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CONSTRUCTION BAR CODE STANDARDS

George Stukhart, Civil Engineering Department
Stephen L. Pearce, Engineering Technology Department

Texas A&M University
College Station, Texas 77843 USA

ABSTRACT

Automatic identification systems, particularly bar codes, are an essential link in achieving an automated construction materials management system. There is a significant future in bar coding, as is evident in other industries. The opportunity to promote data transfer between organizations and companies has not been adequately explored. By following the research and procedures of other industries, it is possible to achieve such standardization. Texas A&M University has completed the first phase of research to determine strategies for achieving standardization. This research, and the background to bar code use, is discussed in the paper.

INTRODUCTION

The most generally accepted definition of AUTOMATION is "processes by which, by the use of suitable closed-loop feedback devices, not only physical but also mental effort is saved". That is, automated processes free one not only from physical work, but also from much of decision-making. "Closed-loop" implies:

> Sensing of some physical attribute
> Comparison against a standard
> Decision as to what type of change or adjustment should be made
> Initiation of any corrective action.[6]

In a fully automated system, there is minimum need for humans to record measurements or other data and make adjustments.

One method used by various industries to achieve automation is automatic identification devices, primarily bar codes. Bar codes offer many of the attributes necessary to achieve automation; they eliminate the need for physical intervention in recording data, or "keying" data on purchase documents, receiving, and inventory records. But bar codes offer much more than a recording function. They can provide the information necessary to indicate how a system, particularly materials, should be adjusted or corrected. Industries other than construction have not only found that materials management can be automated through bar codes. They have also learned that standardization is essential because of the potential benefit to the industry of everyone using the same methods of identification. Some industries decided to standardize early;

others did not standardize until many years after the first use of bar codes. Many, if not most, of the major industries in the USA have found that bar codes are essential to automation.

The purpose of this paper is to show how automatic identification devices, particularly bar codes, can automate construction materials management. Further, although bar coding is still in its infancy in construction, it is not too early to start talking of system standardization. The lesson of standardization is what has made bar codes so widely used in other industries.

ADVANTAGES AND USES OF BAR CODES

Many people are familiar with the use of bar codes in retailing, where packages are identified with a bar code symbol that has certain key information that triggers a computer data base to give price and quantity information. The data base can contain location, supplier, price, and inventory data. The package, however, contains only a small label, which leads people to believe that the bar code label is the source of all data. Actually, bar codes are a means of displaying enough information so that the computer data base can convey information on an item, its origin, the date of checkout, quantity being scanned, location, use, or some other feature. The checkout or scanning process provides a relationship between several pieces of data.[4]

The use of bar codes has great potential in the construction industry; however they are not well understood. They must be used as part of a system which can direct, track, or validate activities.[4] Although the focus of our discussion is materials management, bar codes have uses in controlling schedules, documents, time, and quality; in short, bar codes can be used throughout the construction cycle, but they should not be used piecemeal. Problems arise in implementation because individual initiatives lead to "islands of automation", meaning that users within companies or industries cannot communicate with each other using the bar codes. This significantly reduces their overall contribution to automation.

The accuracy and speed with which a number encoded with a bar code can be entered into a computer is the main attraction to using bar codes. The error rate is in the range of one per 3 to 5 million characters read, compared to 1 per 250 characters for keyboard entry. Further, studies show that symbols could be read 75% faster than typing of encoded data; this does not include the time to read and copy information manually such as is necessary in the field.

Materials management offers a wide range of potential bar code uses. For example, bar coded entry involves encoding the purchase order number on a shipping document. This number, if printed with a bar code, can be entered by the vendor when the shipping document is printed, and scanned by a receiving clerk in the field; inventories are updated, and in the case of partial shipments, shortage reports can be printed automatically.

An example of automation using bar codes is warehousing. Issue from the warehouse can be either partially or fully automated. The data base must contain the necessary information to permit the warehouse personnel to retrieve the proper items according to a particular work segment, commodity list, or equipment part requirement. Assuming the items have been so identified, and the bins properly identified with bar codes, a warehouse clerk can be given a printout of the items to be "picked", proceed to various locations, and with scanner and portable data terminal

in hand, scan each item as selected, and return to the warehouse to upload the collected data. On the other hand, one of major advantages of the use of bar codes in this situation is to pull stock without the use of a pick list. This could be done by loading the work segments into the computer memory and determine the picking order through a set of rules which relate materials selected to the work plan. The computer would download requisitioned items into a portable scanner in the sequence in which they would be picked, with locations.[1]

In more permanent locations a checker could be directed by radio to the proper location, and by use of data identifier on the code at the bin, determine whether the location is correct. The checker could be a robot operated by a central terminal, dispensing with the printout and use of the portable data terminal. Radio transmission of data would ensure more timely information.[5,4]

SYMBOLOGIES, CODES, AND STANDARDIZATION

In the long run, effective use of bar codes depends on attaining some degree of uniformity, first within a company contemplating the use of bar codes, and ultimately within an industry. Other industries have achieved such a goal, but perhaps their task was easier. The automobile industry launched a bar code standardization effort in 1981 and now has an action group charged with the effective implementation of an adopted set of standards. Before discussing the course of our research to date, it is necessary to clarify some terms that seem to confuse bar coding technology. These are the symbols, codes, and the application standard.

The bar code itself, or symbology, is a cipher constructed from a series of light and dark bars organized, according to specific rules, into various patterns which represent letters, numerals, and other human readable symbols. Coding variables include the number of dark bars, the relative positions of bars within the structure, the variable widths of the dark and light bars, and their relative position. The bar code symbol is a combination of all necessary bar code ciphers forming a complete data message, data START/STOP, and check digits for error detection.[2]

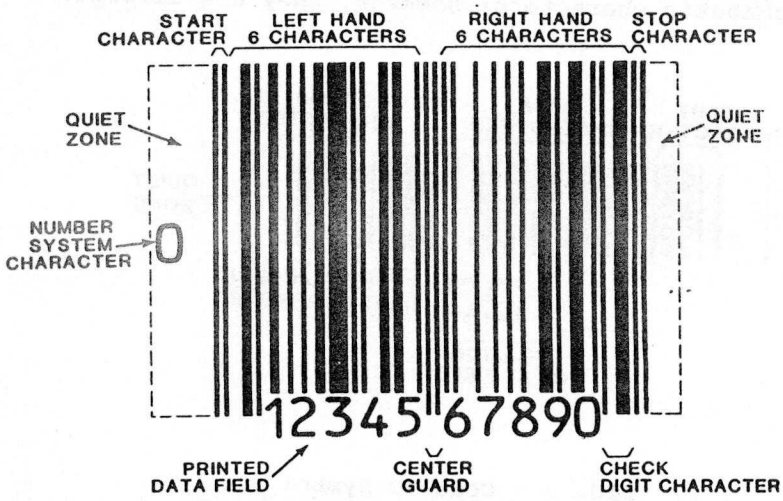

FIG. 1 - Uniform Product Code Symbol
(used with permission of Printronix, Inc.)

Figure 1 illustrates these components in the Universal Product Code (UPC) format. The symbology used to encode data into a series of bars and spaces making up the bar code itself is one of the three building blocks of any bar code system. The other two building blocks are the data format or layout and the data identifier. These are more important than the choice of the symbology itself for reasons discussed later. Nevertheless, the selection of the symbology can limit the structure of data formats and the use of data identifiers. For that reason, a brief discussion of the Code 39 structure is needed.

A more versatile code which has been adopted by a variety of industries was developed by the Intermec Corporation in the late 1970's. This code, called Code 39 or Code 3 of 9, is a variable length, discrete, self-checking, bi-directional, alphanumeric code consisting of a character set that contains 43 meaningful characters. Aside from the other robust features, the main attraction to Code 39 seems to be that it allows encoding variable length codes using both alphabetic and numeric characters.

The code is structurally self-checking and a check digit can be included which will verify whether the preceding characters have been read correctly. This is typically accomplished by using an algorithm to generate the check digit from the data being encoded. At the time the bar code is scanned, the algorithm is again used to compare the check digit against the decoded data. If a discrepancy occurs, the data is not accepted.

The structural simplicity of Code 39 contributes to the extreme accuracy in reading characters encoded with this symbology experienced by the Department of Defense.[8] The structure of Code 39 details a scheme where each encoded character is represented by nine elements: Five bars and the four spaces that separate them. Of these nine elements, three must be wide, with the other six narrow. The name, 3 wide out of 9 was shortened over time to 3 of 9 and then to 39.

Figure 2 illustrates a Code 39 bar code symbol. This illustration does not show alphabetic characters; however, they are allowed.

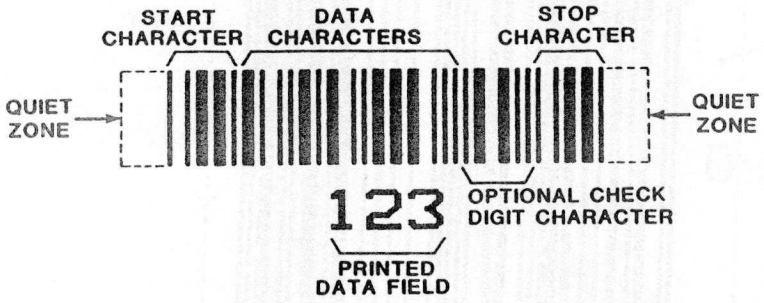

FIG. 2 - Code 39 Symbol
(Used with permission of Printronix, Inc.)

Coding involves classifying information uniformly where a classification is a technique to organize related data in a logical and

systematic order that groups like things together.[7] A code is one or more symbols to which an arbitrarily assigned meaning and/or arrangement has been given which, when deciphered, communicates specific information. For example, it is really not necessary to carry any information at all in an identifier number as long as all users within an industry agree that a particular number represents a certain commodity item. For example, all of the motor vehicles in a given state can typically be discretely identified by a six-character alphanumeric identifier code. While a license plate number carries no information itself, it can be used in conjunction with the appropriate data base in a computer to yield a wealth of information about the motor vehicle and its owner. License plates are uniform in that they all contain a maximum of six characters, for example, and are alphanumeric. With some exceptions, however, license plates do not contain information on the driver, vehicle, or its contents.

Standardization is a tool for securing optimum utilization of resources and maximum efficiency of operations through formal establishment of the most suitable predetermined solutions to recurring problems and needs.[7] The objectives of standardization are virtually the same as the objectives of classification and uniform coding. Standardization in this context is a means to secure optimum use of bar codes on a repetitive basis.

IMPLEMENTING A STANDARD CODING SCHEME

Implementation of bar coding to track and control materials in the industrial construction industry will, at best, be a piecemeal process until standards for codes are adopted within the industries that supply the materials to the construction industry. This is not supposition; it is a statement that is made after a great deal of study in those industries that do use bar codes to track and control the flow of materials on a day-to-day basis. Industries that are successfully using bar codes today include the retail food industry (grocery store checkout), the automotive industry, and the Department of Defense. Once the uniform standard was developed for each of these industries, the choice of a symbology was a routine matter, and implementation of bar code technology proceeded rapidly.

The most important of the tasks to be accomplished and questions which must be answered as a part of the standardization process are listed below:

- Determine whether item identifier codes should contain significant meaning regarding the item's permanent characteristics, that is whether they are in fact "codes" defined earlier.
- Development of item identifiers which allow companies to use their own internal codes and communicate with other parties.
- Development of manufacturer/vendor identification codes which meet the needs of construction. Although supplier organizations are independently developing codes, these do not necessarily meet construction needs.
- Development of formats for identifying engineered items.
- Determining length of identifier codes.

- o Deciding whether several short bar codes are preferable to one large bar code.

- o Deciding the type of bar code symbology or symbologies to be used to encode information.

- o Deciding whether bar coded information should appear on shipping labels and the format, content, placement and method of attachment of shipping labels.

- o Deciding whether only physical products should be bar coded or should drawings and bills of materials also be bar coded; and deciding what information (item identifier, system, manufacturer, location, line, etc.) should be coded.

- o Determining the point in the engineering/construction process where bar code tracking of materials begins.

It makes no difference whether standardization is accomplished on an industry-wide basis or on a company by company basis; the above tasks must be accomplished before a bar code system can be implemented. Standardization within a company permits automatic transmission of data without the necessity of encoding. Standardization on an industry-wide basis could assure that companies within the construction industry would be using compatible bar code systems facilitating the future exchange of information. Industry-wide standardization would be cheaper and greatly contribute to the competitiveness of U. S. industry.

UNIFORM CODING

Uniformity in assigning part numbers (commodity codes) is desirable for two especially important reasons. First, there is a need to keep bar codes fairly short. Long bar codes are harder to scan using a hand-held wand scanner. This is because a hand scanner must be moved across the bar code at a constant rate of speed. In addition, to be really useful in the construction industry (or any other industry for that matter), part numbers and other information must be printed on drawings, invoices, Parts, bins, receiving reports, and routing slips to facilitate the timely, accurate entry of data into computers. Long part numbers printed in bar codes on a shipping ticket or drawing, for instance, simply take up too much room.[3]

The second reason part numbers need to be uniform in nature is to facilitate the handling of the information contained in the number by computers. Information content in a part number is a complex issue. Actually, the more information that is encoded in a given number, the longer that number gets.

The format for coding is one of the most difficult problems of standardization. Common commodity coding would require manufacturers, distributors, vendors, and end-users within an industry segment to identify items in the same manner. In most sectors today, every different manufacturer, distributor, vendor, and end-user has a different part numbering scheme. This leads to many different part numbers for a given item that, in reality, is a commodity.

Uniform formats for coding commodity items is a solution to this problem. The uniform coding scheme does not dictate what number a manufacturer or vendor must attach to a particular commodity item, but rather establishes a format or layout for the number itself. Typically,

the format refers to the number of characters, the meaning associated with groups of characters within the part number, and whether or not the part number can contain alphabetic characters in addition to numeric characters. For example, Figure 3 illustrates an Industry Bar Code Alliance format for commodity item information where F is a flag (data identifier), G is the commodity group, I is the specific item within a group, and C is the check digit.

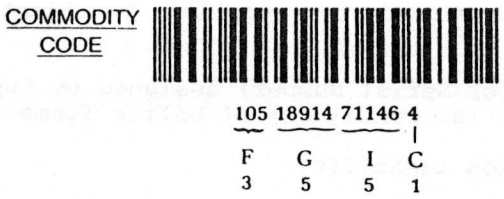

FIG. 3 - Industry Bar Code Alliance Format
(used with permission of the IBCA)

While a uniform code can be meaningless, it is usually important to have some meaning associated with groups of characters associated with the code. This allows computers to categorize numbers in a data base and to manipulate the numbers without intermediate conversion steps. It also allows humans to recognize, distinguish between, and group items with like characteristics. In the construction industry, an example of a uniform data format would be a scheme which called for a fourteen-character alphanumeric part number. The first character would be the logical position for a data identifier. This character tells a computer (and a human) what kind of data follows. For example, the first character might be the letter "P". This refers to a part number and distinguishes the number from a customer order number. The next set of characters could identify the manufacturer. The final set of characters could be used by each manufacturer to identify the specific items in a product line.

SUCCESSFUL APPLICATIONS OF BAR CODE STANDARDS

The automotive industry and the Department of Defense (DOD) are two end-users in the United States which have established bar code standards and are using bar codes to facilitate accurate, timely entry of data into computers. These two industries are much like the industrial construction industry in that they are large, complex, and consume materials supplied by many diverse suppliers. The standards for the use of bar codes developed by these two industries relate not to common part numbering system, but rather to all of the other questions that must be answered before bar coding can be implemented. Recall that these questions must be answered on a company by company basis if they are not addressed on an industry-wide basis.

Because of the diversity of suppliers to the automotive manufacturers, the standards developed by the AIAG vary according to the needs of specific industries supplying materials. Standards have been developed for suppliers of primary metals, for placement of labels on shipping containers, for vehicle identification numbers, and for the use of data identifiers. A sample of data identifier codes extracted from the AIAG Data Identifier Dictionary Standard is shown in the table below.

TABLE 1. AIAG DATA IDENTIFIER CODES (Sample)

Code	Usage
A	Order Number assigned by Customer to identify a Purchasing transaction.
1A	Order Number assigned by Supplier to identify a Purchasing Transaction.
G	Unique number (or Serial Number) assigned by Supplier to identify a Multiple Pack (or Container) of Unlike Items (Mixed Load).
1L	Stocking Location Identifier.
P	Part/Item Number or Product ID assigned by Customer.
1P	Part/Item Number or Product ID assigned by Supplier.
2P	Identification number assigned by Customer to specify the Engineering Change Level for a Part/Item Number.
Q	Quantity or Pieces.
1Q	Length/Theoretical Weight
S	Unique number (or Serial Number) assigned by Supplier to identify a Single Pack (or Container) of Like Items.
1S	Unique Number (or Serial Number) assigned by Supplier to identify a Unique (Individual Item.
V	Supplier Code assigned by Customer.
Z	Internal company/corporate applications use only. Never to appear on item/document which leaves the company.

REALITY IN THE CONSTRUCTION INDUSTRY

While the idea of a common code within the construction industry probably would be advantageous in the long term, individual companies will oppose changing or converting their own standards. This will not negate all the benefits of bar coding because many of those benefits for the construction industry relate to placing bar codes on drawings, bills of material, purchase orders, and having suppliers place bar codes on receiving and shipping papers. Further, bar codes will be used on construction sites to place a company's internal part number on storage locations in a warehouse as well as on parts themselves assuming that the part is large or expensive enough to warrant affixing a bar code label.

The simple fact of the matter is that engineering/construction companies have developed part numbering systems over the years which have meaning to their employees. An experienced person can look at a number on a drawing and determine whether or not the part as indicated by a familiar number is appropriate. Companies which have used a so-called "significant" part numbering scheme for years are unlikely to switch to another scheme.

RESEARCH ON APPLICATION STANDARDS

Texas A & M University has been involved in research on bar code application standards for a year and a half. In the last six months we have interviewed 15 people who are leaders in applying bar codes in other industries, such as automotive, aluminum, grocery, electrical, industrial piping, health care, and the Department of Defense. We have also talked with a few people who are familiar with bar codes in the construction industry.

Of the questions we asked, perhaps the most important dealt with the problems encountered in developing application standards, the solutions to these problems and the strategies recommended as a consequence. The problem which was cited most often was the lack of a common numbering scheme. Each user had a different numbering scheme and wanted to continue using it. The second most difficult problem was that companies were not convinced of the benefits of bar code technology. The third most difficult problem was the competitiveness within the industry and the reluctance to cooperate on developments in which a company has a clear competitive advantage.

Some solutions to these problems are to develop a common transfer code, whereby a common supplier code could be translated in the computer to a user's code. Standards development will have to deal with the fact that suppliers have their own multiple bar code standards and that several construction companies are already developing their own internal codes and standards. Convincing users of the benefits of the new technology is an ongoing process, and application case histories are good vehicles for such education. To convince the leading companies to assist in developing industry standards requires reasonable proposals to convince them that standards are beneficial to everyone.

Several strategies were used by other industries to overcome obstacles to standardization. First, they must understand the technology and the benefits. Second, an action group is needed to promote bar coding and provide a forum for education and discussion of standards development. Third, the construction industry should learn from the examples of other industries. Finally, the first several steps toward achieving standards were suggested. These are:

- Developing a data identifier standard. One could use the AIAG standard in the appendix or modify it to meet construction industry needs.
- Develop a standard for a shipping label. Such a label should contain information to trace a shipment, such as purchase order number, vendor identification, quantity, and serial number.
- Adopt an existing symbology as a standard, probably code 39.

- o Begin work on a standard numbering scheme; this probably includes a translation table which obviates the need for a universal commodity code for the entire industry.

CONCLUSIONS

Bar coding is an automatic identification technique which will enhance productivity in the industrial construction industry by eliminating human error and greatly speeding up the data entry process. Control and tracking of inventory and as-built accountability will improve as data entry relating to these functions becomes real-time rather than after-the-fact as is commonly done today.

Individual companies in the industry are recognizing these benefits and implementing bar code schemes. The missing link, however, is that between materials users and materials suppliers. An essentially manual process takes place when a supplier places a user-specified part number on an item prior to shipment. Manual processes are fraught with human error. Standards must be developed which will eliminate these manual processes. Until such standards are developed, productivity enhancement from the use of bar codes in the industrial construction industry will be unnecessarily limited.

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