ies): ______________________________

____

____

Part III: Interest Level in using Advanced Field Data Collection Technologies

3. **Directions:** In Table 2, please indicate your level of interest in using various advanced field data collection technologies (refer to appendix for a brief description of each). Acceptable responses are listed below:

1: Not Interested
2: Somewhat Interested
3: Very Interested

I: Implemented

Please fill out as much as you can and leave spaces blank if you have difficulty understanding a particular technology.

Part IV: Willingness to Share Additional Information

4. Would you be willing to share additional information regarding your current field data collection approach and/or your interest level in using advanced data collection technologies in your organization? Please circle your response.

YES/NO

Thank you for your participation.

A copy of the survey results will be sent to you as soon as it is complete.

Table 2. Interest Level in using Advanced Field Data Collection Technologies

	Technologies[1]																
	Data Storage				Recognition Technologies				F.R.S.[1]		D.T.[1]		Field Portable Computers			Others, please specify	
Program	Bar Coding	Radio Frequency Identification	Touch Buttons	Magnetic Stripes	Optical Character Recognition	Voice Recognition	Video Logging	Advanced Imaging	Global Positioning Systems	Geographic Information Systems	Radio Frequency Data Communications	Electronic Data Interchange	Pen-Based Computers	Lap-Top Computers	Hand-Held Computers		
Sign Management (e.g., field and warehouse inventory)																	
Pavement Management (e.g., pavement inspection)																	
Bridge Management (e.g., bridge inspection)																	
Traffic Management (e.g., signal inspection and accident counts)																	
Parking Management (e.g., parking lot surveys)																	
Surveying (e.g., utility location data collection)																	
Safety Programs (e.g., accident location identification)																	
Maintenance Management (e.g., bridges, culverts, and signs)																	
Construction Management (e.g., material, labor, and tool tracking)																	
Others?																	

1 = Not Interested; **2** = Somewhat Interested; **3** = Very Interested; **I** = Implemented

[1] Refer to Appendix for Descriptions

SURVEY APPENDIX
DESCRIPTION OF FIELD DATA ACQUISITION TECHNOLOGIES

DATA STORAGE

1. BAR CODING: Description: Self-contained message with information encoded in the widths of black bars and white spaces in a printed manner. Bar coding offers higher speed and better accuracy (1 error/million versus 1 error/300) compared to manual systems. Components: Labels, symbology (UPC and Code 39 are the most popular), readers, and printers.

2. RADIO FREQUENCY IDENTIFICATION (RFID): Description: Technology in which radio frequencies are used to capture and transmit data. RFID can be used for distances up to 324 feet, store up to 64,000 bits of data, withstand extreme temperatures, and no line-of-sight is required. Components: A tag, chip, or transponder (passive or active, and read only or read/write), the antennae, the reader or scanner, and the RF link.

3. TOUCH BUTTONS: Description: Technology in which a memory chip is enclosed in a button-shaped stainless steel package. Data is transferred to a probe or "toucher." Chips are both read and write. This technology offers absolute traceability, adaptability, extendable surface for touching, multidrop capability, active or passive capabilities, and accuracy. In addition, low cost is one of this technology's greatest benefits. Components: The touch memory button, at least one Touch Pen, at least one editor, a personal computer, and several touch transporters (optional).

4. MAGNETIC STRIPES: Description: Magnetic stripes is a technology in which the data are stored on the stripe by magnetizing zones with alternating polarities. The amount of information that can be stored on the stripe depends on the length of the stripe and on the application. Magnetic stripes can hold more information than a bar code label. Components: The magnetic stripe card, the encoder, the reader, and the software.

RECOGNITION TECHNOLOGIES

OPTICAL CHARACTER RECOGNITION (OCR): Description: Technology that utilizes machines to automatically identify human-readable symbols and then transfer their identities into machine-readable codes, so they can be further manipulated by data processors. Components: A means of input for raw data entry, a method of transport for the movement of a document in format of the OCR scanner, a scanner, feature extraction and classification logic, and output.

VOICE RECOGNITION: Description: Voice technology allows the interaction between humans and computers by using speech. Some characteristics are: Hands - free and Eyes-free, voice synthesis and voice recognition. Also, voice recognition systems can offer discrete or continuous speech recognition, speaker-dependents or speaker-independent features, noise reduction capabilities, and a limited vocabulary. Components: Personal Computer (PC), circuit board inserted into PC or portable unit, microphone and speakers, and software.

VIDEO LOGGING: Description: Video logging involves the use of a vehicle and video equipment to record roadway and roadside features. Features that may be measured or located utilizing video logging include pavement condition, pavement width, sign location, shoulder width, length of curves, degree of curves, superelevation, and transverse slope. Video logging is used to record a road inventory for later review in the office. Components: video camera(s), VCR, monitor.

ADVANCED IMAGING: Description: Advanced imaging involves the transferral of video images, whether from video or photographs, into digital images that may be retained by a computer system. The digital images may be stored in computers or on disks or CDs and may also be transmitted via Internet services and FAX lines. Internet services include FTP (file transfer protocol) archives, mailing lists, news groups (USENET), and gopher systems. Components: printer, computer, software, digitizing hardware, displays, cameras, Internet and phone lines, and photo CD systems

FIELD REFERENCING SYSTEMS (F.R.S.)

GLOBAL POSITIONING SYSTEMS (GPS): Description: GPS, or satellite surveying systems, allow an object to be located in terms of longitude, latitude, and altitude based on observations of signals transmitted from satellites. Components: The most important component is the GPS geodetic receiver. Satellite usage is free at this time.

GEOGRAPHIC INFORMATION SYSTEMS (GIS): Description: GIS are computerized database management systems for the capture, storage, retrieval, and display of spatial data. GIS primarily contain map information stored digitally in a database. Components: Hardware, the software, the procedures, and the data.

DATA TRANSMITTAL (D.T.)

RADIO FREQUENCY DATA COMMUNICATIONS (RFDC): Description: Links the collected data (using any Auto I.D. technology) and transmits it to the central controlling computer using radio frequency. The primary application is warehousing. It offers on-line connection between field operations and the central computer. Components: Source of automated data collection, scanners, readers, hand-held terminals, the RF link, and the power sources.

ELECTRONIC DATA INTERCHANGE (EDI): Description: EDI is the intra-Company electronic exchange of data using nationally approved standard formats.

Current standards are: ASC X12 and EDIFACT. Some benefits are: improved accuracy, reduction of data entry, enhanced relationships between companies, reduced paper flow, and standardized procedures. Components: Application software, translation software, and the communication network (point-to-point or VANs).

FIELD PORTABLE COMPUTERS

PEN-BASED COMPUTERS: Description: Pen-based computers use the screen, a special pen attached to the computer, and specialized software to allow direct screen entry of data. They offer handwriting recognition, software navigation, and position control. There are four operating systems, the most common being Pen-Point and PenWindows. Some benefits are: ease to use, one-handed operation, no moving parts, silent operation, and fine motor control.

LAPTOP COMPUTERS: Description: Laptops or notebooks are portable computers, usually weighing less than 10 pounds, that can be taken to the field and include screen, CPU, and keyboard. These computers can be IBM or Macintosh compatible, and provide performance and mobility. Key features to be considered are: availability of an external video connector and an external keyboard port, battery life, integrated pointing device, PCMCIA slots (to include modems, network adaptors, and storage devices), roughness, and a removable hard drive.

HAND-HELD COMPUTERS: Description: Hand-held computers are lightweight, ergonomic devices that can fit into a jacket pocket or a small carrying case. Most hand-held computers provide similar performance to a PC XT. However, models with powerful 386 processors are found actually. They also provide ports for attaching external devices such as bar code readers, printers and wired or radio frequency transmittal tools. Screen size, roughness, available software, and battery life are some features that can be considered when selecting a hand-held computer.

APPENDIX E

SOFTWARE USED IN THE FIELD

No.	Program	Software
1	CM	BASIC
2	CM	LOTUS 123
3	CM	LOTUS 123
4	CM	LOTUS 123
5	CM	PC FILE
6	MM	IN-HOUSE
7	MM	IN-HOUSE
8	MM	TOTAL STATION
9	PARK	AUTOCITE
10	PM	CARTER
11	PM	CARTER FLD INV
12	PM	TOTAL STATION
13	SM	IN-HOUSE
14	SM	LOTUS 123
15	SM	PC FILE
16	SM	SMS
17	SURV	AUTOCAD
18	SURV	CAICE
19	SURV	DATA COLLECTOR
20	SURV	DATA COLLECTOR
21	SURV	DATA COLLECTOR
22	SURV	DATA COLLECTOR
23	SURV	DATA COLLECTOR
24	SURV	EDS
25	SURV	EDSC
26	SURV	GEO-DAT
27	SURV	GEODIMETER
28	SURV	LEITZ
29	SURV	LEITZ
30	SURV	LEITZ
31	SURV	LEITZ
32	SURV	LEITZ
33	SURV	SDC
34	SURV	SDC
35	SURV	SDMS
36	SURV	SDR 33
37	SURV	SOKKIA
38	SURV	SOKKIA
39	SURV	SURVEY STATION
40	SURV	TDS
41	SURV	TOPCON
42	SURV	TOTAL STATION
43	SURV	TOTAL STATION
44	SURV	TOTAL STATION
45	SURV	ZEISS REC500
46	TM	TAS PLUS
47	TM	TCC

SOFTWARE USED IN THE OFFICE

No.	Program	Software
1	BM	CARTER
2	BM	CLARIS
3	BM	DBASE
4	BM	DBASE
5	BM	DBASE
6	BM	DBASE
7	BM	ENABLE
8	BM	IBM FIL&REP
9	BM	IN-HOUSE
10	BM	IN-HOUSE
11	BM	LOTUS 123
12	BM	LOTUS 123
13	BM	LOTUS 123
14	BM	LOTUS 123
15	BM	MS WORD
16	BM	PC FILE
17	BM	PC FILE
18	BM	PC FILE
19	BM	PONTIS
20	BM	PONTIS
21	BM	POWER BASE
22	BM	SMS
23	BM	SOLUTIONS
24	BM	SPREADSHEET
25	BM	SYMPHONY
26	BM	WORKS
27	BM	WORKS
28	BM	WP
29	CM	BASIC
30	CM	CLARIS
31	CM	CLARIS
32	CM	CMS
33	CM	CMS
34	CM	DBASE
35	CM	DBASE
36	CM	EXCEL
37	CM	IN-HOUSE
38	CM	IN-HOUSE
39	CM	LOTUS 123
40	CM	LOTUS 123
41	CM	LOTUS 123
42	CM	LOTUS 123
43	CM	LOTUS 123
44	CM	LOTUS 123
45	CM	LOTUS 123
46	CM	LOTUS 123
47	CM	LOTUS 123
48	CM	LOTUS 123
49	CM	MENTOR
50	CM	PC FILE
51	CM	PC FILE
52	CM	PC FILE
53	CM	PC FILE
54	CM	PENTAMATION
55	CM	POWER BASE
56	CM	PROF. WRITE
57	CM	QUATTRO PRO
58	CM	R:BASE
59	CM	RED WING
60	CM	SOLUTIONS
61	CM	SOLUTIONS
62	CM	SOLUTIONS
63	CM	SYMPHONY
64	CM	VIEW POINT
65	CM	WP
66	MM	AUTOCAD
67	MM	AUTOCAD
68	MM	CARTER
69	MM	CLARIS
70	MM	DATA BASE
71	MM	DBASE
72	MM	DBASE
73	MM	DBASE
74	MM	DBASE
75	MM	EXCEL
76	MM	IBM-FILLING & REP.
77	MM	IDMS
78	MM	IN-HOUSE
79	MM	IN-HOUSE
80	MM	IN-HOUSE

No.	Program	Software
81	MM	LOTUS 123
82	MM	LOTUS 123
83	MM	LOTUS 123
84	MM	LOTUS 123
85	MM	LOTUS 123
86	MM	LOTUS 123
87	MM	MS WORD
88	MM	PC FILE
89	MM	PC FILE
90	*MM*	*PC FILE*
91	MM	PC FILE
92	MM	PENTAMATION
93	MM	POWER BASE
94	MM	Q&A
95	MM	SMS
96	MM	SMS
97	MM	SOLUTIONS
98	MM	SOLUTIONS
99	MM	SOLUTIONS
100	MM	SPREADSHEET
101	MM	SYMPHONY
102	MM	WP
103	PARK	DBASE
104	PARK	IN-HOUSE
105	PARK	LOTUS 123
106	PM	AUTOCAD
107	PM	BRAUN INTERTECH
108	PM	CARTER
109	PM	CARTER
110	PM	CARTER PAV MGMT
111	PM	CLARIS
112	PM	DBASE
113	PM	DBASE
114	PM	DBASE
115	PM	DBASE
116	PM	DBASE
117	PM	ENABLE
118	PM	IDMS
119	PM	IN-HOUSE
120	PM	IN-HOUSE

No.	Program	Software
121	PM	ISU PAV MGMT
122	PM	ISU PAV MGMT
123	PM	ISU PAV MGMT
124	PM	ISU PAV MGMT
125	PM	LOTUS 123
126	PM	LOTUS 123
127	PM	LOTUS 123
128	PM	LOTUS 123
129	PM	MS WORD
130	*PM*	*MULTIPLAN*
131	PM	ORACLE
132	PM	PAVER
133	PM	PAVER
134	PM	PC FILE
135	PM	POWER BASE
136	PM	QUATTRO PRO
137	PM	SAS
138	PM	SAS
139	PM	SPREADSHEET
140	PM	SPREADSHEET
141	PM	VW3
142	PM	WORD PROCESSOR
143	PM	WP
144	PM	WP
145	SM	AUTOCAD
146	SM	AUTOCAD
147	SM	CMS
148	SM	CMS
149	SM	CMS
150	SM	CMS
151	SM	CMS
152	SM	DATA BASE
153	SM	DBASE
154	SM	DBASE
155	SM	DBASE
156	SM	DBASE
157	SM	DBASE
158	SM	DBASE
159	SM	DBASE
160	SM	DBASE

No.	Program	Software
161	SM	DBASE
162	SM	ENABLE
163	SM	FORTRAN
164	SM	IBM-FILLING & REP.
165	SM	IN-HOUSE
166	SM	IN-HOUSE
167	SM	IN-HOUSE
168	SM	IN-HOUSE
169	SM	IN-HOUSE
170	SM	LOTUS 123
171	SM	LOTUS 123
172	SM	LOTUS 123
173	SM	LOTUS 123
174	SM	LOTUS 123
175	SM	LOTUS 123
176	SM	PC FILE
177	SM	PC FILE
178	SM	PC FILE
179	SM	PC FILE
180	SM	PC FILE
181	SM	PC FILE
182	SM	POWER BASE
183	SM	PROF. FILE
184	SM	PROGRESS
185	SM	Q&A
186	SM	Q&A
187	SM	R:BASE
188	SM	SIGN MANAGER
189	SM	SIGN PERF/TRAFFIC
190	SM	SIGNALL
191	SM	SMS
192	SM	SMS
193	SM	SMS
194	SM	SMS
195	SM	SMS
196	SM	SMS
197	SM	SMS
198	SM	SMS
199	SM	SMS
200	SM	SMS

No.	Program	Software
201	SM	SMS
202	SM	SMS
203	SM	SMS
204	SM	SMS
205	SM	SMS
206	SM	SMS
207	SM	SMS
208	SM	SMS
209	SM	SMS
210	SM	SOLUTIONS
211	SM	SOLUTIONS
212	SM	SOLUTIONS
213	SM	SOLUTIONS
214	SM	SOLUTIONS
215	SM	TRAFSIGN
216	SM	WORKS
217	SP	DBASE
218	SP	DBASE
219	SP	IN-HOUSE
220	SP	IN-HOUSE
221	SP	KARS
222	SP	LOTUS 123
223	SP	LOTUS 123
224	SP	LOTUS 123
225	SP	LOTUS 123
226	SP	MARS
227	SP	PARADOX
228	SP	PC ALAS
229	SP	PC ALAS
230	SP	PC ALAS
231	SP	PC ALAS
232	SP	PC ALAS
233	SP	PC ALAS
234	SP	PC ALAS
235	SP	PC ALAS
236	SP	PC ALAS
237	SP	PC ALAS
238	SP	PC ALAS
239	SP	PC FILE
240	SP	PC FILE

No.	Program	Software
241	SP	SYMPHONY
242	SP	WP
243	SURV	AUTOCAD
244	SURV	AUTOCAD
245	SURV	AUTOCAD
246	SURV	AUTOCAD
247	SURV	AUTOCAD
248	SURV	AUTOCAD
249	SURV	AUTOCAD
250	SURV	AUTOCAD
251	SURV	AUTOCAD
252	SURV	AUTOCAD
253	SURV	AUTOCAD
254	SURV	AUTOCAD
255	SURV	AUTOCAD
256	SURV	AUTOCAD
257	SURV	AUTOCAD
258	SURV	AUTOCAD
259	SURV	AUTOCAD
260	SURV	AUTOCAD
261	SURV	AUTOCAD
262	SURV	AUTOCAD
263	SURV	AUTOCAD
264	SURV	AUTOCAD
265	SURV	AUTOCAD
266	SURV	AUTOCAD
267	SURV	CAD
268	SURV	CADVANCE
269	SURV	CAESI
270	SURV	CAICE
271	SURV	CEAL
272	SURV	COGO
273	SURV	DBASE
274	SURV	DBASE
275	SURV	EAGLE POINT
276	SURV	EAGLE POINT
277	SURV	EAGLE POINT
278	SURV	EAGLE POINT
279	SURV	EAGLE POINT
280	SURV	EAGLE POINT

No.	Program	Software
281	SURV	EDS
282	SURV	EDS
283	SURV	EDSC
284	SURV	EDSC
285	SURV	EDSC
286	SURV	EDSC
287	SURV	GSS
288	SURV	GWN-COGO
289	SURV	INTERGRAPH
290	SURV	LOTUS 123
291	SURV	LOTUS 123
292	SURV	MICRO ST.
293	SURV	MICRO STATION
294	SURV	MICRO STATION
295	SURV	MICRO STATION
296	SURV	MICRO STATION
297	SURV	MICRO STATION
298	SURV	MICRO STATION
299	SURV	MICRO STATION
300	SURV	PACSOFT
301	SURV	PACSOFT
302	SURV	PC FILE
303	SURV	PC FILE
304	SURV	PC FILE
305	SURV	ROADCALC
306	SURV	ROADCALC
307	SURV	ROADCALC
308	SURV	ROADCALC
309	SURV	ROADCALC
310	SURV	ROADCALC
311	SURV	ROADCALC
312	SURV	ROADCALC
313	SURV	ROADCALC
314	SURV	ROADCALC
315	SURV	ROADCALC
316	SURV	ROADCALC
317	SURV	ROADCALC
318	SURV	ROADCALC
319	SURV	ROADCALC
320	SURV	ROADCALC

No.	Program	Software
321	SURV	SDC
322	SURV	SDC
323	SURV	SHAVEY1
324	SURV	SOKKIA
325	SURV	TDS
326	SURV	WP
327	TM	CARTER
328	TM	DBASE
329	TM	DBASE
330	TM	DBASE
331	TM	ENABLE
332	TM	IN-HOUSE
333	TM	LOTUS 123
334	TM	PARADOX
335	TM	PC ALAS
336	TM	PC ALAS
337	TM	PC ALAS
338	TM	PC ALAS
339	TM	PC FILE
340	TM	PC FILE
341	TM	R:BASE
342	TM	SIGN PERF/TRAFFIC
343	TM	TAS PLUS

APPENDIX F

Cities

- ☹ Not interested at this time; however, could be in the future.
- ☹ I don't have time to fill this out. Sorry.
- ☺ I completed the survey last week during the APWA conference. Would appreciate a copy of the results.
- ☹ Mailing list error. We are not, nor ever have been XXX Eng.
- ☹ Somewhat interested but no $$ for staff or equipment.
- ☹ We have no bar coding, voice recognition, and pen-based computers at this site.
- ☹ We are still in the Stone Age. EDM & CADD are our newest gadgets.
- ☹ Unsure of what type of equipment we would use.
- ☺ I'd suggest these be filled out. I saw a presentation on this with a video - very good on sign inventory.
- ☺ We issue parking tickets using hand held computers.
- ☺ If feasible, GIS would be nice for keeping track of underground signal infrastructure.
- ☹ Can't accurately answer without Engineer.

Counties

- ☹ XXX County functions entirely under the crisis management philosophy.
- ☹ Very interested but no interest or support from Board of Supervisors.
- ☹ I don't believe anyone would be interested in our Third World Technology.
- ☹ My interest is irrelevant. I could never get it funded.
- ☹ Mostly too much tech. for counties at this time. Give it 10 years.
- ☹ Do not know enough about these possibilities to really answer intelligently.
- ☹ At this time I am not certain of our needs.
- ☹ Interested but lacking in knowledge to complete this portion of survey.
- ☹ Don't know enough about to intelligently answer.

State

- ☺ There are some independently developed applications using Lotus, Pc File, Basic Language. Also, materials has a TSO mainframe system to report best results. Survey data collectors are used to provide info. to design.

APPENDIX G
LIST OF INTERVIEWEES

State

- Donna Buckwald, Construction Management
- Brian McWaters, Pavement Management
- John Ranny, Surveying Management
- Lee Smithson, Maintenance Management
- John Smythe, Construction Management
- Dwight Stevens, Traffic Management
- Fred Walker, Safety Management

County

- Bill Cox, Wapello County Assistant Engineer
- Tom McGovern, Audubon County Data Specialist
- Donald Pool, Van Buren County Assistant to Engineer
- George Parris, Audubon County Engineer
- Randall Schlei, Emmet County Engineer
- Steve Timmons, Emmet County Summer Intern
- Jack Weber, Emmet County Assistant to Engineer

City

- Robert Bailey, Clarinda City Manager
- Jim Brachtel, Iowa City Traffic Engineer
- Richard Fosse, Iowa City Engineer
- Stephanie Hussman, Clarinda City Administrative Support Staff
- Mike Koch, Dubuque Public Works Director

APPENDIX H

EMMET COUNTY OPERATOR'S DAILY EQUIPMENT REPORT

EQUIPMENT NUMBER	OPERATOR		PERIOD COVERED ON THIS FORM MONTH ______ YEAR ______	
TYPE OF FUEL USED-CHECK ONE GASOLINE ☐ DIESEL ☐	ODOMETER OR HOURMETER READING FIRST OF MONTH	END OF MONTH	MILES OR HOURS USED	EQUIPMENT RATE

DATE	FUEL (GAL)	OIL (QTS)	GREASE (LBS)	ANTI-FREEZE (QTS)	LOCATION / PROJECT	MILES/ HOURS USED	FOR OFFICE USE
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							
TOTAL					REMARKS ______		

EMMET COUNTY SHOP REPAIR REPORT

UNIT ______ MAKE ________ MODEL _____ DATE _________
MILEAGE/HOURS ___________ CHECKED BY ____________

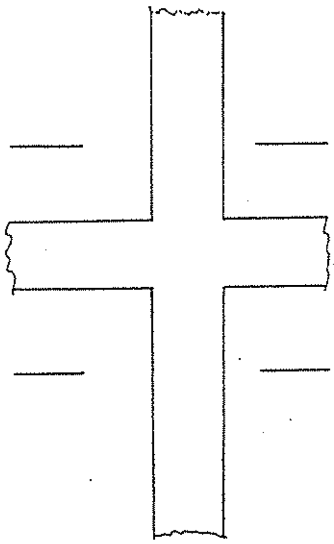
( ) OIL CHECK	( ) BATTERY	( ) START & RUN CHECK
( ) POWER STEERING	( ) RADIATOR	( ) GAS - DIESEL
( ) TRANS & REAR END	( ) LIGHTS	( ) OIL PRESSURE
( ) BELTS	( ) TIRES & PRESSURE	( ) CHARGING
( ) HOSES	( ) WIPERS	( ) WATER TEMP.
( ) BRAKE FLUID	( ) AIR SYSTEM	( ) BRAKES (HYD & PARK OR AIR)
( ) FILTERS (AIR & OIL)		( ) CLUTCH ADJUSTMENT

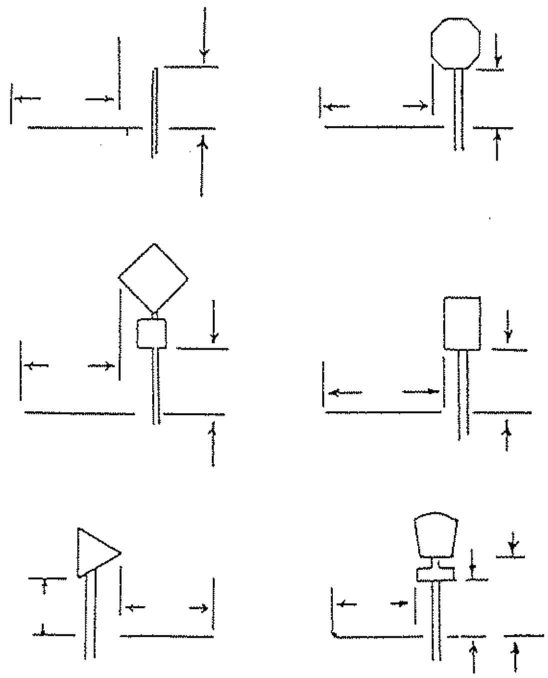
OILS & ANTI FREEZE		TIRES & TUBES			PARTS USED		
QTY		QTY	PART NO.		QTY	PART NO.	
	OIL , QTS			TIRES			FILTER
	ANTI FREEZE, QTS			TUBES			FILTER
				PATCHES			FILTER

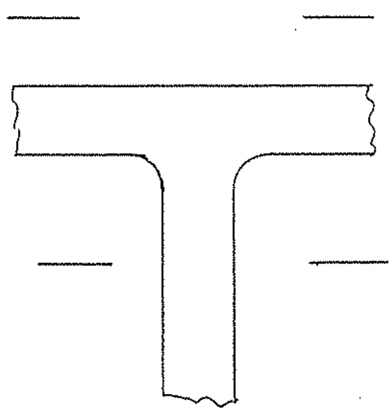
PARTS USED OR COMMENTS: ______________________________

LABOR HOURS: ____________________

EMMET COUNTY
TRAFFIC CONTROL DEVICES







Date: ______________

Location: ______________________________

______ Township ______ Range ______ Section ______ Road No. ______

Sign: ______ Type ______ Size ______ Dir.Fac.(7)

______ Mounted On ______ MUTCD

Comments: ______________________________

____

____

Work Crew: ______________________________

Completed Date: ______________________________

(OVER)

EMMET COUNTY MONTHLY FUEL LOG REPORT

LOCATION:				DIESEL FUEL				Period Covered on This Form Month________ Year______		
	EQUIPMENT NUMBER							PUMP READING		
DATE								A.M.	P.M.	Gallons Used	Gallons Delivered
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
TOTAL											

INVENTORY-SUPPLIES ~~SALES~~

ESTHERVILLE SHOP(#1)ONLY

DATE	QUANTITY	~~ITEM NO.~~ PART NO.	ITEM DESCRIPTION	WHERE PLACED	EMPLOYEE INITIAL

Route ______________ Sheet ______ of ______

VAN BUREN COUNTY SIGN INVENTORY FORM

Begin At: ______________ Date ______________

End At: ______________ Inventory Direction ______________ Technician ______________ Township ______________

Sign Location					MUTCD NO.	SIGN LEGEND	SIGN													REMARKS/COMMENTS
DIS	POS	OFS	HGT	OTN			Size		SHT	MAN	BKG	POT	ISL DAT	COM	SPD	USD	IST DAT	COM	ACT	
							W	H												

Secondary Road Time Sheet

NAME ______________________

ADDRESS ______________________

CITY ______________ IA. ZIP __________

FOR PAYROLL ________ TO ________

LOCATION, ROAD NO., OR BRIDGE NO.	DATE	420 BRIDGES OVER 20 FT.	431 PIPE CULVERT	432 BOX CULVERT	451 BLADING GRANULAR	452 BLADING EARTH	453 DITCHING	461 GRANULAR	464 ASPHALT CONCRETE	467 PORT. CEMT. CONC.	481 DITCH CLEANING	482 SHOULDERS	483 EROSION CONTROL	484 ENTRANCE's	485 TILE LINES	491 BRUSH CLEANING	492 SPRAYING	493 MOWING	521 PLOWING & SPREADING	522 PLOWING & BLADING	523 CHEM. & ABRA. SPRD.	524 MATERIAL's	591 SIGNS	622 REPAIR EQUIPMENT	624 SERVICE EQUIPMENT	650 SUNDRY	MISC.	903 VACATION	904 SICK LEAVE	905 PAID HOLIDAYS	911 CASUAL TIME	956 FUNERAL	INJURY	MILITARY LEAVE	JURY DUTY	FUEL	HOURS/ MILES	MACHINE NO.
	TOTAL																																					

TOTAL STRAIGHT TIME ________

OVERTIME ________

DOUBLE TIME ________

I hereby certify that the amounts on this time sheet are correct and that no part thereof has been paid

Signature ______________________ Payroll No. ________

O.P.C. 4332

NOTES LEVEL/FIELD

PROJECT

LOCATION
SEC. _____ TWP. _____ RNG. _____

PAGE _____ OF _____

INST. | NOTES | ROD/PRISM | DATE | WEATHER | REMARKS

POINT/ STATION	BS	HI	FS	ELEV	REMARKS	℄	

Unit No.______ Driver Name__________ Date________ from____________________Pit

LOAD	TIME	WEIGHT	LOCATION HAULED	MAINTENANCE DISTRICT #
SAMPLE	7:30	14	10-063	11
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

SIDEWALK REPAIR INSPECTION

CITY OF IOWA CITY
DEPARTMENT OF PUBLIC WORKS

DATE: ____________

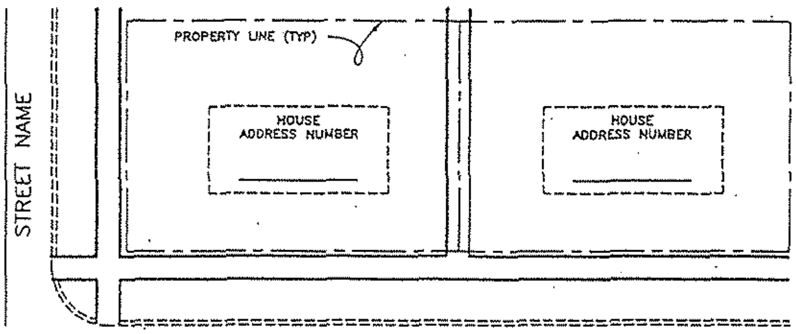
LOCATION/ADDRESS OF VIOLATION: ____________

PROPERTY OWNER NAME: ____________

PROPERTY OWNER ADDRESS: ____________

INSPECTOR: ____________ DATE REPAIRS MADE: ____________

SHOW REPAIR AREAS INDICATING TYPE OF REPAIR AND # OF SQUARES



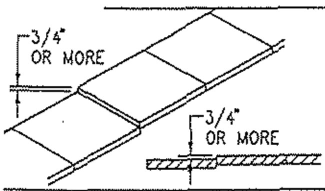
______ Type of Repair
______ # of Squares

______ Type of Repair
______ # of Squares

______ Type of Repair
______ # of Squares

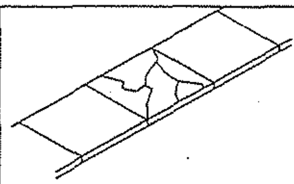
STREET NAME ____________

REPAIR TYPES



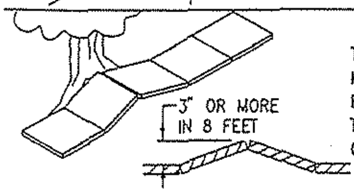
TYPE A

THE SIDEWALK IS CRACKED WITH A VERTICAL EDGE EXISTING OF MORE THAN (3/4) INCH.



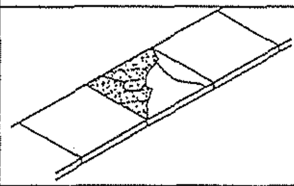
TYPE C

THE SIDEWALK HAS CRACKED INTO MORE THAN FOUR (4) PIECES PER 4' X 4' SQUARE.



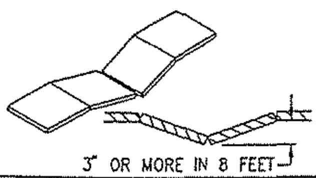
TYPE B

THE SIDEWALK HAS RAISED MORE THAN 3 INCHES IN AN EIGHT (8) FOOT AREA FROM THE NORMAL LINE OF GRADE OF THE SIDEWALK.

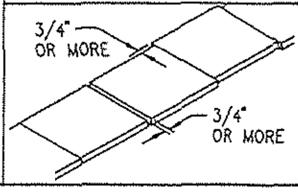


TYPE D

THE SIDEWALK HAS SPALLED OVER FIFTY (50) PERCENT OF THE SURFACE.



THE SIDEWALK IS DEPRESSED MORE THAN 3 INCHES IN AN EIGHT (8) FOOT AREA FROM THE NORMAL LINE OF GRADE OF THE SIDEWALK, OR THE WALK PONDS WATER.



TYPE E

THE SIDEWALK HAS HORIZONTAL SEPARATIONS EQUAL TO THREE-QUARTERS (3/4) INCH OR MORE.

LOCATION OF SIDEWALK:	______ Front Yard	______ Side Yard	______ Rear Yard
WIDTH OF SIDEWALK:	______ 4 Feet	______ 8 Feet	______ Other
DEPTH OF SIDEWALK:	______ 4 Inches	______ 6 Inches	
TYPE OF SIDEWALK:	______ Concrete	______ Other	
AMOUNT OF SIDEWALK TO BE REPAIRED:		______ Square Feet	

EMMET COUNTY

MONTHLY SUMMARY OF OPERATOR'S DAILY EQUIPMENT AND COUNTY SHOP REPAIR REPORTS

EQUIPMENT NUMBER	OPERATOR	ODOMETER OR HOURMETER READING		YEAR COVERED BY THIS FORM
		JANUARY 1	DECEMBER 31	

MONTH	FUEL		LUBRICANT COST	ANTI-FREEZE COST	TIRE AND TUBE COST	EXPENDABLE PARTS	REPAIR PARTS	LABOR COST	MILES/HOURS USED	DOWN (HOURS)	TIMES REPAIRED
	GAL	COST									
JANUARY											
FEBRUARY											
MARCH											
APRIL											
MAY											
JUNE											
JULY											
AUGUST											
SEPTEMBER											
OCTOBER											
NOVEMBER											
DECEMBER											
TOTAL											