



BAR CODE SYSTEM STANDARDIZATION

by

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The University of Texas at Austin**

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BAR CODE SYSTEM STANDARDIZATION

CHAPTER 1:INTRODUCTION

In the book *Future Perfect* the author singles out one company as a stunning example of the shift that will mean success for companies in the next decade. That company is Federal Express, who expertly manages time and space to meet customer's needs. Federal Express can move mail overnight while being able to locate instantly every one of millions of packages. Federal Express uses many means of transferring real-time information; one of these is bar codes on every package. Bar codes provide the means by which Federal Express and their customers track shipping and billing simultaneously. (Davis 1987)

Companies that deliver services in real-time will have a decided advantage over their competition. Real time means that responses to inputs are fast enough to guide the process. (Davis 1987) Real-time information is necessary so that managers can verify events in progress and take necessary corrective actions. A real-time management information system is possible only when managers have the benefit of speed, accuracy, and reliability (Burke 89). Automatic identification techniques are a basic part of computer technology. They access a variety of data and are quick and reliable. Bar code is the most widely used automatic identification technology and is receiving increasing attention from the construction industry.

Many changes are taking place in the construction industry due to extensive use of computers. Automation affects construction industry administration and accounting, project management, and design. Computers rely on data, raw and unorganized records, and process data into information, refined, usable, and structured data that can be easily interpreted by the user. The successful use of computers requires systems integration, developing the full range of automated capabilities, including standards for communication across boundaries, reducing trivial delays, and continuous improvement. Bar codes are not a system but an extremely effective identification tool that supports management systems (Meyers 1991). It is possible to achieve systems integration without bar codes but the user will experience loss of time and accuracy.

The CII has already investigated bar coding in construction. (Bell & McCullough 88, Bell & Stukhart 86, Bell & Stukhart 87). Several other papers discuss uses of bar codes in the construction industry (Rasdorf and Herbert 90, Susca 90, Blakey 90). In the last four years, several companies and government organizations have adopted bar code for one or more construction operations. Despite this progress, the vast number of construction companies have not adopted this relatively simple technology.

The primary reason for this research and this paper is that construction companies are at the beginning of the steep climb of the S-curve of this technology. (Foster 1986). The knowledge is available, the processes well-known, the technology relatively simple, and the cost of entry relatively low. This one technology can have significant benefits to users. Although there may be many reasons why companies are not taking advantage of bar code, one major reason is the lack of standards. (Stukhart and Pearce 89, Stukhart and Cook 89, Stukhart 90). Without standards, companies will develop their own requirements, and it will be difficult and costly for trading partners to exchange information. In effect there will be "islands of automation". This is true in all automation.

To achieve the overall objective of increasing the use of bar codes in construction, this paper has the following goals:

1. To reemphasize the benefits and costs of employing systems using bar code in

construction. By pointing out these benefits, perhaps more companies will be convinced to take advantage of bar code.

2. To provide a current, comprehensive reference on bar coding in construction.
3. To show how a common shipping label standard has evolved and how it will improve the materials management system.
4. To show some future trends in bar coding.

CHAPTER 2: INFORMATION PROCESSING TECHNOLOGY

2.1 IMPORTANCE OF INFORMATION PROCESSING:

Information can be classified as historical, comparative, essential and real-time. Examples will illustrate these classifications. First, information should be available when needed and only some information is needed immediately. Information on the completion of prior activities is *historical*; information on the relative economics of alternatives is *comparative*; and drawings and specifications are *essential*. Information on an ongoing activity is *real-time*. The importance of real-time information is that it permits corrective action before the activity becomes history.

Some of the reasons for a control system are safety, productivity, cost, preventive maintenance, production, quality, security, and accountability. There is also a need to control the integrity of the process itself. A systems analysis must identify what and where information is needed, by whom, and what the delivery system is. The analyst must also know how the user will respond to the information. Users may range from unskilled workmen to engineers and managers with differing needs and differing levels of training in technology. The process of information flow must accommodate the requirement of each user.

The analysis helps to determine who requires what information, when, why and in what form. Often symbolic representation is used. A manager may require the information in economic terms while a technician wants it displayed graphically. Information can be delivered visually or vocally. There may be a need for certain information at one site or at several. Input devices may be keyboard, touch-screen, scanners, voice, radio frequency, or optical, depending on the skills of the workforce, the investment in technology, volume of data, and need for real-time information.

Professionals in the decision-making process of the construction industry are increasingly using the information processing ability of microcomputers. To make timely, accurate decisions, they must have complete information ready at hand and the tools to interpret the available information. There are database management systems (DBMS) to store, manipulate and transmit the necessary information. Despite the complexity, speed and accuracy of modern computer systems, time and accuracy are still lost due to humans, who are no faster or more reliable than they were years ago.

2.2 CONSTRUCTION INFORMATION NEEDS:

Engineering and construction end-users require different types of information e.g. - financial, time, personnel, plant and equipment, and inventory. Each of these functions requires a good database with specific information. For example, financial information requires changes in cash flows and accounts. Labor information requires time and attendance data. Materials management requires data on inventory, shipments, receipts, quantities, and many other fields. In the next sections, various construction management information systems are described.

2.2.1. Cost:

Owners, construction managers, and contractors should project cash flow very closely; this requires use of advanced tools and constant attention. Costs of personnel, materials, equipment, and capital are required. There is a need for information to use in budgeting, forecasting, design, historical records, estimating, productivity measurement, progress reports, and accounting.

2.2.2 Time, Attendance, and Work Tracking:

Every project needs information on personnel time, attendance, and work assignment. This is needed for cost reports, cash flow projections, estimates, and productivity assessments. Labor time and attendance systems record time "punches" and classify according to skill. Information can be sorted by time on project, contract, activity, and craft. Labor expenditures are usually classified by project or work package and stages in the project. Information should be real-time and historical.

Time, attendance, and work assignment information is needed for all hourly and salaried employees. The data required are of two types. One is the data which provide time on and off the project, start and stop of any event, numbers of entries, work package assignments by individual or craft, and overtime. The other is the indirect data that interprets time or work assignment, or provides explanation for the blanks in the records. Time (and many other types of data) can be classified in different ways. Direct or real time categories are: -IN normal time, IN overtime, OUT lunch, and OUT end of the shift (Sharp 90). The indirect data includes the historical record of time accumulated. This is used for computing pay, vacation time, sick leave, holidays, and other administrative time.

Work assignment tracking is an extension of time and attendance and tells what people do on the job. It is valuable in situations where individuals perform a variety of tasks in one shift and there is a need to allocate time, effort and materials to each task. This type of information is needed for billing, analyzing work patterns and eliminating many charges previously included in overhead. (Sharp 90) Information on work assignments can be classified as comparative and historical.

2.2.3 Schedule and Resource Control:

A schedule contains activities and associated resources. As the project uses resources and completes activities schedules are updated. The schedule must indicate status of completion of the activities and the type and quantity of resources. This will provide information needed for cash flow, payments, overall status of completion, forecasts, and effort remaining. Schedule status will permit changes in methods, resources, and management actions to affect the durations and costs. This knowledge is important in future plans and projects.

2.2.4 Materials Management :

Materials management is one of the key activities on a project. Its importance in improving productivity and cost has been discussed in several CII studies the last few years (e.g. Bell and Stukhart 1987). Materials management has many functions or subsystems. These include purchasing, expediting, quality control, transportation, receiving, storage, issue and disposal. Each of these functions has its own essential needs for information. The Project Materials Management Handbook (CII 1988) has a detailed discussion on the materials management function and its needs. For example, purchasing needs information on the source, cost, specification, and delivery of materials; transportation requires the origin, carrier, delivery terms and destination. Receiving requires the transaction and packaging information, and whether a package is a total, partial, or mixed shipment. Storage needs to be able to receive, issue and inventory; that is, to identify items accurately, to locate and account for them. The destination or use of the items is also needed. Much of this information is needed in real time, as well as being essential and historical. Information on costs and delivery schedules could be classified as comparative.

2.2.5 Tool Tracking:

Tool tracking is a special case of materials management. Tools must be closely controlled because they are costly and the craft depend on them being available every day. In addition to the information required for materials management, tool tracking on construction sites requires daily information on to whom, when, and items are issued. This information should be real-time. There is a need to know when certain tools need calibration and safety checks. Historical data on use will provide information for replenishing worn out or damaged tools and estimates of future needs.

2.2.6 Document Control:

In any industry there are many documents that are essential and many others are merely informative or transitory. In construction the term essential could be applied the drawings, specifications, quality reports, safety checks, and many other types of information. These files or records can be considered as documents. There are various physical forms of documents such as paper, magnetic tapes, films, disks, and optical storage media. The tools required to produce and duplicate various forms may vary, but the reason for and method of detailed document control is similar.

The data requirement for document control includes the identification, origin, date of transaction, location, and accountability. To label a document one must know what it is. Is it a folder of papers, a collection of related media in a folder, or, maybe even a computer file? For example, a quotation file may contain a request for quotation, a bill of materials, an estimate from previous purchase orders, a comparative statement and final proposal, and an approval sheet. All this information could be stored in the document control system under the category of 'quotes'. A document log should provide information on origin, destination, number of copies in circulation, and who is responsible for the document.

2.2.7 Drawing Control :

Drawings are a special class of essential documents, because they are project and location specific. There are many types and quantities of drawings on a single project. There are conceptual final design, contract, working, shop and record drawings. To keep track of all the drawings requires external control data similar to other documents plus unique identification by project, location, and revision number. Data regarding the effect of materials changes in the drawings and other impacts can also be stored on a master document that includes the drawing. Of course, drawings can be computerized, retained in electronic form through series of revisions, or maybe never printed in final form.

2.2.8 Quality Control:

Most industries place great emphasis on quality. The construction industry is no exception, seriously studying prevention, appraisal and correction of defects. Quality-related data include preventive measures, checklists, test results, defects, statistics, tolerances, and quantities. Quality control data is most valuable when processes can be observed in real-time, but historical data on inspection, tests, or defects is also important.

2.2.9 Equipment Management:

The desired data content of a vehicle and equipment management system have been studied by the US Army Corps of Engineers Research Laboratory (Hicks and Fuerst 90):

1. Equipment identification, type, description, manufacturer, model number, serial number, warranty, in-service information, fuel and oil type, depreciation, service, major components, operating hours or mileage, and date of observation.
2. Task or activity definitions, descriptions, resources, and codes
3. Work order information: Person performing work, equipment identification, code, description and warranty information. System should be able to check for parts, review maintenance history, and list problems.
4. Preventive maintenance capabilities: Schedule, work orders, descriptions, workload forecast, code, and work order if applicable.
5. Fuel consumption
6. History of maintenance and work orders.
7. Parts inventory: Description, stock number, vendor, associated equipment, stock levels, reorder point, location storage, quality data on parts.
8. Purchasing: Purchase requests, orders, blanket purchase orders, relate shortages to work orders.
9. Employee and time management. Personnel data, such as number, grade, and hourly rate.
10. Work tracking: Time on a work order, non-productive time, resources assigned to work.
11. Budget, financial and reporting capability.

2.3 AUTOMATION OF THE ENGINEERING/CONSTRUCTION PROCESS

2.3.1 Data Integration:

Bar code standardization, the subject of this paper, is one contributor to a system of integrated data concepts that includes CAD, electronic data interchange (EDI), database sharing, expert systems, and other automation concepts. Manufacturing industries have tried to build automation into their processes by using robotics, but have, instead, developed "islands of automation". The construction industry has a fascination with robots, but also realizes that a systems approach to automation is necessary. (Keen 1991). A single database concept is recognized as a long term goal and has been achieved in some construction systems, such as materials management. Some companies have developed sophisticated systems that incorporate engineering, cost and schedule data into these single databases. There are no universally accepted standards for these databases, however, and only a few large companies have pioneered this effort. Standards are the first step toward reaching this total automated process (Keen 91). Standards have been achieved on some operations, such as electronic data management, including EDI and bar code.

2.3.2 The Need for Timely Information:

Real-time information is most valuable because it enables the user to exercise control over an ongoing process. A system that is processed manually or one that is partially automated requires processing of information by several parties. In a typical engineering operation data is "inputted" and "outputted" several times (Keen 91). This operation consumes unnecessary time and paper work, and there is too great a chance for errors. More importantly, data, like money, declines in value with time. There is no measure of this value but any user can recall instances where extensive information on construction activities has little or no value after a certain time.

2.3.3 Quality of Information:

We measure the performance of an information system by the number of correct pieces of information transmitted minus the number of times that the information system is unable to respond even though information exists. The performance of the database, and the linkages and terminals are measured by their accessibility and the ease and accuracy with which they transmit requests and return answers (Churchman 68). The project needs information that is accurate so that key people can make the correct interpretations and decisions. Multiple manual handling of information can cause inaccuracies, biases, or filtration of necessary information.

It is well established that the error rate for typing by an expert typist is about one in 300 characters entered (Palmer 89). The error rate for manual entry by unskilled persons is greater. Assume that a partially automated process produces data, such as a drawing number. This number is copied manually at two business locations. If each person has one chance in 20 of making an error there is a 10% probability of an error in the transmittal. If there are hundreds of transmittals there will almost certainly be many errors. Documents will be lost, or delayed, causing considerable confusion and lost time.

Another potential problem in data quality is the lack of discrimination. Information should be pertinent to a given process. Extraneous information can overwhelm the user and be a cause of inaccuracies. Careful systems analysis will eliminate much of this information overflow.

CHAPTER 3: JUSTIFICATION FOR BAR CODE SYSTEMS

3.1 SYSTEM BENEFITS :

Previous studies (Bell & McCullough 88) listed tangible benefits due to use of bar codes in particular applications. The major direct benefit of bar code is in more timely decision-making and better use of resources. It is the intent of this section to discuss the system tangible and intangible benefits to a system using bar codes. We will assume that bar codes and associated preprocessors are the means of providing system input and/or feedback. This is frequently done by accessing a database. Figure 1 shows a schematic where bar codes are used to input to the database and for correcting or checking data. A formal feedback loop is essential if the user is to exploit the lessons of experience. The user can only make adjustments which affect current performance if real-time information is available. This implies that time is essential in generating feedback, so automatic identification is valuable in updating a system.

Bar codes offer error rates of less than one character in a million and speeds of entry 20 or 30 times faster than humans. This has important implications in the overall performance of projects. Control theory says that one must measure a response five to ten times more accurately than it is to be controlled. Since bar code is virtually error-free, a system such as automated materials management using bar code is superior to one in which all computer entries are manual. The system benefits are better identification, reduction in losses, less inventory, and less paperwork.

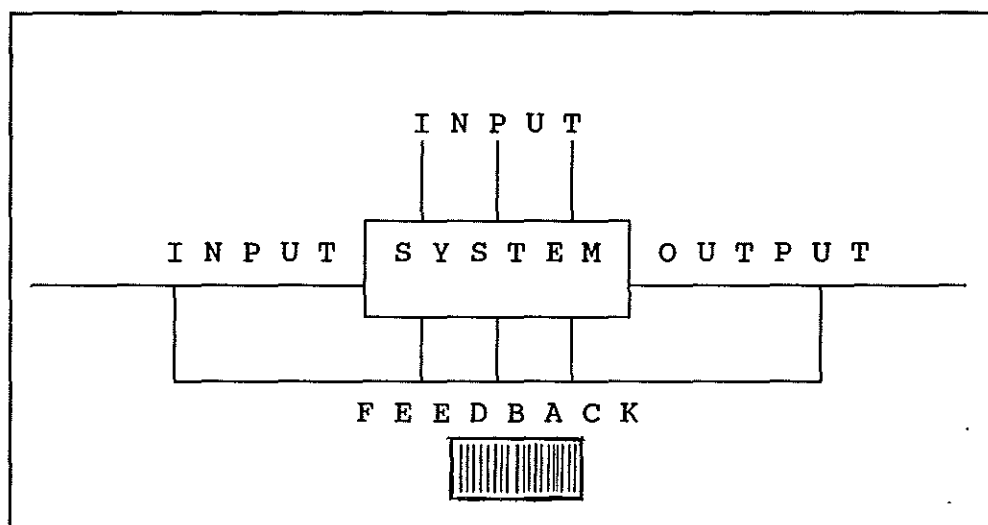


Figure 1 Schematic of information flow in a system

As discussed earlier, there is increasing project complexity and use of computers. Computers are faster, more accurate and less expensive. Despite these rapid advances data entry is still slow and error prone, largely because it is done by humans. Automatic identification devices ensure that the power and speed of computer systems can be at least partially matched by the input device. Automatic identification equipment usually operates on-line, so that as soon as the information is scanned by a bar code reader or other device, it is available to the user's computer system. The data may be used immediately or be available for subsequent use. As an example, tool

control using bar codes not only provides accurate and rapid data entry; it also provides a database. This database, showing the history of tool issues can provides accurate information for planning, estimating, and other uses.

Sometimes it is difficult to justify the installation of automatic identification system merely by only comparing rates of return. Certain extrinsic factors should also be considered, like the adoption of automatic identification system by competitors, pressure from customers and suppliers, and the education level of the work force. Competitors might respond to their customers' needs faster with sophisticated automatic identification system. Once upon a time grocery stores checked everything manually. One grocery chain invested in bar code to scan check-outs, forcing competitors to adopt similar systems. Automatic ID increases the perceived value of products and services, which translates into higher profits, increased market share and lessened sales effort.

3.2 BAR CODE APPLICATIONS :

Sections 3.2.1 through 3.2.7 will discuss benefits accruing to specific applications of bar code technology in the construction industry.

3.2.1 Time & Attendance :

The goals of automatic labor tracking using bar codes include: reporting labor time with accuracy of one minute or less, providing labor payment information as soon as it is incurred, improving the accuracy of billing statements, and eliminating excess idle time. The last goal is achieved by identifying the work tasks having an excess labor.

Benefits

The benefits from using bar-code technology and automated systems for labor tracking and time & attendance reporting include the following:

1. Decrease in payroll expenses - Manual data transcription like reading time punches and converting them into work hours is eliminated.
2. Decrease in administrative expense - Flexible work schedules can be carried out if the project simplifies the tracking of the work force. This will reduce the administrative overhead required for implementing flexible work schedules.
3. Decrease in overpayment and under payment - Manual payroll techniques on an average overpay employees by 0.5 % (Sharp 90). Automated tracking can reduce about 0.25 % of hourly employee payroll overpayment. Similarly, any underpayment to the employees can also be eliminated.
4. Improve productivity - The bar code system provides supervisors with a tool to determine who is absent and to achieve or replan work that would otherwise be left undone.
5. Elimination of recording errors due to mechanical systems or human error. The bar code system will also end most of the transcription errors.
6. Improve security of information - For security reasons more than one copy of the time records can be obtained at very little additional cost and kept in a secure place. Unauthorized access to the records can be reduced. Only the employee or the administration will have access to privileged source information (Sharp 90).

7. Increased precision of labor costing - The increased precision in time reporting will improve labor costing. This will increase the accuracy of bid estimates and enhance chances of winning bids and increase market share.

Cost

The cost of installation of a time and attendance system using bar codes, reported by one general contractor is:

• Installation & training associated with four time clocks	\$21,483
• Bar code badges	\$ 5,220
• Badge laminator	\$ 416
• Programming (Labor Sheet)	\$ 1,094
• Miscellaneous service & support	<u>\$ 186</u>
Total	\$28,399

Another company reported that installing a custom-designed bar code system to clock employees on and off job sites saved money for its customers and saved administrative expenses. Installation of the bar code system cost roughly \$25,000. They compared this cost to the cost of a manual system, which is \$75,000. They claimed to have saved at least \$50,000 in reduction in the number of time keeping clerks. (Susca 90). The other system benefits, such as automatically compiling labor usage and improved planning and estimating were not reported; however, these could be substantial.

3.2.2 Schedule and Resource Control:

Most project schedule overruns are caused by the lack of adequate resources needed to accomplish individual activities on time (Rasdorf & Herbert 90). Bar code technology can be used to obtain accurate and speedy information on needed resources directly from the site. This information is used to record and update data. The materials resources, if identified by appropriate bar code labels, can be tracked using portable scanners from the time the resource enters a job site until it leaves or is consumed. Keypad can be used to enter any additional information not included in the bar coded label. Similarly, the details of start and finish of any activity on the construction schedule can be recorded using activity labels or cards that include name, number, duration, resource identifier and status of the activity.

The use of data cards for field materials control is discussed in a previous report (Bell & McCullough 88). When activities are completed and resources are used the information is downloaded into the schedule and materials management databases by scanning appropriate labels, or cards. The early information on the progress of work and use of resources gives managers an advantage in avoiding delays due to any possible resource shortages.

3.2.3 Tool Control:

A major application of bar codes in construction is in tool control systems. Tools can be tracked by a bar code menu, a tag, label or etching on the tool. Many companies use labels on bins and menus to track tools, but there are a number of labels on the market that have good adhesive properties and withstand severe environmental conditions. Labels are made of metal, both steel and aluminum, and plastic such as polyester, vinyl and synthetics such as DuPont's Tyvek. The use of high quality labels and tags should be limited to high value or critical items such as power tools.

Etching is being investigated by tool manufacturers but etching is an expensive alternative and to date has not been used in the field. See the discussion on labels in 4.5.2.

Tools can be identified using a non-significant or a significant coding system. There are advantages to each. A non-significant number allows the company to use off-site printing of a stack of labels. This label becomes a license plate; the database provides tool identification and other information. A significant number such as a stock code should be used for power and safety tools, especially tools that need calibration based on hours used. When the tool is issued and the bar code label scanned, various data may be entered such as tool number, condition, the time and date of issue, and to whom issued. The database contains a variety of other information: tool cost, location, project, safety criteria, availability, and history of use.

Benefits

An automated system will result in the benefits below. Although some systems use manual entry of data, bar codes are the most rapid and accurate method of achieving these benefits.

1. Reduction in issue time. One company reported that the old "brass" method issue and receiving time has been cut by 2/3.
2. Reduction in losses. This same company reported that tool loss has been eliminated. With 2000 transactions per day over 4 months they have not lost a single tool. The usual loss is at least 5% of the tool inventory.
3. Accurate perpetual inventory. Real-time information is available on the use of tools; this information is valuable for replenishments, usage history, and possible reductions in the inventory. The discussion below on materials management will cover the cost of inventory.
4. Improved tool accessibility: Accurate information on the location of tools will increase their availability on the site. The use of "gang boxes" for storing tools results in considerably larger inventories if the same number of tools are to be made available to everyone. With a bar-coded system, tools can be used by different craft every day.
5. Improved employee accountability. Employees know that the system has charged them with items and this has resulted in much greater individual accountability. They are actually returning items that were usually considered consumed when issued.
6. Improvement in future estimates - The history of tool use provides the system with complete information on where used, frequency of use, and quantity. This will improve estimates of future tool use.
7. Improvement in procurement. Procurement is more efficient by avoiding over-stocking or under-stocking of tools.

Costs

One construction company provided information on hardware and software costs of a bar-coded tools system:

HARDWARE COST

Label Transfer Printer	\$ 4,796
Portable Data Terminal (8 Nos.)	\$ 9,208
Communication Dock (3 Nos.)	\$ 480
Laser Scanner (5 Nos.)	\$ 3,980
Light wand (6 Nos.)	\$ 972
Twinax Adapter	\$ 876
Power Pack (4 Nos.)	\$ 120
Modem (4 Nos.)	\$ 240
Wedge (4 Nos.)	\$ 1,780
Forms Printer	\$ 6,000
Manuals	\$ 995
PC Label Program	\$ 737
PC IRL Development Language	\$ 396
IBM PC (2 Nos.)	<u>\$ 3,000</u>
Total	\$33,580

SOFTWARE MANHOURS

Tool Program	312 MHrs
IRL Issue Inventory/PDT	200 MHrs
Main Frame	550 MHrs
IRL Site Training	<u>30 MHrs</u>
Total	1,092 Mhrs

3.2.4 Materials Management :

The two major uses of bar codes in most industries are inventory and shipping and receiving. These account for at least half of all the bar code uses. Bar coding of materials and containers is probably the function that provides the greatest benefit. Bar coding and real-time data communications combine to provide the following unique benefits to materials management:

Benefits

1. Receiving: Construction companies need to identify the contents of a container quickly and positively and move the items to the correct location with minimum delay. If storage space on the site is restricted, the proper identification is even more critical because projects are operating in a Just-In-Time mode. Information on goods received on a site can be determined by scanning a bar coded shipping label. In the future, most, if not all,