ELECTRONIC DOCUMENT MANAGEMENT IN CONSTRUCTION USING AUTO ID

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ABSTRACT

The construction process relies upon the effective management of a variety of project information including drawings; specifications; bills of quantities; and other technical data. The method of information transfer determines the ease with which information can be assimilated and used into the construction process. Despite the widespread use of computers for the generation of project information, hard copy documentation remains the primary method of information transfer within the construction industry.

Electronic Document Management (EDM) systems offer a level of control over information flow within the construction process, whether documents are in hard copy or in electronic format. However, many of the existing methods of information transfer undermine the performance of EDM systems in two respects; (1) they require the user to re-enter information to register incoming documents into a data base; (2) they cannot interpret and manipulate information contained in or supporting the document.

This paper describes a method of bar coding hard copy drawings in order to electronically transfer document information from designer to contractor. This approach is designed to improve the functionality of EDM systems where hard copy documents predominate. The paper also considers the requirements for bar code application standards which would further improve the data exchange process concerning documents.

Keywords: Auto-ID, bar coding, Computer Aided Design, document management, drawings, EDI, standards.

INTRODUCTION

The construction process demands timely project documentation which can be easily assimilated. Failure to effectively locate and manage documents during a project may result in delays and incorrect decisions. Bentley (1981) suggests that late project information is frequently a key factor in causing quality problems on site. The difficulty of managing construction information is compounded by the large volumes of documentation produced. Turk and Bjork (1994) estimate that the total number of documents which relate to a single building structure may typically be in the order of 10,000: most of the documents are stored on paper.

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In order to deal with the volume of documentation produced during the construction process, Electronic Document Management (EDM) systems have evolved to impose a degree of control over information management within both design and contracting organisations. The functionality of EDM systems varies from those designed to register and archive specific documents, to systems which provide more advanced features allowing control over the movement and status of a variety of documents. Such systems may be designed to accommodate information in a variety of formats, including hard copy, from external sources. However, the process of registering and recording documents of this kind can be a costly and time consuming exercise.

Automatic Identification (auto-ID) technologies provide a variety of methods for storing machine readable information on physical objects, which would overcome the need to re-enter information concerning documents. The most common auto-ID technology is bar coding which has proven to be ideally suited to a variety of construction applications. Bell and McCullouch (1988) list a number of bar code applications in construction including material take-off; materials management; warehouse inventory; scheduling; time keeping; and cost engineering.

In most applications involving bar codes, the labels provide nothing more than a 'number plate' in order to identify an *object* and subsequently lookup information stored on a central database. However, recent advances in 2 dimensional symbologies now allow significant amounts of information to be stored *within* the label itself. The ability to transfer data in this way has particular advantages within the construction industry where electronic communication and access to remote data bases is frequently impractical. Another advantage of the 2 dimensional symbology is real time data processing capability (McCullouch and Lueprasert, 1994).

This paper considers a procedure for bar coding hard copy drawings. A prototype system, which was used in a design build project, is used to illustrate how this is accomplished. The purpose of the system is to improve the basic operational requirement of an EDM system by circumventing the need to re-key information. This in turn will reduce erroneous entries and encourage the use of more extensive document information. Secondly, the bar code system will provide a convenient vehicle for document information transfer between organisations involved in both design and construction.

DRAWING EXCHANGE FORMATS

Although several different types of document are produced during design and construction, including specifications; bills of quantities; correspondence; and financial documentation, a significant proportion are in the form of drawings. Mackinder and Marvin (1982) suggest that diagrammatic representation is particularly suited to the design process, as information can be quickly retrieved. Normally, the number of drawings may amount to hundreds or thousands for sizeable projects or those incorporating sophisticated components (Shih, 1994).

Over the past ten years the manual preparation of drawings within the design process has largely given way to computerised automation in the form of CAD. In 1980 a few large practices introduced experimental systems (Winch and Deeth, 1994). However, subsequent advances in both hardware and software have led to a significant increase in CAD utilisation. The RIBA (1990) found that two thirds of

medium to large practices (more than eleven architectural staff) use CAD applications.

The ability to generate drawings using CAD provides significant scope for electronic data interchange (EDI) between project design professionals. EDI is concerned with the electronic transfer of documents within the trading or project cycle. This may be carried out by the exchange of a physical medium (e.g.. diskette) but more commonly involves direct transmission by satellite or cable. However, despite advances in communication technologies, LAN's (local area networks) and WAN's (wide area networks), the temporary nature of relationships within construction inhibit direct electronic links. O'Brien and Al-Soufi (1993) identify the one-off nature of construction work, the transient existence of project teams, the diversity of project members and the cyclical nature of the wider economic climate as factors which mitigate against more permanent relationships in construction.

Watson (1990) considers that CAD data exchange has only been a practical reality in the last ten years and still presents some difficulties. Practical problems which inhibit CAD data exchange include incompatibility between systems and the reliability of file exchange formats. De Vries and van Zutphen (1992) identify that such factors lead to unsatisfactory ad-hoc translations and in many cases communication is performed using traditional drawings. Even where CAD data exchange has been performed by computer diskette, the authors of this paper have observed the simultaneous transfer of hard copy drawings as a means of validating file interpretation.

Whereas the ability to generate and manipulate drawings electronically is a practical reality within many design professions, few site locations posses the necessary resources to accept CAD data. This reflects the historically low level of information technology (IT) investment within UK construction. The Building Centre Trust (1991) claimed that UK contractors spend only 0.5% of turnover on IT, far below the average for other sectors.

The displacement of hard copy drawings by CAD based electronic drawings has been limited in construction for a number of reasons identified by Watson (1990): these include the lack of suitable data exchange standards; incompatibility between systems; and the transient nature of communication links between companies. Additionally, the legality of issuing drawings electronically is currently in question under many standard forms of contract. As a result the transfer of hard copy drawings between design professionals and contractors is likely to remain the principal method. The continued use of hard copy drawings will demand a high level of manual data entry in order to register incoming documents. This format will also limit the ability to interpret and manipulate information contained in or supporting the document.

DOCUMENT MANAGEMENT IN CONSTRUCTION

In response to the volume of documents which contracting organisations must process, EDM systems have evolved to perform a variety of document management functions. Many systems are designed to deal with documentation in several formats, both electronic and hard copy. A key requirement is the ability to deal with

information produced within the organisation as well as exchanging information with external sources.

EDM systems offer significant scope for more effective co-ordination of information within the construction process; this area has been the focus of a number of current applications. Turk and Bjork (1994) categorise a range of basic document management functions which such systems are designed to fulfil:

- Electronic archiving of documents
- Creating, modifying and printing documents
- Getting or referencing external documents
- Providing document confidentiality and security
- Management of the relationship between documents.
- Extracting documents or data from documents

Current methods of drawing transfer limit the functionality of EDMs in two areas. In order to deal with documents which originate from external sources, such systems demand a level of user data input in order to register the identity of incoming documents in the data base. As a result current procedures for re-keying information are both time consuming and prone to error. Typically, site staff may spend a significant amount of time in registering the receipt of drawings on medium to large projects.

In addition, the nature of hard copy documentation limits the degree to which such systems are able to interpret and abstract the information which is contained in, or supports documentation. Hard copy documents *can* be scanned into EDM systems. However, the scope for subsequent information manipulation is often limited. When considering drawings it is apparent that textual information forms an integral part of the document in the form of dimensions; annotations; as well as information underlying it such as specifications and schedules. The current inability of EDM systems to abstract such information limits the scope for the provision of more advanced EDM functionality.

USING BAR CODES AS DATA CARRIERS FOR DRAWINGS

With the continued reliance on hard copy formats, the ability to attach electronically readable information to drawings represents an indispensable part of an EDM system. Auto ID technologies allow electronically readable information to be attached to a variety of *objects* using bar coding, magnetic stripe, radio frequency tagging or optical character recognition technologies. These technologies are used in situations which require rapid and accurate data entry into computer systems. Conventional bar codes, whilst being extremely cost effective, are limited by their low information density. This is because the vertical dimension of a bar code carries no information. The alternative is to use checkerboard or 2D bar codes which exploit the vertical dimension. Figure 2 shows an example of a 2D bar code known as PDF417, developed by Symbol Technologies, which is able to encode as many as 2725 data characters from the entire (255 character) ASCII set. The

physical size of the bar code is dependent on the amount of data encoded, with labels typically having a dimension of 50 x 30 millimetres.

Typical size 50 x 30 mm.

Figure 2 - PDF 417 symbol.

The complete specification for PDF417 also provides a number of data security options including error detection and sophisticated data recovery algorithms. Even in situations where the label has been torn or distorted, data recovery is still possible. The effects of increased information density are considerable and enable the carriage of entire files of information within the symbol. McCullouch and Lueprasert (1994) consider a major advantage of this is the capability of real time data processing, removing the need for a data base look-up. Pavlidis *et al* (1992) argue that high density bar codes can effectively substitute for EDI in locations where communications are unreliable or absent. This is likely to apply to many links between sites and design offices within construction.

2 dimensional bar coding provides an effective medium for the transfer of drawing information. 2D bar codes allow sizeable amounts of data to be encoded during the design process and can be transferred simultaneously with the drawing to site. Since the label can be fixed to the drawing, a seamless link between paper based and electronic information is created. This reduces the risk of incorrect identification and overcomes the problem of re-keying information. In addition, the ability to provide data security prevents information loss as a result of any subsequent 'marking' of the label during use.

BAR CODE GENERATION DURING THE DESIGN PROCESS

Computer based document management systems require a range of information to be entered into a data base in order to identify incoming drawings. Typically, this will include the drawing title; drawing number; revision; scale; and date of issue. Full electronic automation of the registration process would require all such information to be embodied within the bar code. Additionally, this information should be presented in a human readable form to enable visual inspection. Figure 3 illustrates the system developed during a pilot study to encode drawing information within PDF bar codes.

This pilot study was undertaken in conjunction with a large design and contracting organisation. The project chosen featured a multi-disciplinary in-house design team producing drawings under a design and build contract. A system was developed which used high density bar codes to communicate drawing information between a

design office and site location. The basic operation of this system involved the electronic generation of PDF bar codes within CAD drawings - immediately prior to printing and issuing to site. Subsequently, drawing information contained within the PDF code was scanned directly into the site data base.

Contact: Pilkington Glass Ltd
Prescot Rd, St Helens, WA10 3TT

Tel: 01344 384833

Notes: Revised drawing issue due to change in glazing. New unit comprises Pilkingtons double glazed unit (6mm Suncool Blue with 4mm Clear Float

Project Title: Liverpool Royal Infirmary		
Drawing Number: A 123		
Title: First Floor Plan		**Revision:** A
Scale: 1:100	**Drawn By:** LM	**Date:** 20/09/95

Figure 3 - Drawing Title Box with accompanying machine readable PDF label.

One of the major advantages of this system was the elimination of the need to re-key information to register drawings after receipt on-site. The ability to scan information directly into the data base dramatically reduced the time spent by site staff registering drawings and eliminated the risk of incorrect data entry. As well as automating drawing registration, the system also enabled the control of drawing use during the construction process. The ability to electronically identify drawings allowed the user to verify use of the most recent revision and allow rapid access to any associated information held within the data base.

Although scope existed for involving external design team members in the pilot study, system use was limited to communication between design office and site. This approach minimised capital outlay and simplified implementation. The basic equipment required for the study was one bar code scanner and decoder at an approximate cost of £1200. Modifications to the existing CAD system and site data base were carried out in-house at minimal cost.

Although the intention in this pilot study was to communicate basic drawing information, the findings also pointed towards additional data which could be encoded within bar codes to aid the overall process of document management. One of the biggest problems encountered in the co-ordination of drawings, both during

Further, Nigro (1988) suggests that in situations where revised drawings require indexes to be updated, the index numbers are often incorrect or omitted.

In response to these problems, Shih (1994) proposes the use of an electronic indexing system for the management of drawings. However, the means by which reference information is transferred between remote data bases must be addressed. Traditionally, drawings contain reference notes which indicate the existence of supporting details. These are used to cross reference drawings manually. As an alternative, 2 dimensional bar codes can be used as a medium for storing this information in an electronic format. Figure 4 shows a typical relationship between a drawing, its related *annotations* to details and the bar code containing associated annotated information. Notice that information within the annotation can be tagged to enable access by other applications. For example, the reference to the U-value in Figure 4 could be tagged electronically and subsequently used in a computer spreadsheet to enable the calculation of the overall U value of a building. Alternatively, a structured data file can be used to replace the free format text annotation.

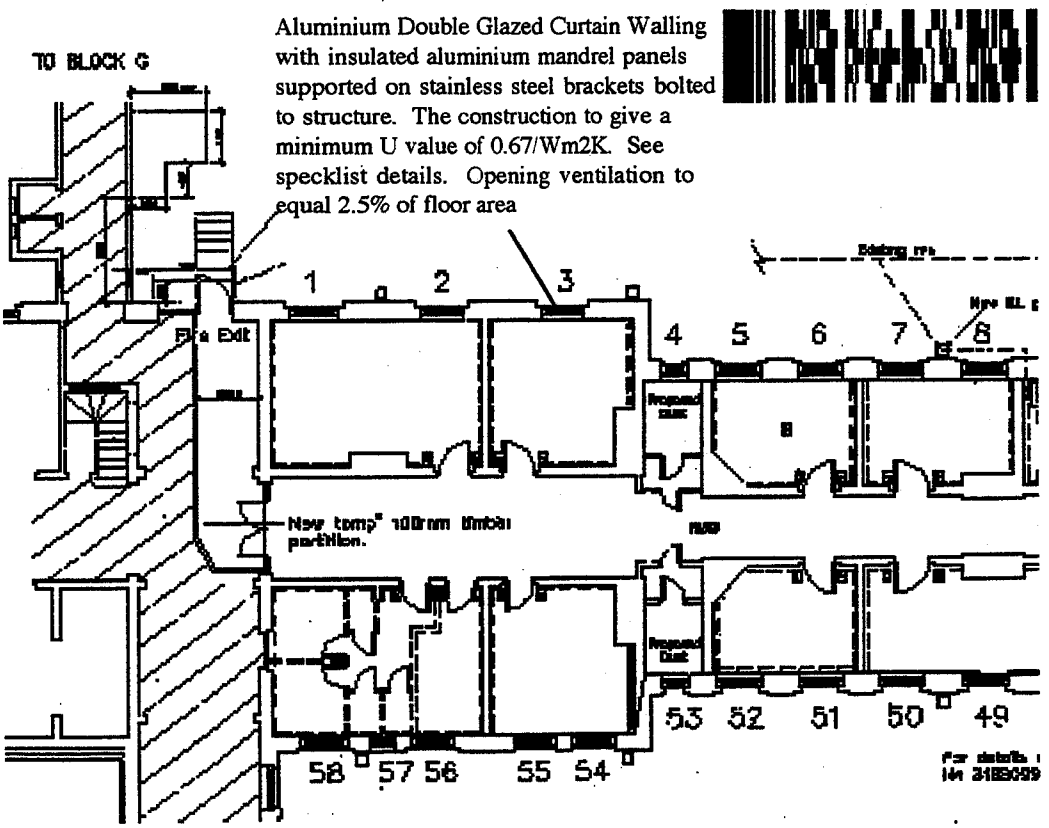

Figure 4 - Bar code representation of indexing information.

Reference information contained within a drawing is traditionally represented in human readable text. Visual inspection of the drawing allows manual referencing of supporting details. As an alternative, the reference information needed to *index* the drawing with supporting details could be represented electronically by a bar code. One further step would be to include a hypertext link within this. Reference material could then be accessed by simply clicking on sensitive text. In situations

where a drawing gives reference to many details, this would allow rapid extraction and incorporation of index information within the site data base. Such an approach would simplify the cross-referencing process by allowing the user to reconcile both a drawing with supporting details, and a detail with all applicable drawings.

BAR CODE PRODUCTION.

Although labels could be physically attached to drawings, the wide-spread use of CAD design packages provides an ideal situation for using an integrated system for administering bar codes. Almost any CAD system can be programmed to bar code drawings during the design process. Figure 5 illustrates the system developed by the design organisation who participated in the pilot study to encode drawing information within 2 dimensional bar codes using AutoCAD.

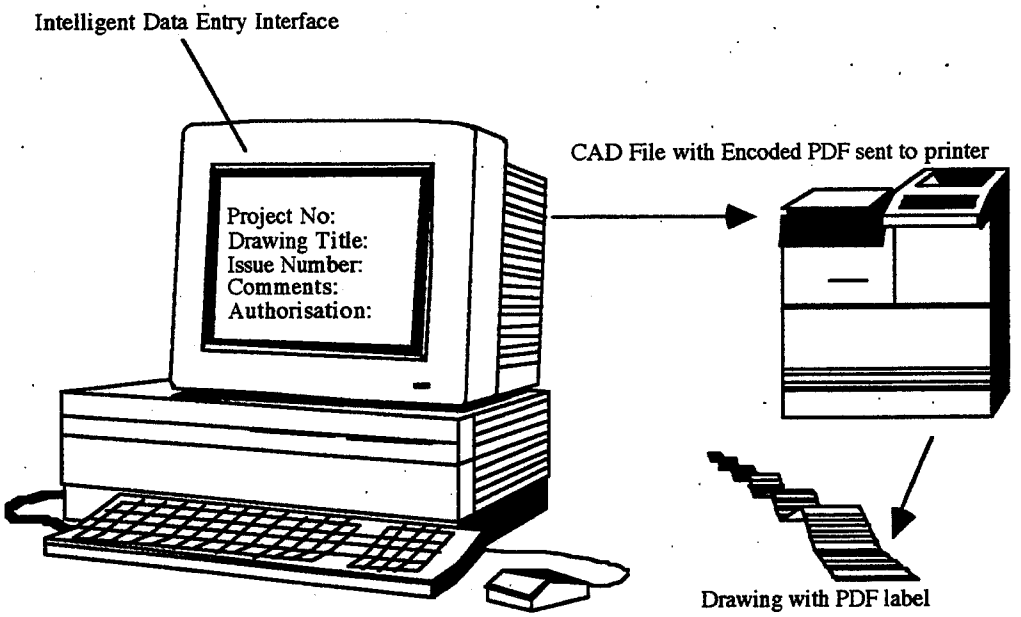

Figure 5 - 2 dimensional bar code generation in CAD

The central component is the *intelligent entry system* which allows full control over how information is encoded within the bar code. This stage is vital to the document management process. The uncontrolled generation of printed drawings can lead to unsequenced issues and may result in designers or contractors working to the wrong drawings. To remove this possibility, the system automatically date stamps the PDF and automatically logs the modification number (issue number). A variety of supporting information can be encoded including the date of expiry and the expected return or revision date required of recipients. Some of the document information will already exist within the CAD drawing data base, which is then incorporated into the PDF file. The PDF label is structured as a data file to enable automatic retrieval of information by a database. The PDF encoding software contains all the encoding rules necessary to construct an electronic representation of the bar code. The PDF file produced is then relayed back to the CAD data base; subsequently appearing within the drawing by means of an appropriate driver.

DECODING THE BAR CODE LABEL

In order for the drawing recipient to be able to successfully use the information contained within the bar code, consideration must be given to hardware and software requirements In the pilot study, the two critical stages where decoding of the bar code occurred were:

1) arrival of documents at the site office on receipt from the designer The absence of a hard wire connection means that document management information cannot easily be transmitted by conventional EDI methods. The PDF file provides a reliable method of identifying the drawings and circumventing the EDI process.

2) arrival of documents at the main contractors office on receipt from specialist contractors and sub contractors. Invariably, design information arrives in a number of formats. The use of PDF labels by all participating contractors makes the management of the drawing information more manageable. The ability to print labels using low cost printers (including dot matrix printers) makes the technology accessible to small contracting firms.

In order to read the information contained in the PDF label, a 2 D scanner, a decoder and a computer are required. The error rates experienced with the bar coding system were exceptionally low. On the rare occasion when decoding was unsuccessful, *no information* was transmitted rather than *incorrect information.* This behaviour is attributable to the presence of error checking algorithms in the decoder. The transmission rates from the PDF scanner to the computer were dictated by the baud rate setting. Even with the low baud rate setting, the speed of decoding and transmission were considerably faster than any form of manual data entry.

CONCLUSION

The fragmented structure of the UK construction industry has undoubtedly hampered adoption of EDI as a means of electronically transferring drawings and other information between parties within the construction process. Despite the increasing use of CAD technology within the design process, transfer of hard copy drawings remains the primary method of communication between designer and contractor. Reliance on this format severely limits the ability to abstract and assimilate information contained within drawings.

This paper discussed the use of auto-ID as a means of transferring drawing information. The major advantage of this approach lies in the ability to access and abstract information contained within the drawing. Bar coding provides an indispensable tool for effective incorporation of hard copy drawings into the construction process.

The use of bar coding by single organisations for the purpose of document management will only provide localised benefits. The full benefits of auto-ID can only be realised if adopted by a number of participating organisations in a project. A natural extension of this is the formulation of industry wide standards for bar code applications such as document management.

ACKNOWLEDGEMENT

This work forms part of the Engineering and Physical Sciences Research Council funded research project "Auto ID technologies in construction." (Grant ref. GR/J/11508).

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