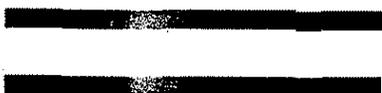


CONSTRUCTION AUTOMATION USING PEN-BASED COMPUTERS

**Final Report
Iowa Highway Research Board
Project HR-368**

January 1996

Project Development Division



**Iowa Department
of Transportation**

**Final Report
Iowa Highway Research Board
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**Construction Automation
Using Pen-Based Computers**

**John M. Smythe, Construction Engineer
prepared by
Donna Buchwald and John Rasmussen
Office of Construction
Iowa Department of Transportation
Ames, Iowa 50010
(515)239-1352**

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AUTHOR(S)

John Smythe
Donna Buchwald
John Rasmussen

PERFORMING ORGANIZATION ADDRESS

Iowa Department of Transportation
800 Lincoln Way
Ames, Iowa 50010

ABSTRACT

The Iowa Department of Transportation is committed to improved management systems, which in turn has led to increased automation to record and manage construction data. A possible improvement to the current data management system can be found with pen-based computers. Pen-based computers coupled with user friendly software are now to the point where an individuals hand writing can be captured and converted to typed text to be used for data collection

It would appear pen-based computers are sufficiently advanced to be used by Construction inspectors to record daily project data. The objective of this research is to determine if:

- ◆ Pen-based computers are durable enough to allow maintenance-free operation for field work during Iowa's construction season.
- ◆ Determine if pen-based computers can be used effectively by inspectors with little computer experience.

The pen-based computer's handwriting recognition was not fast or accurate enough to be successfully utilized. The IBM Thinkpad with the pen pointing device did prove useful for working in Windows' graphical environment. The pen was used for pointing, selecting and scrolling in the Window applications because of its intuitive nature.

TABLE OF CONTENTS

	PAGE
<u>Introduction</u>	1
<u>Objective</u>	1
<u>Project Description</u>	1
<u>Testing</u>	2
<u>Implementation</u>	4
<u>Project Cost</u>	4
<u>Discussion</u>	4
<u>Conclusion</u>	5

DISCLAIMER

The contents of this report reflect the views of the authors and do not necessarily reflect the official views of the Iowa Department of Transportation.

This report does not constitute and standard, specification or regulation.

Introduction

As the Iowa Department of Transportation strives for increased efficiency, the allocation of time needs to be managed frugally. As spending increases on construction projects, more effort will be required to record and manage construction data. Although the DOT has evolved from hardback field books to standard forms, the growth needs to continue to reduce the frequency in which data is handled.

The intent of this research project is to determine the benefits of automating field inspection using pen-based computers. Several states, local governments, and businesses have researched the use of pen-based computers. At least two states have already implemented pen-based computing into their construction inspection.

Computers used in this evaluation were IBM 360P models. They are similar in style to most laptops except for the screen. Pen-based computers have special screens that contain a transparent wire grid which generate an electromagnetic field. The pen emits a faint signal that interrupts the field when it is in contact with the screen. The computer then uses integrated software to record the location and order of the pen strokes. This information is converted into typed text or may be saved as a handwritten field. Traditional computers are interfaced via keyboard, which requires training to be efficient. Pen-based computers may be interfaced either by writing on the screen with an electronic pen or with a keyboard. This quality allows the computer to be more intuitive and require less operator training. In addition, the screen portion of the laptop can be folded over the keyboard to provide a clipboard type tablet. The pen for the computer is stored in a compartment next to the screen for convenient access. Seven of these models were purchased for testing.

Objective

The primary objective of this project was to determine whether the Iowa Department of Transportation could benefit from using pen-based computers for record keeping. Benefits to be studied were inspector satisfaction, quality of inspectors' paperwork and durability of the unit.

Project Description

Pen-based computers were provided to project personnel to assist them in record keeping. The inspectors kept their records on the pen-based computers and printed them as required. The intent of this project was to determine the inspectors' ability to interact with the computers. Benefits and criticisms were reported as they became apparent. This information was useful for implementation of the pen-based computers.

Testing

The research was conducted on seven computers. These computers were assigned to field personnel and used with forms created for FieldBook during the 1995 construction season. FieldBook is software currently being developed by the Iowa DOT to be used for accessing the Construction Administration System (CAS). The inspectors used the computers in the field to determine if the hardware was durable enough for the environment in which they were to be used and to determine if the handwriting recognition option could meet our needs. Some of the pen-based computer user's comments are given below.

Dan Steenhard, Inspector
New Hampton RCE Office

The pen isn't capable of converting handwriting to typed text, because the computer is slow and about 80% accurate in converting the handwriting...However, the pen is about twice as fast as the mouse on any other laptop...

Dakin Schultz, Inspector
Ames RCE Office

The pen is handier than the mouse even though writing isn't practical...There is an option to train the computer to recognize my handwriting, but I haven't had time to explore that option...It makes getting around in FieldBook easier since there are a lot of Windows and scroll bars in the program.

Janet Wastaney, Secretary
Creston RCE Office

No one uses the handwriting features of computer regularly because it is slow and not always accurate...The pen is great for getting around in Windows because it is more natural to point at what you want than to aim the mouse... In one instance an inspector's screen stopped recognizing the pen so the mouse had to be used. The inspector had a tough time using his computer while sitting in the truck without the pen. The inspector, not wanting to give up the computer kept using it with the mouse. Finally, the inspector returned the computer to be repaired. The inspector's hard drive was simply removed and placed in another computer the same day. The inspector was delighted he could keep updating his records while waiting for the computer to be repaired.

Some advantages of the pen-based computers in comparison to hand written record keeping was the ability to automate data entry, perform calculations and store project information. Additional benefits

include an easy interface tool for the inspectors to navigate through Windows and interchangeable hardware. The disadvantage of the pen-based computer is the handwriting capabilities are not advanced enough to be used by itself for data entry. The computer can't convert the text fast or accurately enough to be used regularly. An example of the handwriting recognition capabilities can be found in Table 1. This unedited example took about two minutes to complete, writing at a normal speed.

Table 1. Hand Writing Recognition Example

ABCDEFGHIH-TIKLMNOPQRSTUVWXYZ
 abcdefghiLlmnopqrstuvwxyz
 123451789 o

The pen based computers have a training program to help the computer and user agree on what pen strokes correlate to certain letters. However, the computer only recognizes the order and location of pen strokes. Therefore, some of the mistakes above can be attributed to some pen strokes not intersecting each other or made in the wrong order.

The computers durability was studied by recording maintenance work required all of the units. Of the 82 total units, our records show that 30 hardware repairs were required over a one year period. The problems with the computers were recorded when they came in for repair and are rank ordered in Table 2.

Table 2. Computer Hardware Deficiencies

Number of Computers needing Similar Repair	Problem noted in Maintenance Records
7	Screen Unresponsive
5	Computer Won't Turn On
5	Screen Blotched/Watermarks
2	Diskette Drive Won't Work
2	Broken Mouse Buttons
2	Damaged Hard Drive
1	Serial Port Won't Work
1	Screen Scratched
1	Diskette Drive Runs Constantly
1	Broken Latch
1	Strange Noise In Hard Drive

According to our records most of the problems experienced with the computers have nothing to do with its' pen capabilities. Of the 30 deficiencies, less than half can be attributed to the computers special screen and pen.

Implementation

The test computers were advantageous over the current methods of data collection. Most of the benefits can be attributed to the speed of automation in comparison with hand written records. Originally the test pen-based computers were to be a variety of machines from different vendors. Some of the pen-based computers didn't appear to be good platforms because they required external keyboards and disk drives. Two vendors' were chosen but one was bought by a competitor and no longer produced pen-based computers. Therefore, the IBMs were purchased because they had the best configuration, similar to any other laptop, and were readily available. An additional 75 pen-based computers were purchased to move toward the departments automation goals.

Project Cost

The project was allocated \$33,000 and was to be funded 100 percent by state primary funds. The actual cost for the project was \$30,057.93 for the computers and software.

Discussion

Handwriting recognition applications need more development before implementing, the pen however, is a good tool for Windows' graphical interface. The IBM Thinkpad did prove to be suitable hardware for field use and had benefits obscure at the beginning of this research. One benefit included easy hardware replacement on units that failed. For instance, the IBM hardware is modular in form so anyone can easily remove a component and place it into another pen-based computer. This proved useful for some repairs during the study. An additional benefit is the pen-based computers are compatible with the Departments movement toward automation using the Construction Administration System (CAS) and will provide the platform for CAS when it is implemented.

Conclusion

Pen-based computers are not advanced enough to rely solely on the handwriting recognition capabilities for construction record keeping. Some deficiencies of pen-based computers are:

- 1) They are too slow in converting writing to text to be efficient.
- 2) Inaccurate in converting writing to text.

The computer does have an option of training itself to recognize individual handwriting to reduce the inefficiencies of the handwriting recognition. This exercise does prove to be helpful, but does not allow one hundred percent accuracy. These findings are based on handwriting of seven different inspectors and vary greatly based on individual hand writing legibility.

The advantages of the pen-based computers we purchased was the hardware itself. All of the IBM Thinkpads come with modular components. This feature allows easy component replacements and upgrades on the user level. The advantages of the pen-based computers in this study were:

- 1) Interchangeable hardware keeps downtime during repairs to a minimum.
- 2) The pen is quick and natural to use in the Windows environment.