# AUTOMATED SITE MATERIALS MANAGEMENT - A PROTOTYPE

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## INTRODUCTION

It is generally recognized that construction productivity is no longer measured only in the context of worker output divided by worker input. Project performance is the result of the efficiency of a complex of resources such as materials, equipment, capital, energy, engineering, and management. The ability to combine these resources into an efficient organization depends, to a large extent, on the flow of information. At the managerial and technical level this is being aided through automation in the use of computers, CAD, and decision-making tools.

Advanced technology is also being promoted as a means of solving many of the labor productivity problems, but not necessarily replacing labor. Labor, machines and information exchange all have a logical place and a complementary relationship is the most productive. The aim of Computer Integrated Manufacturing is not to eliminate direct labor costs but to automate the flow of information through a factory, producing savings in indirect costs, quality control, and schedules (Business Week, 1986). This implies that a logical step in construction automation would be to place more responsibility for planning and executing the work in the hands of the people doing it, through some simple, reliable mechanisms which do not replace workers, only make them more productive.

Interestingly, the major benefit of automation in manufacturing is in materials handling, where up to 50% of the total automation effort is expended. Achieving such automation benefit in construction would probably not be feasible because of the non-repetitive nature of the work and the large investment needed in some materials handling equipment such as that used in manufacturing. Nevertheless, the flow of information through the materials cycle can be improved by many simple means, requiring minimum cost with considerable benefit. We have seen one such device in our stores where a clerk passes a wand over a bar code to tally an item at the check-out counter. The potential for such use in construction is tremendous; a few such uses include materials control, timekeeping, drawing control, and payrolls. The advantages are obvious: data accuracy, reduction in documentation requirements, control and accountability, and speed. It seems logical that if the flow of data can be demonstrated as feasible, in a sense analogous to manufacturing, the next step would be a prototype materials handling system which relies on the data for calling out materials. Furthermore, if the data management system can be precisely defined, such definition would provide the criteria and specification for an automated materials handling system.

This paper will emphasize one phase of the operation, concerned with field materials control. The purpose of this discussion is not only to highlight the significant gains possible through bar coding, which probably do not need elaboration, but to show, in detail, how such a technique could be used to solve some of the most nettlesome problems of materials control on the jobsite. With the use of bar coding come some other problems and requirements, such as standardization, coding, and job redesign, all necessary to gain the fullest benefit of such a technique. Finally, if bar coding can be used in conjunction with some other, more efficient techniques, such as Just In Time and materials delivery, there is the prospect of improving materials handling through reducing materials on site.

## THE CONSTRUCTION MATERIALS CONTROL CYCLE

Probably at least 50% of all medium and large construction projects use some form of computerized materials management system today. Such systems generally provide good tracking capability from the engineering requirement to field delivery. To illustrate the scope of the materials management cycle and the current impact of automation refer to Figure 1. Materials control starts with the the identification of commodities and quantities in the bill of materials. Such identification can be manual, although in the near future it is likely that a computerized data base will be generated by CAD. From the BOM the purchase order is derived. These documents (or data) identify the requirement and the line items by originator's (engineer, owner, contractor) code. Unfortunately there are no industry standards for coding either bulk materials or engineered materials. As a result, coding systems and specifications of design firms must be transferred to the contractor and the vendor.

The requirements material control cycle is generally executed in the home office, especially on engineer-construct projects, with a team of engineering and materials specialists; it could also be performed on the site by the project engineer or similar individual. The purchasing function could likewise be done in the home office or on site, depending on the size and type of project. There must be communications between the organizational entities performing these functions, as well as the field materials group.

CONSTRUCTION MATERIALS MANAGEMENT

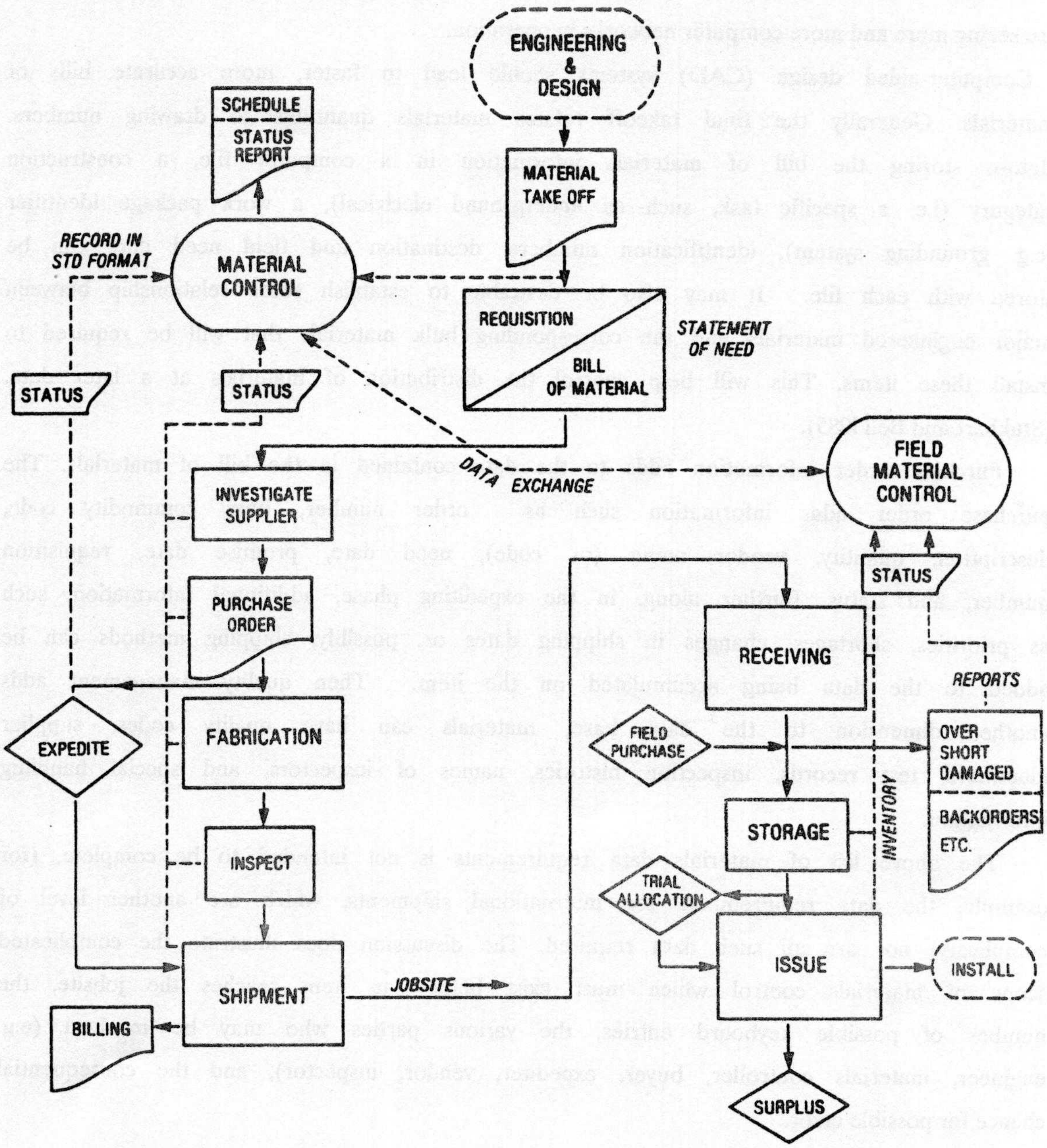


Figure 1

Such communications are essential to reduce duplication and to allow the materials management function to operate. In the majority of the projects in the industrial sector, such communications exist through either batch or real time computer networks. There is a lower limit to the size of projects on which such computer use is feasible, but we are seeing more and more computer networks in operation.

Computer-aided design (CAD) systems should lead to faster, more accurate bills of materials. Generally the final takeoff relates materials quantities to drawing numbers. Before storing the bill of materials information in a computer file, a construction category (i.e. a specific task, such as underground electrical), a work package identifier (e.g. grounding system), identification numbers, destination and field need date can be stored with each file. It may also be desirable to establish some relationship between major engineered materials and the corresponding bulk materials that will be required to install these items. This will help control the distribution of materials at a later date. (Stukhart and Bell 1985).

Purchase order information adds to the data contained in the bill of materials. The purchase order adds information such as order number, item commodity code, description, quantity, vendor name (or code), need date, promise date, requisition number, and status. Further along, in the expediting phase, additional information, such as priorities, shortages, changes in shipping dates or, possibly, shipping methods can be added to the data being accumulated on the item. Then quality management adds another dimension to the data base; materials can have quality codes, supplier identifiers, test records, inspection histories, names of inspectors, and special handling information.

The above list of materials data requirements is not intended to be complete, (for example, the data requirements for international shipments, which are another level of complexity) nor are all such data required. The discussion does illustrate the complicated scope of materials control which must exist before an item reaches the jobsite, the number of possible keyboard entries, the various parties who may be involved (e.g. engineer, materials controller, buyer, expediter, vendor, inspector), and the consequential chance for possible error.

## FIELD MATERIALS CONTROL

The materials control cycle is continued at the site, where several different functions must be performed and tracked: receiving, accounting, handling, storage, retrieval, issue, installation, quality checks (at various levels and stages), and, possibly, reordering, disposal of surplus, and transfer of accountability to startup, maintenance or other activity. There are several performance objectives which determine the amount of data inherent in the field materials control system:

- o Information must be accurate and current.
- o Information must relate to the needs of the user, that is, to drawings and to terminology which is readily understandable by the crafts.
- o Common items must be related through a code and specification.
- o The data contained in the original bills of materials, especially regarding work packages, must be present in the field; this objective is necessary so that trial allocations can be made from materials on hand against projected work. These allocations are a significant enhancement to planning and productivity.
- o The system must be able to issue the correct materials to the responsible foreman, subcontractor, or work area. If the system can perform a trial allocation against a specific work package, the materials can be pulled, tagged, bagged and issued and tracked to the work area. In some systems the capability to perform such allocations and issue exists today for certain materials. (Cato and Early 1986).
- o Conversely, the materials control system must be able to reflect instances where individuals request materials that have already been issued, to requisition materials shortages against particular work segments, and to indicate the status of materials availability for performing a particular work package or those identified in a certain drawing. Some existing materials systems function such that drawings are not released to the crafts, or to an on-site fabrication shop until all materials are available. Other systems release drawings regardless of materials status, leaving it to the superintendent to determine if work should start. (Stukhart and Bell 1986).
- o The system must be simple, so that inventories can be accomplished easily and regularly, quantities reconciled, and changes accommodated.

The more advanced field materials control systems are analogous to the shop scheduling function in manufacturing (see Modern Materials Handling Nov 1986), in which computer systems that govern shop floor scheduling and materials movement calculate machine and manpower needs on some regular basis. In the reference article, bar codes are used to provide information from a work station as to whether the station is available for work and thereby call forward parts. A similar field concept is the thrust of this research. As indicated above, there are trial allocation systems for certain commodities, such as piping, which can match materials to field work planned for a certain period; what does not exist is a closed loop which can automatically forward materials when called for, and record the actual delivery of such materials at the work station. Bills of materials (for use in trial allocations) are generated with varying degrees of information available and the concept has so far been used on a limited basis, although with considerable benefit (Cato and Early).

The needs of the industry are to expand the trial allocation feature to an automated call-forward concept that is simple, error free, and readily available to the craft. The most promising technology for this is bar coding, or perhaps other automatic identification devices. Such devices are rapidly being adopted by many industries, but in order to be fully effective there is a need for uniform coding and a study of the data which the codes are to portray.

## DATA EXCHANGE REQUIREMENTS

Field material control is, as discussed above, only part of the overall materials control system. In a larger orientation, that of the total project control system, materials control must interact with other control systems, that is, cost, schedule, construction, engineering, accounting, and quality.

This ability of the materials system to "converse" with other systems in the project implies that an integrated data base is needed for various uses, and coding schemes required such that information can be conveyed via computer rather than by hard copy. For example, CAD can provide design information in the form of an electronic data base (Cleveland 1986) which allows the user to plan the sequence of construction activities in the computer, and to introduce codes which reflect locations, modules, line numbers, system, drawing, subcontract, or other responsibility. Such data entry can be accomplished using the computer keyboard or a predetermined set of bar codes. This electronic transfer of data has the advantage of flexibility as well as time, because changes, which are usually quite numerous, can be easily accommodated in the computer, but are difficult to control on hard copy documents.

There is an obvious need for a relational data base which can be structured for various purposes, one of which is materials control, or more specifically, field materials control. Furthermore, there is a need for a code, or string of characters which will capture a variety of information about an item, as distinct from a part number, which is used solely for component identification (Peterson 1987). Coding is the "application of symbols that reflect an arbitrarily assigned meaning and/or arrangement, which, when deciphered, communicates specific information" (Hyde 1981). It is significant that in the sense identified by Hyde arbitrary codes or noncodes include much of the information that is needed to assist the automated material handling process, that is, provide for efficient recording, sorting, and retrieval from storage in the construction materials handling process. That is, noncodes include "where used" information, which is nonpermanent, as distinct from information which classifies materials according to their basic characteristics. Hyde states that the system (not the code) should provide where-used information, in other words the location and task.

The analogy to manufacturing is again worth investigation, because one method of formalizing the coding process is the use of Group Technology (GT). GT provides a method of organizing data bases so that dissimilar parts having the same GT code can be routed to the same end product. GT is the technique for manufacturing small to medium lot size batches of parts of a similar process, that is, the method of manufacturing is the unifying process; inherent in this is the simplification and standardization of designs and thus bills of materials). Whether this method could be used in construction is not known, but there are some similarities:

- o GT coding encourages standard designs even though there are slight differences in the specification.
- o GT accomodates dissimilar materials, geometry and sizes.
- o Work can be completed in a specific cell.
- o Machines in the cell are scheduled as a single unit.
- o Work is accomplished in a limited location or grouping.

We are just starting to research the complexities of materials coding. Defining a common materials code or set of codes is a major task, one which many in industry believe not possible of accomplishment. A few facts are worth emphasizing, however:

- o Materials coding offers significant cost benefits to the construction industry.
- o There are a wide variety of coding techniques in use, as is evident from some preliminary questionaire data.
- o A few major companies are attempting to achieve some uniformity, at least withn certain sectors of the market.

## BAR CODING

For the foreseeable future, bar coding offers the best solution to capturing data related to materials control on the jobsite. A bar code is a group of alternating black bars and white spaces of varying thicknesses. These parallel bars are arranged in one of several patterns to provide information on any number of subjects. Bar code reading is achieved through a beam of light which is directed at the symbols, such that the reflected light is read and converted to a code consisting of numbers and letters through one of a variety of processes.

The most widely used decoding process in the automotive industry and government is the code 39 symbology, an alphanumeric system. This system has the greatest potential use in construction, because of its growing acceptance elsewhere and the fact that it permits up to 15 identifying characters. The term code 39 is derived from the fact that each character is represented by 9 elements, 5 bars and 4 spaces - 3 wide and 6 narrow. In Figure 2, for example, the first character could be the letter 'A', the second the number 0, and the third the letter 'P'. (Baker 1984, Burke 1984, Stull 1987).

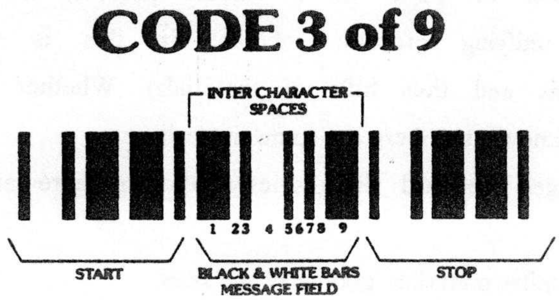


FIGURE 2 - CODE 39 SYMBOL

Bar codes have wide application in the warehouse. They can be used for receiving, storing, picking, sorting, and checkout. Most of these steps are performed manually now, either on cards or keying into the computer. Bar codes can be provided by manufacturers, distributors, or by the contractor on site. The number and variety of uses is considerable, and the division of responsibilities between the contractor and vendor can vary. The vendor can include a bar code on materials to indicate its commodity code, or the bar code can be placed on the design drawings and the bills of materials to indicate the location, system, or other information. These codes can be placed on the tag accompanying equipment or certain materials such as cable, which are specifically designated for certain work.

Research on this subject is in its infancy in the consruction industry in the United States, although other industries, such as automotive, have been organized to develop industry standards for symbology, shipping and other applications (Hitchcock 1986). For example, the primary metals identification tag approved by the AIAG contains eight different codes (e.g. product identification, supplier, serial no., customer order no., and codes for various treatments, weight and quantity). Attempting to standardize this type of data within the construction community is a formidable task. But there is an analogy to the telephone system, in which customers had to accept some type of protocol if they were to communicate outside their own community.

## THE BAR CODE AS AN EXPERT SYSTEM

Assuming that a company can undergo the expense of putting bar codes on their primary materials (such as engineered equipment and fabricated materials, as a minimum), the bar coding acts as a pseudo-expert system in that the craft, by using code readers in the field, can duplicate the functions of materials control now performed manually. To illustrate:

- o The inventory and trial allocation system, now performed on the computer, can be further automated by bar code entry of storage and retrieval information so that materials can be sorted by work package, drawing number, location or user ID.
- o The users or craft foremen can be issued a coded card which indicates their identification number, work assignment, and location. These are used to "withdraw" a quantity of materials on a daily basis; these materials are tagged with readable and bar coded information when issued.
- o Materials are tracked from arrival on site to final installation through their permanent code, although the non- permanent features may eventually be deleted. Bills of materials will be updated to reflect issue and installation. Completed punch list items can also be bar coded to reflect work completed. As-built information will be entered automatically from coded tags into the computer system.

## CONCLUSION

Standardization of construction industry materials management would eliminate redundant effort, raise productivity, and lower costs. Although there are initial costs, and many other obstacles to standardization, the opportunity to standardize is much greater than in the past because of automatic identification technology. It is important to start some form of uniform materials identification protocol before individual companies proceed along their independent paths to implement bar coding; once they have put systems in place it will be even more difficult to change and to communicate.

## REFERENCES

Anon. (1986) "Automatic I.D.Delivers the Data for Warehouse Efficiency," Modern Materials Handling, Vol 41 N4, Spring, pp. 77-80.

Anon. (1986) "High Tech to the Rescue", Business Week, June 16, pp. 100-108.

Baker, E. F. (1984) "Bar Coding - The Catalyst: The Opportunity for Obtaining Maximum Production Benefits," Readings in Productivity Improvements, Proceedings American Production and Inventory Control Society, pp. 105-113.

Burke, H. E. (1984) Handbook of Bar Coding Systems, Van Nostrand Reinhold Co.

Cleveland, A. B. (1986) "Impact of CAD on Consstruction Management in the Future," The John J. Kirlin Inc., Lecture Series, Lecture No. 5, December, The University of Maryland.

Hitchcock, A. L. (1986) "Bar Coding Moves Metals Into the Age of Computers," Advanced Materials and Processes, Inc. Metals Progress, 10/86, pp. 87-89.

Hyde, W. F. (1981) Improving Productivity by Classification, Coding and Data Base Standardization: The Key to Maximizing CAD/CAM and Group Technology, Marcel Dekker, Inc., N.Y.

Peterson, D. K., Hyer, N. L., and Zmud, R. W. (1987 "Group Technology: A foundation for CIM Information Management," CIM Review, Vol. 3, No. 2, pp. 48-55.

Stukhart, G, and Bell, L. (1985) "Attributes of Materials Management Systems," Prepared for the Construction Industry Institute, University of Texas, Austin, TX.

Stull, J. (1987) "The Importance of Identification and Bar Coding to Construction," unpublished paper presented at the American Society of Civil Engineers Convention, Atlantic City, April 28.