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Automatic Data Collection Technologies in a Construction Curriculum

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The construction industry is a data-driven service industry. Studies indicate that 80 percent of the information collected by a department (division or office) must be shared with others. The Department of Building Construction and Contracting (BC) at Purdue University embraces the philosophy of teaching students to manage the process of construction through the utilization of technological and data management skills derived from academic learning and field application experience. Gaining experience in the application of the new technologies of Automatic Data Collection (ADC) is one method available for students to become key elements in assisting companies to adopt and effectively utilize them. Therefore, the department began the process of implementing ADC technologies into the curriculum through a process of grant application and award (The 1995 Zinger Award). Survey results from the grant indicated 0.8 percent of the companies surveyed used bar coding, and that a large 69 percent knew little or nothing about bar coding and ADC. However, 43 percent indicated they would like to know more. Included is a discussion of what ADC technologies are, how ADC is being implemented into the BC program, and the expected outcomes.

Key Words: Bar Coding, Tool Tracking, Automatic Data Collection, Keyless Entry, Construction Curriculum

Introduction

Construction is an intensive data (information) driven service industry. The entire process of estimating, scheduling, planning, tracking, document control, construction, management, and supervision of a construction project is simply the accurate and timely gathering and sharing of information with others. Studies indicate that 80 percent of the information collected by a department (division or office) must be shared with others. Those companies who manage their data gathering and dissemination processes best generally yield the best profits. How profitable are companies with good data gathering and dissemination skills? On the average, their yield is one-and-one-half to three percent net margin (CFMA, 1995). Notice two things about such a low margin. First, it doesn't take much of a loss to place the company into a negative position. Second, it doesn't take much of a productivity gain to increase or double the margin. Since the industry is so intensively data driven, and the primary productivity problems (lack of materials, lack of tools, lack of instructions, and rework) are management problems, it appears management is having a data breakdown (Construction Labor Motivation, 1982).

Why do we have such problems with the collection and distribution of data? A primary reason is the human factor. Human data entry, whether written or keyboarded, is inherently error prone. Studies show that humans performing manual data collection and manual data entry tend to have one error in every three hundred characters entered (AlMusa, 1994). Applying Automatic Data

Collection (ADC) technologies to data collection and data entry tasks will eliminate these two error-prone and time-consuming activities, and pose an error rate of one in one to three million characters (D. Dunlap, 1995). As a result, ADC technologies allow management to run the business, instead of allowing business to run the management.

The Department of Building Construction and Contracting teaches individuals how to manage the construction process. The department's philosophy is to be on the leading edge of applied construction technology. Currently the department is completing the first year of a two-year grant to implement bar coding into the construction curriculum. The Field Engineering (surveying) Lab was the first area in the curriculum to adopt bar coding for the purpose of tracking equipment, job locations, preparing equipment status and maintenance reports, and to record time and attendance of students.

The department has a two-fold purpose in the utilization of bar coding. The first is to expose the students (future constructors) to the use of bar coding by having them check equipment in and out to various field lab locations representing job sites. The second purpose is to actually instruct them in the process of designing and implementing a bar code application to solve a specifically perceived company need. The goal here is to have students graduating who are familiar with bar code technology and unafraid to apply it in an industry setting.

ADC Technologies

ADC is a family of technologies that can place accurate and timely data at the fingertips of faculty, staff, students, management, and labor. ADC is an acronym used to describe direct entry of data into a computer system, or other medium, without using a keyboard. According to ALMUSA (1994), ADC technologies roughly fall into six categories: optical, magnetic, electromagnetic, biometric, touch based, and smart card.

These technological tools automate the repetitive information demands of modern business. The successful application of ADC technologies requires a careful study of the work process that is being considered for adaptation. A process study of the Field Engineering Lab was done and revised several times to determine the best adaptation of bar coding to the everyday functions of checking equipment in and out for lab exercises. Careful process study provides clearer understanding of laboratory management practices, allowing faculty and staff to improve them. Management practices can be improved by ADC in three specific ways:

1. Data entry is streamlined, automated, and inexpensive
2. Accuracy, speed, and reliability are the underlying reasons for implementing an automatic data collection system
3. Programs or companies incorporating ADC into their educational or work structure acquire measurable returns through the improved efficiency of existing processes (D. Dunlap, 1995)

Accurate information in meaningful detail allows faculty, staff, students, management, and labor to track equipment in batch or real time, and therefore, know how the equipment in the labs and field operations are performing. One can choose the initial ADC tool from among the following ADC Technologies.

- Optical: Bar coding (includes two dimensional symbologies); Optical character recognition (OCR); Vision systems; Mark sense; and some Biometrics Magnetic: Magnetic stripe
- Magnetic ink character recognition (MICR)
- Elemmagnetic: Radio frequency identification (RFlD); and Radio frequency data communication (RFDC)
- Biometric: Voice recognition systems Touch: Touch screens; Button memory
- Smart Card: Card-based storage/retrieval device

Discussed further are the various types of ADC technologies:

Optical type of ADC Technology Bar Codes

Bar coding has been accepted and applied in a wide variety of industries. Of all of the ADC technologies, bar coding probably has the broadest potential for application. What is a bar code? Printed bar codes, called symbols (or symbology), are typically a series of alternating light and dark "bars" which are produced according to published specifications. Bar codes are inexpensive to produce, and are therefore disposable, highly accurate, and tolerant of moderate amounts of damage. They can be optically read by a wide range of scanning methods (AIM^{usa}, 1994).

At last count, there were approximately225 known bar code symbologies. Only a few are widely used. Traditional bar codes are linear (one dimensional). Popular in industrial, medical, and government applications is Code 39, an alphanumeric symbology with self-checking properties that offers a variable length and a high degree of data security. This seems to be the symbol of choice for construction, and is what we are using at Purdue. Bar code applications appear unlimited. It is an extremely effective identification tool that provides accurate and timely support of the data requirements for sophisticated management systems. Bar code usage generally increases accuracy and productivity, creates cost saving, and improves business operations (AIXTOMATIC ID NEWS, 1995-96).

Bar Code Scanners

The scanner actually reads the bar code symbol. Scanners can be broken into two main categories: Contact and Non-contact. Contact scanners must touch or come into close proximity to the bar code symbol. Wands are examples of this type of scanner. Non-contact scanners do not have to be in close proximity to the bar code symbol in order to read it (AIM^{usa}, 1994).

Optical Cards

Optical cards are credit-card-size plastic cards. Data is stored on a plurality of tracks that can be read optically. Though these cards can store a great amount of data in a very small space, the data is not easily updated or changed (ADI[usa], 1994).

Magnetic type of ADC Technology Magnetic Stripe

Magnetic stripe technology uses the magnetic field of an encoding head to record data in the form of magnetic flux reversals. The best-known applications are on credit and debit cards for use in automatic teller machines (ATMs) and point-of-sale (POS) terminal (AIM[usa], 1994). The Electromagnetic type of ADC Technology RF Data Communications (RF/DC) is an exciting technology for the construction industry. In the material-handling industry, RF/DC allows shipping, receiving, storage, retrieval, order picking pick-slot replenishment, real-time information gathering, and other instructions to be transmitted directly to and from terminal operators and the host computer (AIMED, 1994).

Radio Frequency Identification (RF/ID)

Radio frequency identification (RF/ID) is basically an electronic form of bar coding where electronic labels (or "tags") are programmed with unique information and attached to objects that need to be identified or tracked, such as pallets, vehicles, automated guided vehicles, etc. Read ranges from less than 1 inch to 100 feet or more are useful in rugged industrial environments where other contact or near-contact ID readers would be damaged or misaligned during operations (AIMusa, 1994).

Smart Card type of ADC Technology Smart Cards

The smart card is a method of Automatic ID that uses a credit-card-size plastic card with one or more microchips embedded in it. The term "smart card" is also applied to plastic cards that only contain memory and are used for applications such as coin replacement or units of inventory. Contact less smart cards are read and are written | to remotely by radio frequency signals for toll collection, container contents, and vehicle identification (AIM[usa], 1994).

Touch type of ADC Technology Memory Buttons

The memory data container is an electronic identification device accessed when touched with an E metal probe or wand that reads the data on the memory chip. Memory buttons are often used in harsh environments where contact reading is acceptable or desired (AIM[usa], 1994). Biometric type of ADC Technology Voice Input/Output Voice recognition technology converts sounds, l words, or phrases spoken by humans into electrical signals and transforms these signals into coding patterns with l assigned meanings. Voice recognition is ideal where speed, accuracy and real-time data are a requirement. Biometric ADC Technology is most beneficial when an operator's hands or eyes are occupied in activities such as in laboratory work, bridge inspection, inventory control, forklift operations, and especially in quality control for automotive manufacturing (AIM[usa], 1994).

EDI

Electronic data interchange (EDI) is the application-to-application electronic exchange of business data found in invoices, purchase orders, and dozens of other business transactions. EDI reduces lead times and inventory levels, improves bi-directional information accuracy, reduces management costs, and improves the quality of products and services (AIM^{usa}, 1994).

Drafting the Klinger Award Proposal

The characteristics of ADC briefly discussed above have primarily been adapted, tested, and proven in industries other than construction and education. The Department of Building Construction and Contracting (BC) agreed that the ADC technologies were sufficiently powerful, developed (user friendly), inexpensive, and cost effective (ROI) that it was highly probable that the construction industry is on the verge of adopting many of them in the near future (three to five years). With this in mind, the 1995 AGC Klinger Award Proposal to bar code the curriculum was drafted.

The primary concept of the Klinger Proposal was to implement first the most cost effective, applicable technology into our curriculum. Through phone interviews and personal interviews, the department became acutely aware that the initial application of ADC technologies in the construction industry has been primarily bar coding used for tool tracking. The department also discovered that bar coding was the simplest and least expensive application of the ADC technologies. The Klinger Award was received, and implementation of bar coding into the curriculum was initiated.

Implementing a Bar Code Plan into a Construction Curriculum

A committee was formed to work on the implementation of bar coding into the curriculum. A questionnaire was developed to ascertain knowledge of the use of bar coding in the construction industry. The questionnaires were mailed to 1000 randomly selected AGC contractors, 600 top mechanical, and 400 top electrical contractors in the US. In addition, a phone interview questionnaire was prepared and a list of bar code users was developed through referrals. The committee visited the sites of several types of businesses that are bar code users to personally view how their systems functioned. Sites visited were:

- The Purdue University Tool Crib, Purdue University, W. Lafayette IN
- Landis and Gyr (manufacturer of electrical meters), Lafayette, IN
- The Caterpillar Engine Facility, Lafayette, IN

Furthermore, the committee attended seminars and institutes, and read about and compared a half dozen off-the shelf software and hardware packages that would track tools. The committee also considered semi-custom software and full custom applications. After all of this, it was decided to use an off-the-shelf tool-tracking program. After careful study and many live interviews with bar code users, a vendor, Tool Watch, Inc., was contacted and the department' s position was described. The vendor asked for a proposal. In order to develop the proposal for Tool Watch, the department committee had to study the applications (processes) in our curriculum that were most likely suited to bar code adaptation. A proposal was prepared based on identified needs and capabilities. ToolWatch, Inc., accepted the proposal and sent all of the hardware and software needed to set up two labs with tool and equipment control bar code systems.

Results

Results from the survey from the grant indicated that 0.8 percent of the companies surveyed used bar coding, and that a large 69 percent knew little or nothing about bar coding and ADC. However, 43 percent indicated they would like to know more.

Implementation of bar coding began in the Field Engineering Lab. Equipment and field books are controlled as well as time and attendance. The department committee, along with the responsible faculty and lab coordinator, were charged with the development of the goals and objectives of bar code application in the Field Engineering Lab.

The second lab to be brought on line as an actual Tool Crib operation is the Construction Lab. Data bases are being created toward that end.

A third lab, the Field Operations Lab. (FOL), is an office being established on the mezzanine of the Construction Lab. This office replicates the functions of a superintendent's trailer on the job site. From the FOL, the juniors will be supervising the freshmen as they are building structures in the Construction Lab. The juniors collect and report data using bar codes and scanners; they gather data concerning inventory, productivity, tool control, and safety. This information is loaded onto the job site computer (in the FOL) and sent to the Project Management Office Lab on the 4th floor, where the seniors can use the information to determine productivity, adjust schedules, and receive field orders.

The above application of bar coding is one way that students are provided the opportunity to use an ADC technology and learn what it can do. A second step is to actually show them how to develop and implement a bar code system. One of the most interesting aspects is the requirement that in order to develop and implement a bar code system, it is necessary to break down the information and work process to study them in detail (D. Dunlap, 1995). This seemingly small step is of major importance to the success of using ADC technologies. It is also an important step in analyzing and managing a company or a project. With this in mind, Dr. Fritz Muehlhausen is preparing a block of lectures and hands-on exercises where juniors in the site-planning course will develop a bar coding system for a company. Completing this course will prepare the students for the opportunity to apply their knowledge in the field in as early as the summer between their junior and senior years.

Conclusion

There is not a single best ADC technology. The application and surrounding conditions will determine which ADC technology best suits a curriculum or a company's needs. Since 1990, the ADC industry has been one of the fastest growing segments of the information collection technology market. Study evidence indicates that 80 percent of the information collected in a department must be shared with others (D. Dunlap, 1995). Therefore, the question should be, "How important is timely, accurate, and reliable data collection?" If making precise business decisions based on collected data is important, how can you not use an ADC technology? Can a company or an institution afford not to? The future of ADC applications in the construction industry and in the academic community will only be limited by a lack of imagination and an unwillingness to embrace these new data collection technologies. Cost will not be the deterrent, user friendliness will not be the deterrent, only industry's refusal to change will keep the construction industry from utilizing ADC technologies. However, the saving grace will probably be, that if the competition effectively uses a new technology, other companies will be forced to use it in order to compete (D. J. Collins, 1994). The bottom line is that graduates exposed to new technologies in their undergraduate curriculum may very well become the change agents of the construction industry. Similar to what is now occurring with the utilization of computers in construction, once basis foundation of a new technology is financially successful industry or academia. The users will become very creative in the application of ADC technologies. This is only the beginning.

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