Taking a Computer to the Construction Job Site

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The feasibility of using a portable computer at the construction job site is investigated. By the use of a portable computer, the workers can have access to a large amount of data and critical management information. The availability of a portable computer would allow the management staff in the office to better communicate with the foreman, the foreman to more effectively manage construction projects, and the inspector to more accurately inspect construction quality. Two approaches to taking a computer to the construction job site are discussed: a pocket handheld computer and a voice-activated, head-mounted computer. Each is evaluated for capabilities and limitations. Currently, a wide variety of portable computers is available to suit the needs of the specific application. However, there are not enough software packages available for use on portable computers. Additional software development effort on portable computers would make them more useful at the construction job site. These portable computers are tools to help collect information for improving the existing management process, increasing awareness by construction workers of construction quality concerns, and promoting more scientific methods of improving various construction operations.

As more decisions are made at the construction job site, the amount of information needed at the job site is increasing. These important decisions are often made at the foreman level. Therefore, the foreman becomes a key person in improving construction productivity. The foreman, managing the construction crew, currently needs, at a minimum, a pocket calculator to convert measurement units, calculate volumes of work performed, and so forth. The question addressed in this paper is whether it is necessary to take a more sophisticated computer than a pocket calculator to the construction job site. Many papers have emphasized the use of computers in the field office environment, but not at the job site level by the construction workers.

In the past, a number of studies have identified ways to improve construction productivity, but they are short of recommending a tool to improve it (*1*). The objectives of this research are to investigate the uses of computers at the construction job site, identify available computer hardware and software, and evaluate them for possible application in the construction job site environment.

COMPUTER NEEDS AT CONSTRUCTION JOB SITE

The ever-increasing amount of information needed at the construction job site, along with the availability of smaller computers, has created a demand for computers at the job site. There are certainly construction operations that, if improved by use of computer, would result in savings in both time and money.

One of the most common problems in construction operations is the communication gap between various parties—project engineers, superintendents, foremen, and construction crews. This communication gap can be greatly reduced if all parties use the same procedures such as construction scheduling methods, measures of construction productivity, and so forth. These measures of construction productivity, for example, have been available only to management staff in the office environment. Such valuable information was not available to field workers because of their limited access to the computer and the difficulties of verbal communication between office and construction crews.

Although laptop computers are becoming commonplace in many industrial applications, they can still make quite a stir when they are used at the construction job site. A number of so-called palmtop computers are available in the market. They are handy, light, small, and inexpensive. They are about the size of a checkbook, so they can easily be put into the pocket. Another class of computers that can be used is a voice-activated, head-mounted computer with a small computer screen attached to the head. This would make an ultimate portable computer with two hands free for other functions.

CURRENT USE OF COMPUTERS IN CONSTRUCTION

Recently, new computer applications and technologies have been given the utmost priority in construction research. New directions in computerized construction research have been identified as (*a*) projectwide data base and communication, (*b*) knowledge-based expert systems, (*c*) simulation of construction activities, and (*d*) robotics (*2*). Most computerized construction research so far seems to emphasize research tools more than the real problems at the construction job site.

Construction companies are actually decentralizing their computer resources by putting personal computers at the field office. One study reported that the decentralization permitted greater flexibility in job cost control and construction scheduling applications (*3*). It also indicated that there were training needs for field personnel regarding the use of the computer.

Automated inventory control at the construction job site using a bar code technology has been proposed (*4*). Inventory control of construction resources such as materials and equipment can be automated using a bar code label. The label can

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be read by the bar code scanner. A limited set of job site activities can also be identified using an activity identification sheet of corresponding bar codes. Bar code technology is becoming popular as a means of collecting construction field data, but it may require a number of expensive hardware elements, such as scanner, remote reader, and concentrator, let alone lots of bar code labels.

Recently, a knowledge-based expert system was developed on a desktop computer to provide advice to inexperienced inspectors concerning how to identify and correct deficiencies in the asphalt pavement construction operation (*5*). A great area for an expert system application on a portable computer appears to be to help inexperienced inspectors at the road construction job site.

HAND-HELD COMPUTER

Recently, smaller computers such as laptop and notebook computers made headlines in many computer magazines (*6–8*). Much of the functionality of these computers is now available on even smaller palmtop or hand-held computers, which can slip into the pocket (*7*). The size of hand-held computers is in the range of checkbooks and VHS tapes. They look like pocket calculators but act like desktop computers. There are a number of manufacturers of such pocket hand-held computers in the market, including SHARP Wizard, Psion Organizer, Atari Portfolio, Hewlett-Packard 95LX, Poqet PC, CMT MC-Series, National Datacomputer, and so on.

The reduction in the size of computers was accomplished because of a miniaturized PC-compatible motherboard with performance about 2.5 times that of an IBM XT (*8*). There is much variation among different hand-held computers in size, functions, and so forth. This paper does not evaluate each hand-held computer for its capabilities, but evaluates hand-held computers in general for construction job site applications. A detailed evaluation report on a specific hand-held computer can be found in a computer magazine (*8*). One study evaluated various field inspection methods for collecting pavement distress data and concluded that hand-held computers are relatively light, inexpensive, and easy to use (*9*). The general capabilities and limitations of hand-held computers are summarized as follows (*10*).

1. The small keys on most hand-held computers are not as easy to use as those on larger desktop computers. Entering information into hand-held computers is very awkward. They should be used for tasks that do not require much typing. The small screen can display up to 8 lines and 80 columns.
2. Most hand-held computers can be connected to a desktop computer. The hand-held computers support serial communications, so that information can be transferred between them and desktop computers in the office. Computer programs can be created on any computer and downloaded into hand-held computers.
3. Some hand-held computers have their own programming language and removable mass storage. Therefore, an application program can be written, compiled, and stored in an EPROM that functions like a disk drive. Peripheral devices such as printers, bar code readers, magnetic card readers, and modems are available for certain types of hand-held computers.
4. Quite a few hand-held computers are general-purpose computers for which a wide variety of software and hardware is available. In general, hand-held computers have slower CPUs and less RAM than desktop computers. The battery on some models may not last long enough for extended use outdoors.

The first requirement in the use of computers at the construction job site is to select the hand-held computer that best fulfills the needs of the application. Factors to consider when selecting a hand-held computer are durability, RAM and EPROM capacity, operating system and DOS compatibility, communication characteristics, and cost.

Several hand-held computers are available that would suit specific application needs. However, hand-held computers need more commercial software packages, the availability of which would make hand-held computers more attractive. Currently, a number of general software packages are available for the hand-held computer, including spreadsheets, data base management systems, advanced calculator, appointment/telephone book, file manager, communications programs, and so forth. However, not many software packages are available for hand-held computers for specific applications such as the construction job site (*11*).

ON-SITE SOFTWARE PACKAGE

The On-Site software series is developed by On-Site Technologies. It is a simple construction management tool for foremen at the construction job site. All programs were written in BASIC and are available on SHARP pocket hand-held computers. The structure of the program is simple, and the use of the program is easy. The objectives of the On-Site software package are to assist the foreman in determining actual costs and variances and in identifying delays and extra costs, to tell the crews how to improve their performance, and to give superintendents objective criteria for cost improvement awards.

Their simplicity allows the programs to be easily adapted by the foremen. The foremen can be guided through the program by answering mostly yes or no questions. The On-Site software package is shown in the Figure 1. The current On-Site software package includes functions such as performance audit, daily log, and cost analysis. On-Site software is intended to provide a foreman with the tools needed to better manage construction operations. The use of On-Site software, in general, involves five steps (*12*):

1. The estimated quantities and costs of the work to be performed are loaded into the On-Site software by a superintendent.
2. The actual cost of productivity is computed from job site data input by a foreman and compared against the estimated unit cost after the first phase of the work.
3. The foreman and crew answer a series of questions regarding conditions that might have affected productivity such as weather, safety, crew size, and so forth.

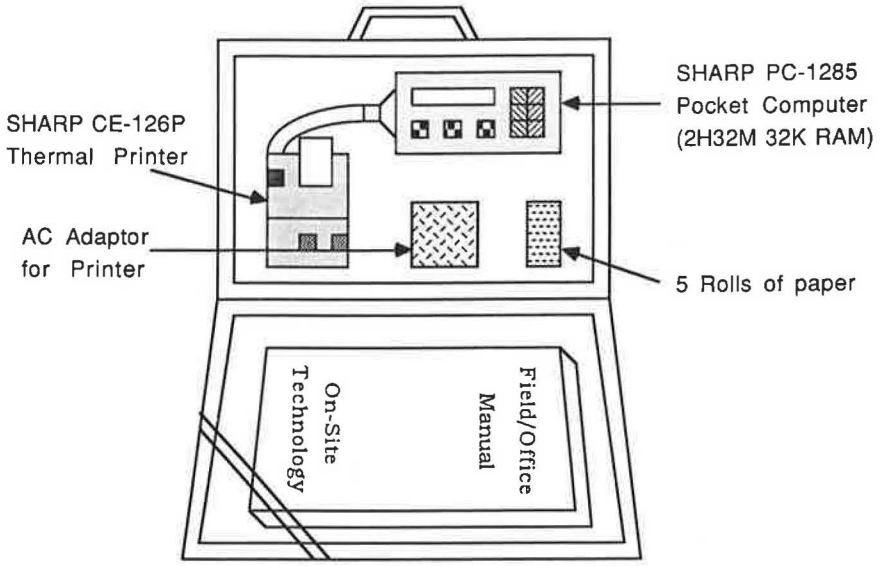

FIGURE 1 On-Site software package.

4. The foreman repeats Steps 2 and 3 after each day's work. The actual unit cost is compared with the one estimated by the superintendent.
5. The foreman prints out the actual unit cost with job site conditions and sends it to the superintendent for a feedback resolution of delay factors and a basis for recognition and reward.

A number of advantages can be realized by using the On-Site software package: establishment of specific performance goals, immediate awareness by the crew of its performance, increased interaction between office and job site, reduction of labor costs with increased productivity, and elimination of excessive paperwork.

The limitations of the On-Site software package are as follows:

1. Each contractor has a different way to manage construction activities, which may require customization of the software.
2. Use of hand-held computers with small screens and keys could be a nuisance to some foremen.
3. The capabilities of the current version of the On-Site software package include only limited areas of construction management, such as daily log, cost analysis, and performance audit. Additional functions should be added in other construction management areas, such as equipment inventory, short interval scheduling, change order/estimator, and inspection.

VOICE-ACTIVATED HEAD-MOUNTED COMPUTER

Hand-held computers have an inherent limitation: users have to use hands to hold them. One solution is to use a voice-recognition system with a computer screen hanging in front of the eyes. The first head-mounted computer was developed by NASA's Ames Research Center. It developed the Virtual Interface Environment Workstation, a wide-angle, head-mounted, stereoscopic display system that the operator's voice, position, and gestures control. Two disadvantages to this headset approach are as follows (*6*):

1. The user is tethered to one place.
2. It is very complicated to switch back and forth between different tasks if the users have to take off the headset every time they want to see something outside.

To reduce these limitations, a new head-mounted device was developed to show two-dimensional display to one eye while the other sees the real world. This device, called "Private Eye," a tiny computer screen, was developed by Reflection Technology. Private Eye weighs 2.25 oz and produces a 720- by 280-pixel display in a viewing window less than 1 in. square. It displays 280 lines with 720 columns (*13*). Private Eye allows users to work at other tasks while viewing important data such as construction schedules. By making displays more portable and less obtrusive, more areas, including construction job sites, become accessible to computers.

The first portable computer that can be worn as a helmet, headset, or work vest, called CompCap, was recently introduced by Park Engineering, Inc. (*14*). A schematic diagram of the CompCap unit configuration prepared by Park Engineering is reproduced in Figure 2. CompCap uses a Private Eye display device with voice data entry system and memory card interface with belt-mounted drive. It uses a voice recognition system called VMKEY developed by Convox, Inc., which allows the user to speak to the computer through a microphone. Convox states that this computerized voice recognition system remains an unreliable technology because of uncontrollable variations in the way that normal speech is produced in an uncertain and noisy acoustic environment (*15*). A special microphone may be used to suppress noise in a typical construction environment.

The CompCap computer is DOS-compatible, so it can be used to run any DOS-compatible software package. The

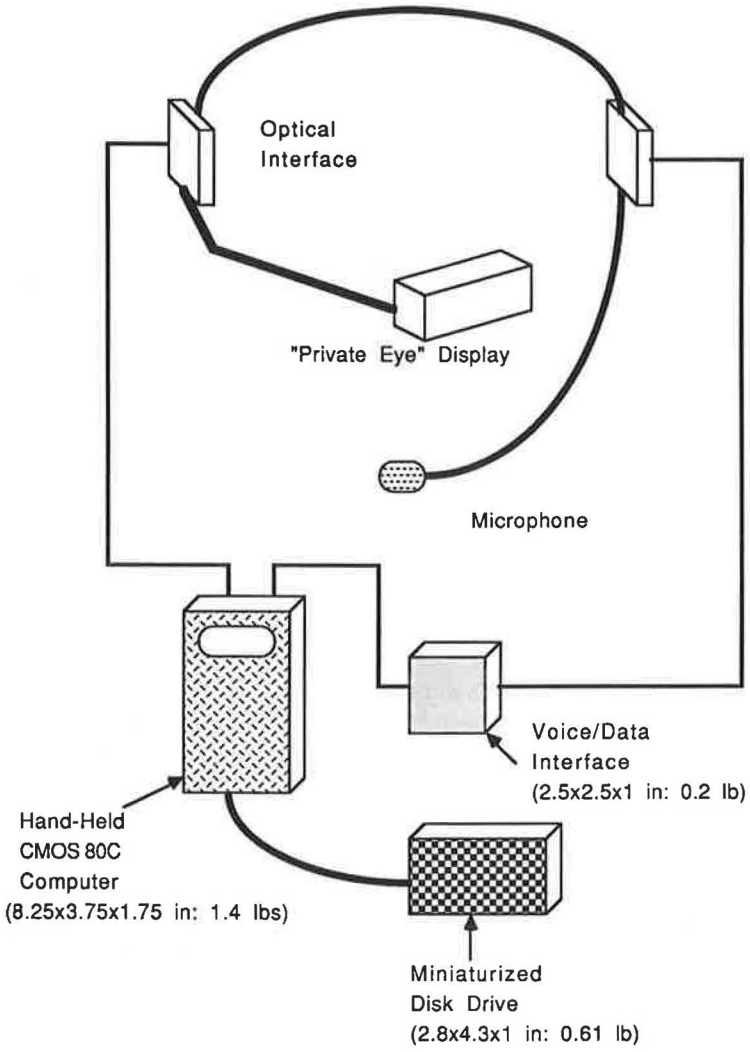

FIGURE 2 Configuration of CompCap ergonomic computer.

CompCap unit can be used at the construction job site for more detailed instructions and graphic displays for construction scheduling and inspection. For example, the memory joggers from the inspection guidebook (*16*) can be recalled with appropriate graphics using CompCap to help inspectors refresh their memories for specific inspection tasks. Since the CompCap unit was just released in 1991, no software packages are available for use at the construction job site using CompCap.

SUMMARY AND CONCLUSIONS

The advent of smaller computers with greater capabilities has motivated the authors to investigate the feasibility of using a computer at the construction job site. Although computers have been used extensively in the office environment in the past, the potential of using computers in the construction job site environment has just begun to be realized. The construction job site is usually an outdoor and noisy environment, and the prospective users of a computer at the construction job site probably never used a computer in the past.

By the use of a computer at the construction job site, the construction workers can have access to a large amount of data and critical management information. The availability of a computer would allow the management staff in the office to better communicate with the foreman, the foreman to more effectively manage the construction project, and the inspector to more accurately inspect construction quality. For example, a foreman who notices any work dclays can correct the problem instantly instead of waiting until the labor productivity report is generated next day or even next week. This will improve construction productivity.

Various portable computers were developed and used by other industries such as utility metering, automobile renting, and manufacturing operations. A wide variety of portable computers is currently available to suit the specific needs of the application at the construction job site. This paper presents two approaches to taking the computer to the construction job site: pocket hand-held computers and voice-activated, head-mounted computers. Hand-held or head-mounted computers can greatly enhance the availability of critical information at the job site level, which would eventually improve construction productivity.

Significant demand seems to exist for such portable computers at the construction job site. However, not enough software packages are available for use on portable computers at the construction job site. Additional software development would make portable computers more useful at the job site. A customized development effort may be needed for each contractor, because construction operations at the job site would be different for various contractors.

Portable computers cannot replace the current construction management or inspection process currently existing in many organizations. The hand-held and head-mounted computers are tools to help collect information for improving the existing process, increasing awareness by construction workers of construction quality concerns, and promoting more scientific methods of improving construction operations.

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