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IMPLEMENTATION OF INFORMATION TECHNOLOGY IN MATERIALS LOGISTICS IN THE UK CONSTRUCTION INDUSTRY

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New electronic information and communication technologies are transforming the way many business processes are performed in companies. Improvements in efficiency and reductions in the cost of obtaining, processing, and transmitting information are changing the way business is conducted. An audit of the implementation of these technologies, could help raise awareness of current technological developments and identify opportunities being missed and obstacles to implementation.

The paper presents results of a survey into the implementation of information and communication technologies in materials logistics in the UK construction industry. Even though implementation is on the increase, evidence suggests that the construction industry lags behind the rate of innovations in other industries.

Keywords: communication, contractor, information, supplier.

INTRODUCTION

This paper is in four parts: the introduction; research methodology; results; and conclusions. The introduction section explores the strategic relevance of information and communication technologies and their positive impact on business processes. The various technologies and the categories into which they fall are also described.

New information technology has been assessed to be of strategic significance in the way business is conducted (Porter and Miller 1985). This technology encompasses data recognition equipment, computers, communication technologies and affiliated software and services. These technologies permeate and transform the way processes are performed and the nature of their linkages throughout the supply chain. As a consequence, the boundaries of what is possible in processing information is expanding while the cost of storing, manipulating and transmitting the information is falling. These technologies have also reduced error rates resulting from manual data handling. For example, studies show that the error rate in recording data via bar codes is 1 in 3,000,000 compared to 1 in 300 if manual data entry is employed (McKenney and McFarlan 1982).

As well as affecting how individual activities are performed, these technologies are also enhancing the ability of individual companies to exploit linkages between activities both within and between companies via new information flows. Through these technologies, companies can now co-ordinate and integrate their processes more closely and efficiently with those of their trading partners, enhancing collaborative interrelationships among businesses and expanding the scope of industries in their

performance improvements. A number of these technologies were reviewed by Alkaabi (1994) and Back and Bell (1994). The technologies can be classified into three broad categories: automatic identification (Auto-ID) technologies; computers-based technologies; and electronic communication technologies.

Automatic identification technologies

Automatic identification technologies can be used to enter data onto computers electronically. There are many types and well known ones include: bar codes, voice recognition, electronic document imaging, magnetic stripes, radio frequency tagging, optical character recognition, machine vision and touch memory (Alkaabi 1994). Among all these, bar codes have attracted wider usage in many industries than any of the other techniques (Alkaabi 1994) and the potential for their application in the construction industry has been reported in a number of recent publications (Baldwin *et al.* 1994, Finch *et al.* 1996, and Marsh and Finch 1998).

Computer based data management technologies

Computer management technologies include integrated database management systems, and recently the intranet. An integrated database management system is an information management system which allows users to organize, store and manage data that may relate to an activity such as a project, electronically. The data can be entered and stored once, accessed, transferred, combined, sorted, manipulated and reused by different users for different applications, all without printing and re-keying.

Due to the success of the internet's world wide web (WWW) pages, companies have also begun to employ web pages and browsers to operate information systems referred to as intranets. These are internal corporate computer networks which supply non-public company information in WWW style using internet protocol. The technology connects users to corporate databases thus enabling the pooling of information across the organization via web browser technology.

Electronic communication technologies

Instead of manual data entry using the keyboard, auto-IDs can be used to enter data electronically on computers. Once entered, data or information may further be made available to other organizations electronically via communication technologies like electronic data interchange (EDI), electronic mail (E-mail) and extranets.

EDI is a direct computer to computer transmission of business data in standard format. It eliminates the need for re-keying of information. The technology can be used to transmit documents like requisitions, requests for quotations, purchase orders, shipping documents, materials lists, invoices and payment transfers between designers, owners, contractors and materials suppliers.

E-mail and extranet are internet-based communication technologies. E-mail is said to be one of the reasons many business/domestic users have signed on to the internet (Cleary 1998). It has found application for tasks like electronic document interchange or as a rapid text messaging system. The technology can transmit messages on real-time and is highly cost-effective; data transmission charges being only a fraction of the costs of facsimile technology (Cleary 1998). As messages and documents can be read and stored on the computer for later use, there are also savings on the use of printers and paper consumption.

Intranets discussed earlier are equipped with an internet gateway which restricts entry by outsiders. Trading partners may be permitted limited access via extranets.

Because intranet technology is identical to the internet, companies can use it for both interior messaging or publishing and as internet for cost-effective communication links. Extranets enable suppliers and customers to establish a walled-off section of the internet (Cleary 1998). In effect, this is a virtual private network which companies in a supply chain can use to streamline their business transactions. Within the construction industry, significant benefits appear to accrue from application of these technologies in materials supply logistics activities (Back and Bell 1994, Carter *et al.* 1996, and Alkaabi 1994).

Applications and benefits of information and communication technologies

Simulation of electronically integrated supply chains using bar codes, electronic data interchange and integrated database management systems between contractors and suppliers pointed to potential savings in cycle time of the order of 48 - 76% and cost savings in labour of 24 - 50% in the procurement of construction materials (Back and Bell 1994, Carter *et al.* 1996). Furthermore, a bar coding feasibility study at a company specializing in the manufacture of pre-cast concrete flooring systems in the UK established the following savings (Alkaabi 1994):

- an 85% time saving in clerical time for entering data on to the company's computer;
- a 70% time saving in checking beams prior to delivery; and
- a 30% time saving in locating beams within the stockyard.

Results of these studies suggest that high level usage of information technology can yield significant improvements in the delivery of construction materials. Arising from this observation, the objective of this paper is to present results of a survey into the implementation of information and communication technologies in materials supply logistics in the UK construction industry. Benefits and obstacles to implementation of these technologies are identified.

RESEARCH METHODOLOGY

From reviewed literature, two near 'mirror image' questionnaires on materials logistics, one for contractors and the other for suppliers were developed, pilot-tested and distributed to industry. Near 'mirror image' means that nearly all the questions were asked of respondents from the perspective of both buying and supplying companies. This approach made it possible to compare responses from buying companies with those from supplying companies.

Samples

A total of 71 companies ranked among the top 100 UK contractors, based on turnover (Construction News 1996), were sampled at random and sent the contractor questionnaire. Of the 71 sent, 35 returned usable questionnaires represented a 49% response rate.

The second questionnaire was sent to a total of 76 construction materials suppliers. These were sampled from the top 25 (based on turnover) UK construction materials suppliers (Construction News 1996) supplemented, due to inadequacy of the sample size, by another sample from suppliers listed in the Construction and Civil Engineering CD - ROM (1997, July-October). Of the 35 questionnaires returned, only 30 were usable representing a response rate of 40%.

To complement responses to questionnaire items, nine contractors and five construction materials suppliers from the surveyed companies were further interviewed for in-depth views pertaining to implementation of information and communication technologies. Both responses from questionnaire surveys and those from interviews were of companies that were more active within the UK construction industry and were limited to experiences of large-scale contractors and suppliers.

Types of interviewed companies and individuals

The nine contractors that were interviewed had 1996/97 annual turnover ranging from £80 million to £400 million and workforce ranging from 120 to 3,500 people. All the interviewees, except one buyer, held positions equivalent or above that of manager in their companies. Their experience in the industry ranged from 8 to 36 years and all were either directly involved in procurement/materials management or had detailed knowledge of the function.

Quoted 1996/97 annual turnovers of the five suppliers that were interviewed ranged between £203 million and £7.224 billion, their workforces ranged from 776 to 40,400 people. In comparison, these companies were larger than interviewed construction companies, both in terms of turnover and workforce. Interviewed experts from supplier companies were all senior managers with several years of experience in the construction industry ranging from 4 to 26. Their experiences were in areas of sales, marketing and general management and all were selected in their respective companies as individuals competent to answer questions on issues relating to supply of construction materials and interactions of their companies with contractors.

RESULTS

The two questionnaires investigated the use of information and communication technologies in three respects: the use of the technologies in internal materials management processes of both suppliers and contractors; the use of the technologies between suppliers and construction sites on one hand - and between contractors and their construction sites on the other; and inter-organizational use of the technologies between contractors and suppliers.

Internal usage of information and communication technologies

Table 1 shows that 667% of the contractors and 63% of the suppliers used integrated database management systems (IDBMS) 'Occasionally' to 'Always', 43% of the contractors and 43% of the suppliers used electronic mail 'Occasionally' to 'Always', and 23% of the contractors and 43% of the suppliers used electronic data interchange 'Occasionally' to 'Always' in intra-organizational materials management processes.

Among auto-IDs, electronic document imaging was used 'Occasionally' to 'Always' by 23% of the contractors and 17% of the suppliers. Bar codes were used 'Occasionally' to 'Always' by 23% of the suppliers but by none of the surveyed contractors. The usage rates of the rest of the auto-IDs was very low. These results suggest that data entry into computers of surveyed companies was predominantly manual. This finding was also acknowledged by Construct IT (1998) who observed much evidence of manual data entry.

Table 1 further shows results of the two-tailed Wilcoxon-Mann-Whitney test for group differences in the usage of information and communication technologies in materials management processes by suppliers and contractors. There were no significant differences between contractors and suppliers in their intra-organizational

Table 1: Comparison of use of information and communication technologies by contractors and suppliers in internal materials management processes

| Information and communication technologies and methods | Suppliers | | | | Contractors | | | | Probability Wilcoxon-Mann-Whitney 2-tailed p |
|--|-------------|------------------------|-----------------|-------|-------------|------------------------|-----------------|-------|--|
| | No of cases | Occasionally to always | Rarely to never | Total | No of cases | Occasionally to always | Rarely to never | Total | |
| | m | (%) | (%) | (%) | n | (%) | (%) | (%) | |
| Integrated Database Management Systems | 30 | 63.3 | 36.7 | 100 | 35 | 65.7 | 34.3 | 100 | 0.3393 |
| Electronic data interchange | 30 | 43.4 | 56.6 | 100 | 35 | 22.9 | 77.1 | 100 | 0.0905 |
| Electronic mail | 30 | 43.4 | 56.6 | 100 | 35 | 42.9 | 57.2 | 100 | 0.8845 |
| Bar codes | 30 | 23.3 | 76.7 | 100 | 35 | 0.0 | 100 | 100 | 0.0067* |
| Radio frequency tagging | 30 | 3.3 | 96.7 | 100 | 35 | 0.0 | 100 | 100 | 0.2801 |
| Magnetic stripes | 30 | 6.7 | 93.3 | 100 | 35 | 0.0 | 100 | 100 | 0.1237 |
| Voice recognition | 30 | 3.3 | 96.7 | 100 | 35 | 8.6 | 91.5 | 100 | 0.5124 |
| Electronic document imaging | 30 | 16.7 | 83.3 | 100 | 35 | 22.9 | 77.1 | 100 | 0.4587 |

*Result statistically significant at 5% significance level

Table 2: Comparison of use of information and communication technologies in materials management processes between purchasing offices of contractors and construction sites and, offices of suppliers and construction sites

| Information and communication technologies and methods | Suppliers | | | | Contractors | | | | Probability Wilcoxon-Mann-Whitney 2-tailed p |
|--|-------------|------------------------|-----------------|-------|-------------|------------------------|-----------------|-------|--|
| | No of cases | Occasionally to always | Rarely to never | Total | No of cases | Occasionally to always | Rarely to never | Total | |
| | m | (%) | (%) | (%) | n | (%) | (%) | (%) | |
| Integrated Database Management Systems | 30 | 33.3 | 66.7 | 100 | 35 | 28.6 | 71.5 | 100 | 0.9938 |
| Electronic data interchange | 30 | 13.3 | 86.7 | 100 | 34 | 11.8 | 88.2 | 100 | 0.1862 |
| Electronic mail | 30 | 23.3 | 76.7 | 100 | 34 | 38.2 | 61.8 | 100 | 0.1684 |
| Telephone | 30 | 96.7 | 3.3 | 100 | 35 | 97.1 | 2.9 | 100 | 0.6820 |
| Facsimile | 30 | 93.3 | 6.7 | 100 | 35 | 97.1 | 2.9 | 100 | 0.7529 |
| Post | 30 | 86.7 | 13.3 | 100 | 35 | 91.3 | 8.6 | 100 | 0.3377 |

use in materials management processes of integrated database management systems, electronic data interchange, electronic mail, radio frequency tagging, magnetic stripes, voice recognition and electronic document imaging. Only bar code technology showed a significant difference in its usage by contractors and suppliers. More suppliers, 23% compared to 0% of contractors used bar codes 'Occasionally' to 'Always'. An earlier survey by Alkaabi (1994) had also shown that suppliers used bar codes more than contractors.

Use of information and communication technologies between contractors and their construction sites, and suppliers and construction sites

Table 2 also shows that there were no significant differences in the usage of all the technologies and methods between suppliers and sites, and contractors and their sites. The table further shows extent of usage of information and communication technologies and media by contractors and suppliers in the exchange of information

with construction sites. The telephone, facsimile and post were more widely used than electronic technologies. Over 85% of both contractor and supplier groups used the telephone, facsimile and the post (word of mouth and paper-based methods) 'Occasionally' to 'Always' in their materials management processes with sites. Both groups exhibited very low usage rates of IDBMS, EDI and e-mail (electronic data based technologies) with each group indicating that over 60% used these technologies 'Rarely' to 'Never' in exchanging information with construction sites.

Inter-organizational usage of information and communication technologies in materials supply logistics activities between contractors and suppliers

The two-tailed probability test results in Table 3 show no significant differences in the extent to which respondents said identified information and communication technologies and methods were used in materials supply logistics between contractors and suppliers. The table shows that the telephone, facsimile and post were used by over 93% of responding suppliers and 100% of responding contractors "Occasionally" to 'Always' in the exchange of information between contractors and suppliers. Both groups exhibited very low usage rates of IDBMS, EDI and e-mail, with around 73% of suppliers and 80% of contractors indicating that they used these electronic data management technologies 'Rarely' to 'Never'.

The telephone and paper based facsimile and postal services were the most widely used information and communication technologies in inter-organizational materials supply logistics activities between suppliers and contractors; suppliers and construction sites, and between administrative offices of contractors and their construction sites. The percentages of both contractors and suppliers that used electronic technologies such as integrated database management systems, electronic mail, and electronic data interchange in external materials supply logistics activities 'Occasionally' to 'Always' were still relatively low. In the case of EDI, findings of the study by Akintoye and McKellar (1997) showed that the industry still had a long way to go before the technology was used regularly for information exchange.

In internal materials management processes, the usage of integrated database management systems by both contractors and suppliers was fairly high compared to the other technologies. Data entry was still predominantly manual. These findings were also observed by Construct IT (1998), whose study noted much evidence of manual data entry and existence of islands of automation which required external bridging to achieve more effective use of information and communication technologies.

Even though the usage of information and communication technologies among the interviewed companies was generally still low, both interviewed suppliers and contractors reported a number of benefits in their usage of the technologies. The companies were also aware that the industry was changing rapidly in its implementation and usage of information technology.

Benefits reported from implemented information and communication technologies

Table 4 shows the benefits of using information and communication technologies reported by the interviewed companies. Most of these benefits related to internal usage of information and communication technologies in materials management processes where the study revealed a higher usage of integrated database management systems by both contractors and suppliers. Even though cost reduction was not

Table 3: Comparison of inter-organizational use of information and communication technologies in materials management processes between contractors and suppliers

| Information and communication technologies and methods | Suppliers | | | | Contractors | | | | Probability Wilcoxon-Mann-Whitney 2-tailed p |
|--|-------------|------------------------|-----------------|-------|-------------|------------------------|-----------------|-------|--|
| | No of cases | Occasionally to always | Rarely to never | Total | No of cases | Occasionally to always | Rarely to never | Total | |
| | m | (%) | (%) | (%) | n | (%) | (%) | (%) | |
| Integrated Database Management Systems | 30 | 26.6 | 73.4 | 100 | 35 | 5.8 | 94.2 | 100 | 0.2371 |
| Electronic data interchange | 30 | 26.7 | 73.3 | 100 | 34 | 5.8 | 94.2 | 100 | 0.5796 |
| Electronic mail | 30 | 26.6 | 73.4 | 100 | 34 | 17.6 | 82.4 | 100 | 0.498 |
| Telephone | 30 | 93.4 | 6.6 | 100 | 35 | 100 | 0 | 100 | 0.1244 |
| Facsimile | 30 | 96.7 | 3.3 | 100 | 35 | 100 | 0 | 100 | 0.7795 |
| Post | 30 | 96.7 | 3.3 | 100 | 35 | 100 | 0 | 100 | 0.8822 |

Table 4: Benefits reported from use of information and communication technologies by interviewed contractors and suppliers

| Benefits experienced by contractors | Benefits experienced by suppliers |
|---|--|
| Fast access to data | Cost reductions. |
| Quicker information flows between sites, administrative offices and among personnel | Accurate information, leading to time saving and improved customer service |
| Increased work output. | Enhanced ability to tie customers to the business of the supplier |
| Improved quality and efficiency in communication | |
| Less errors in data entry | |

Table 5: Obstacles to introduction of information technologies in materials management processes among interviewed companies

| Obstacles identified by contractors | Obstacles identified by suppliers |
|---|--|
| Incompatibility of technologies in use. Companies using their stand-alone databases, incompatibility of information technologies between departments, incompatibility of technology formats between contractors and suppliers, and problems in the design of bespoke systems were the cited problems. | Required internal re-organization and the scale of the operation needed to introduce information and communication technologies. |
| High cost of the technology leading to lack of expenditure on software and hardware. | Inability to see any major benefits from the high cost of the technology leading to reasons for lack of expenditure on the technology. |
| Fear of change resulting in lack of confidence in using the technology. | |
| Non-availability of people with IT expertise. | |

mentioned among interviewed contractors, probably because as a benefit it was difficult to quantify, the benefits they cited have a bearing on reduced cycle times and improved productivity in the procurement of construction materials. In addition to time savings, interviewed suppliers acknowledged cost reductions as a result of implemented IT. Considering that usage of information and communication technologies was relatively low among the interviewed companies, these benefits suggest that the potential to reduce costs and materials procurement time with increased usage of the technologies in materials logistics was high.

Interviewed contractors and suppliers were aware that the industry had historically failed to keep up with developments in information and communication technologies in the past, resulting in fewer companies having fully explored the possibilities of using information and communication technologies and fewer having taken advantage of the technology. A range of factors that impeded implementation of information and communication technologies are identified in Table 5, the main ones being that designers, suppliers, contractors and sub-contractors were not agreed on standards. Incompatibility of IT technologies was often even within organizations. Other obstacles to implementation included inability to see major benefits from the high cost of the technology; fear of change and the scale of the operation needed to introduce IT. It was also pointed out by one contractor that unlike in manufacturing and retailing, each construction project is unique and it is difficult to use similar information and communication solutions each time.

CONCLUSIONS

Results of surveys and interviews with UK contractors and suppliers concerning the use of information and communication technologies in materials management have been presented. Despite the major benefits identified in literature, results indicate that the extent of usage of information and communication technologies by both contractors and suppliers was relatively low. Obstacles to implementation included incompatibility of technologies in use, high cost of the technology, fear of change, required internal re-organization and the scale of the operation, and inability to see any major benefits from the high cost of the technology. Among electronic data management technologies, only integrated database management systems were fairly widely used in internal materials management systems. Data entry was still predominantly manual. Externally, the telephone, facsimile and post were used 'Occasionally' to 'Always' by over 82% of contractors and suppliers.

Other information and communication technologies such as the intranet and extranet which were not included in the reported survey have also come into common usage. Further work is required to investigate, periodically, the obstacles and benefits associated with implementation of both known and emerging technologies and the findings publicized so that the technologies may be exploited by the wider industry.

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