INTEGRATING PERMANENT EQUIPMENT TRACKING WITH ELECTRONIC OPERATIONS AND MAINTENANCE MANUALS

Electronic operations and maintenance manuals

D. WIRT AND G. CROUCH
Anderson and Associates, Blacksburg, Virginia, U.S.A.
W. E. SHOWALTER
Virginia Polytechnic Institute and State University, Blacksburg, Virginia, U.S.A.

Durability of Building Materials and Components 8. (1999) *Edited by M.A. Lacasse and D.J. Vanier*. Institute for Research in Construction, Ottawa ON, K1A 0R6, Canada, pp. 2716-2723.

Abstract

Permanent equipment may be delivered months in advance of installation on a construction project. It may be received, stored off-site, transported to on-site storage, installed, and tested. During construction, there are obvious advantages to knowing where each piece of equipment is at any given time. During operation, the owner of the project needs to know the status of equipment during operation and be able to find the proper operating and maintenance information when required. We have completed a trial system on a wastewater treatment plant project that uses bar codes to track equipment from receipt to installation, and then is used to interface with an electronic operation and maintenance (O&M) manual. The O&M manual can be accessed in a variety of ways, including bar codes on the equipment, selecting the equipment on electronic drawings, and pointing and clicking on digitized photographs. The interface to the electronic O&M manual can be a valuable added service to the owner.

Keywords: Bar codes, construction, information technology, data collection

1 Benefits of bar code tracking

Bar coding is incredibly fast and error free compared to standard keyboard entry of data. With a laptop or smaller computer, it is possible to have an encyclopedia of information immediately accessible. With bar code technology, one quick scan can perform complex computing operations or yield instant access to information on particular equipment such as location, status, specifications, submittal data, etc. For example, a construction superintendent in the field would need only to turn a

notebook computer on, scan a bar code, and end up logging current time, location, site conditions, or even pinpoint a certain item in a huge database and review the appropriate specifications or specification manual.

Manufacturing companies recognized the potential for increased production using bar codes over a decade ago. Bar coding is often the primary foundation to computer automation of manufacturing. A bar code system integrated with automated material handling helped General Electric reduce the manufacturing time of aircraft engine components by 30% and boosted productivity by 50%; boosting production from 207,000 units to more than 320,000 units with essentially the same work force (Pashall, 1986). Additional benefits included reduced cycle times, reduced work-in-progress inventory, and nearly perfect work-in-progress tracking accuracy.

Merchandise distribution companies also recognize the potential of using bar codes for increasing production capacity. As Elizabeth Arden's business grew, the traditional solution for increased capacity was to add more workers at their primary distribution center in Roanoke, VA. However, the faster the workers picked merchandise for shipping, the longer it took to get orders out the door (Field, 1997). Bar coding proved to be the core of the solution. A Code 39 bar code is automatically assigned to each order the moment the order is taken from the customer. Bar code scanners are strategically placed along the conveyor system, from empty carton stage to the end of the dock, as well as on all forklifts, for permanent tracking through the entire process. Radio frequency (RF) communication with all scanners permits real-time tracking of all cartons as well as real-time inventory management from any terminal in the facility. Bar coding permitted the use of an automated picking system, automated conveyor sorting, and an automated weigh-in-motion system.

Benefits for Elizabeth Arden were tremendous: a 24 hour operation was reduced to 8 hours a day, with a reduction of full-time work force from 180 to 120 employees for the same workload. During the peak season, the temporary work force was reduced from 150 to 30 employees. The $3 million system had a two-year return on investment. Over 3,000 customers can now expect same-day shipping perfume goods where before it was often a week or more, enjoying virtually 100% shipping accuracy. Elizabeth Arden now has immediate visibility in inventory control because of radio frequency and bar code systems.

2 Bar codes in construction

The Construction Industry Institute undertook a study of bar code applications in construction (Bell and McCullouch 1988, Bell and Gillis 1989). A review this work is not possible here, but it forms the foundation for this project. Many others have published work in the application of bar codes to construction as well. This paper presents one application.

Many large construction companies are using bar codes to manage aspects of their work. They see the reduction in potential for errors and the speed of entry as the primary benefits. Included are Fluor Daniel, M. W. Kellogg, Bechtel, and H. B. Zachary; focusing on areas such as small tool tracking, time and attendance, structural

steel tracking, materials management, and workflow.

With the recent increase of commercially available and user-friendly bar code systems, small and medium-sized construction companies can take advantage of bar codes in managing their work. In the fall of 1996 the Virginia Tech Construction Affiliates, a partnership between Virginia Tech and a consortium of construction companies, became interested in studying field data acquisition applications. A significant portion of the resulting Field Data Acquisition Project was permanent equipment tracking, with an effort to apply existing bar code technologies to applications in the construction industry.

Permanent equipment tracking is particularly suitable to the design and construction of wastewater treatment facilities. State regulatory commissions are stringent on operation and maintenance (O&M) requirements of wastewater facilities, because a shutdown of a system could pose a serious health threat to a community of people. On typical construction projects, O&M manuals are compiled from submittal information from equipment manufacturers; submittals often end up on-site, at the engineer's office, at the contractor's office, etc. For wastewater facilities, the state regulatory commission requires that the engineering design firm for the project prepare and bind an O&M manual including all pertinent submittals, and certify that all facility information is included and accurate.

At the beginning of this study, Anderson and Associates, Inc., a member of the Virginia Tech Construction Affiliates, was managing the design and construction of the Fort Chiswell Wastewater facility in Wythe County, VA. Anderson was interested in taking the O&M preparation one step further and considering the possibility of providing an electronic O&M manual as a value-added service for the contractor and owner.

Potential benefits of an electronic O&M manual are numerous. During construction, the contractor could immediately know the location and status of equipment by taking a virtual site tour using electronic drawings, or scanning a bar code on a particular piece of equipment. During operation, the owner could access equipment information in the same manner, and review specifications, maintenance logs, or any other information that would be linked to the electronic tracking system. Likewise, the owner could go to a particular piece of equipment and scan a bar code and access with guaranteed accuracy the same information. Such information could help avoid common problems, such as ordering an incorrect repair part for a pump because of mistakenly reading the O&M specifications for the wrong pump, a potentially costly and serious mistake.

The scope of this project was to develop a PC based electronic tracking system using linear bar code technology and commercially available software. The first objective is equipment tracking during the construction phase. The second objective is to link the information to an electronic operation and maintenance system for the owner during the operation phase.

2.1 Permanent equipment tracking project

Selected site – Fort Chiswell Wastewater Project, Wythe County, Virginia. With the assistance of Anderson & Associates, Inc. and W. Rogers Construction Company, a 500,000 gallon per day wastewater treatment facility was used as a pilot project. The $3.3 million project was in the construction phase at the time of this study, and much of the equipment was still arriving to either the site or W. Rogers' warehouse, ideal for testing bar-code applications.

Bar code labels - Compliance labeling versus labeling at receipt – Compliance labeling refers to product suppliers complying with standardized bar coding labels on products as required by the customer. Many manufacturers and retailers require their suppliers to become electronic commerce trading partners: product must be bar-code labeled per specified guidelines prior to shipment to allow electronic shipment tracking and to coordinate product identification in the customer's database.

Compliance labeling was not considered in this project. Given the small scale of this project, such a requirement was not deemed necessary. Nor would it be practical since the construction of the facility was concurrent to this study. However, on a large project with a large inventory of equipment, or especially where materials such a fenestration goods have a wide array of sizes very similar in appearance, compliance labeling could be a real asset to electronic tracking. In this case, it was considered more rational to label equipment at time of receipt.

Code 39 bar code symbology was used for this study. Code 39 is the most frequently used symbology in manufacturing and industrial bar code systems (Lee, 1997). It allows a variable length code of any of the 128 alphanumeric ASCII characters and is an easily read code in terms of scanning.

A critical link in a bar code system is the durability of the bar code labels in the working environment. The harsh construction environment poses a serious threat to the quality of the bar code system, and continues during operation for a wastewater facility as studied for this project. If a label cannot withstand the environment, and thus cannot be read by a scanner, the bar code system is rendered inoperable. The focus of this study did not include label durability. Metal-etched bar code tags along with specialty products such as Bumpy Bar Code™ are commercially available, and a fair amount of construction research has focused specifically on label durability in the construction environment. It is worth noting here that label durability be a primary consideration when developing a permanent tracking system.

Equipment labeling - An initial challenge was being able to effectively label equipment, regardless of the location that it was received. Ideally, any location receiving equipment would have a bar code reader for automatic data input. Realistically, as may be expected on an actual project, equipment may arrive and a bar code reader is not accessible. The method chosen to accommodate varied conditions of receipt was to furnish an equipment receipt log, having paired labels beside of each entry. As a piece of equipment arrives on-site or to off-site storage, a bar code tag is placed on the equipment. Data is then entered directly into the database if the bar code system is available. Else, data is entered in the log next to the remaining identical bar code label, or the remaining label is peeled off and placed on

the equipment invoice for keyboard data entry.

There were several advantages to this labeling method. For the small size and relative complexity of this project, it was not deemed necessary to have the bar codes coordinated with database entries prior to equipment receipt. Rather, as invoices are logged, bar codes could be coordinated at that time. Also, a metal etched label or other type of specialty label could easily be substituted for the equipment label for durability requirements.

Computing and bar code platform – Microsoft Windows® was chosen for the operating environment. Many construction companies are using Windows or NT for office personal computing, and especially so in field applications. Specifically, Microsoft Office® was used, providing powerful and economical capabilities for integrating bar coding technology with database and CAD technology. Microsoft Word, Excel, Access, or any other similar Windows applications are likely candidates for building an equipment database, and subsequently an electronic O&M manual. This is advantageous since most PC users seem to stick to one application, such as Word or Excel, and will give almost any excuse to avoid learning other applications. Further, without the integration offered in the Windows environment, bar code systems usually require extensive custom programming, which is cost prohibitive in small-scale bar code systems as proposed herein.

The Wasp Nest® bar code package, by Informatics, Inc., has several features that were desirable for this project. Wasp Nest is a professional bar code scanning and labeling package designed to integrate bar coding into any Windows based applications. This package can turn any personal, laptop, or handheld computer into a complete bar code system in minutes. Labels can be generated, scanned, and decoded for all popular bar code symbologies. Labels can be printed using ordinary laser or ink-jet printers. Very little training is required to be quite proficient for users familiar to the Windows environment. Current costs for a one-user package range from $200 street price for complete package with economical wand scanner to $600 street price for same package with laser scanner and support for two-dimensional scanning. The package with wand scanner was used in this study. With built-in remapping features, bar coding can be powerfully integrated into tracking with little or no additional Visual Basic® programming required.

Visio Technical® provided a powerful means of integrating bar coding and the database and AutoCAD® site drawings together. The actual AutoCAD site plans were imported into Visio. Features that make Visio unique for this application are that custom shapes can be created that have built-in intelligence; an intuitive interface for linking to the bar codes and database information simply requires a good understanding of the Windows environment; advanced tracking capabilities can be performed if the user is adept with C, C++, or Visual Basic for Applications. Working drawings can be imported from any of the popular CAD software packages, and are fully editable. The result is that “smart” shapes can be created on actual site or building plans which can be linked to virtually any application that is Microsoft ODBC (Open DataBase Connectivity) compliant. In this case, a “smart” shape is created and placed on the drawing where each piece of equipment is currently located

on the site. The shape is then hyperlinked to the desired information in the database for status, location, specifications, or other desired information.

Computer – A Toshiba Pentium 120 notebook computer was used in this study, being portable, relatively fast, and having ample storage capacity. It was readily available and was a good fit for this project. The computer was loaded with the required software, and outfitted with a wand scanner.

One concern in using this setup was durability of a notebook computer in the construction field. A common criticism for computers in the construction field is lack of resistance to the harsh environment, especially from being dropped onto the ground. It is worth noting that the initial intention for field use was to use a portable data terminal similar to, but more rugged than what United Parcel Service (UPS) and Federal Express use. However, a sales associate for a prominent bar code manufacturer said that admittedly, bar code equipment has not been developed to date, by his company, that is intended to meet the rugged requirements of the construction field. And so, considering the ability to integrate all of the commercially available components using the Windows platform, along with the power of having a complete database with intelligent electronic drawings, a notebook computer was considered to be the best option.

2.2 Using the bar code system

The initial step on the construction site was to bar code label permanent equipment. Bar code labels were affixed to equipment stored on site as well as several pieces already installed. Digital photographs were then taken of each piece.

At the same time, the electronic layout was taking shape in terms of tracking software for the contractor during construction. The site and building plans for the project, in AutoCad® Release 13, were imported into Visio Technical in fully editable format. Some extraneous information was deleted to optimize processor speed. When equipment was bar code tagged, a smart shape was also created on the electronic site plan, corresponding to the current location. The bar code decoder was remapped so that when scanned, the particular bar code would direct the user to the location on the site plan. By hyperlinking the smart shape, a powerful feature of Visio, the user selected the shape and was directed to a page with digital photograph of the equipment, current status, and related specifications. An important note is that the shapes can be linked in the same manner to any ODBC compliant applications desired.

In practice, while the contractor is using the electronic layout for construction tracking, the design firm would be building the electronic O&M manual on the same electronic framework. Some manufacturer's operations and maintenance manuals are available on electronic media. Other submittals received in paper form, would be digitally scanned into an ODBC compliant application, such as Microsoft Word, Excel, or Access.

For the O&M manual, smart shapes were hidden where the permanent equipment was shown on the plans. The bar code decoder again was remapped so that a bar code scan directed the user to the piece of equipment on the electronic plans. This configuration yielded a twofold result: a plant operator could directly scan a bar

code labeled piece of equipment, and would be directed to the plans to confirm a correct scan. Second, the operator could access the electronic drawings on the computer, and select the same piece of equipment from a remote location. From that point, selecting the shape would direct the operator to a digital photograph, corresponding O&M information, maintenance log, etc.

This project resulted in several significant implications. The cost of the software and bar code equipment was on par with any other software used in the typical office, and the cost of the computer basically depends on the level of compactness and performance desired. Anderson & Associates, Inc., being the design firm responsible for delivering the O&M manual, is highly computer oriented in their work, as are most design firms. The implication is that an electronic O&M database containing drawings, specifications, O&M, photographs, and even video imaging could be powerfully integrated, and delivered to the contractor and owner without great effort beyond what is already required. Further, this electronic package could be supplied on CD-ROM. This could be a value-added service, with opportunity for being paid services that are of value to the contractor and owner.

3 Conclusion

Using the Wasp Nest® bar code package, along with Microsoft Office® and Visio Technical®, a bar coded electronic O&M manual was developed. The user can scan a bar code label that is attached to a particular pump, motor, etc. and access assembly diagrams, specifications, and log repair/maintenance data. The AutoCAD® site drawings were also linked to the O&M manual. In this manner, the user opens the computer files of the site and building plans, selects the particular item, and accesses the same information while sitting at a remote location.

An important conclusion is that a database containing drawings, specifications, O&M, photographs, and even video imaging could be powerfully integrated using CD-ROM technology. This system, including costs, could be incorporated into a project at the planning stages, and carried throughout to project completion and into operation, with all parties using the same information.

4 References

Bell, Lansford C. and Bob G. McCullouch. 1988. "Bar Code applications in construction." Source Document No. 33. Construction Industry Institute, Austin Texas.

Bell, Lansford C. and Joe K. Gillis. 1989. "Bar Code implementation guidelines and tutorial part I: Guidelines." Source Document No. 46 Part 1. Construction Industry Institute, Austin Texas.

Field, Karen A. (1997). “Upgrade Cuts Two Shifts Out of the Work Day”. Modern Materials Handling. April. pp 30-33.

Lee, Glenn. (1997). “The Auto ID Book: Bar Coding and Automatic Identification Technlogies”. Second edition. Informatics, Inc., Plano, TX.

Pashall, Michael R. (1986). “Bar Code Tracking Helps Boost Productivity 50%”. Modern Materials Handling. November. pp 80-82.