DATA INTEGRATION AND CONSTRUCTION CONTRACTING: BARRIERS TO IMPLEMENTATION

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In previous work, the authors have shown that the UK construction industry has been slow to exploit many of the benefits of Information Technology in the running of its routine work. While software is quite widely used, in most cases only a fraction of the capabilities are employed. In discussions with representatives from the industry, the opinion was expressed that this might well be due to a lack of integration in the operating systems of most companies. Following these discussions the authors carried out a survey of construction firms to determine their attitudes to data integration.

This paper deals with the concept of an integrated data handling system and the problems facing its introduction in the UK construction industry. The results of the survey are analysed and discussed. The influences of such issues as the industry climate and culture are taken into account.

Keywords: integration, organization, construction contracting, data

INTRODUCTION

In both the developed and developing world, construction is one of the largest industries operating today; this is certainly true of the United Kingdom. In the UK, construction has been compared unfavourably with other sectors of manufacturing industry, and there has been a movement towards using such comparisons to see if there are lessons which might profitably be drawn (Egan, 1998). Aircraft manufacture and the automotive industry are sectors with which comparison can be made. These industries are comprised of a few large firms, whereas in the UK, the construction industry numbers in excess of 160,000 firms, most of which are small, employing under 25 people. Fewer than 50 employ more than 1200 people (Harvey and Ashworth, 1997). Other striking differences are that the aircraft and automotive industries are very capital-intensive, and their products are planned in minute detail before production commences. They produce large numbers of a limited number of designs. In construction this is not the case. Work will frequently begin on site before all details of the building (which will often be unique) have been agreed and planned.

Data handling and communication in construction are therefore a matters of vital importance. The commitment of labour, materials, time and money hangs on working to the correct information and data. Use of incorrect data can compromise the scheduled completion of a project and lead to wastage of resources.

It has been recognized for some time that the handling of information and business data is a crucial aspect of business organization. In a small company, one man can probably hold most of the essential operating data in his head, but as companies become larger and more complex, this becomes impossible and organizational structures are required to handle data. Max Weber coined the term ‘Bureaucracy’ in Germany in around 1910 to describe these structures. The dynamics of the

Sturges, J and Bates, M (2001) Data integration and construction contracting: barriers to implementation. *In:* Akintoye, A (Ed.), *17th Annual ARCOM Conference*, 5-7 September 2001, University of Salford. Association of Researchers in Construction Management, Vol. 1, 179-87.

organizational processes make these structures essential for the control and efficient running of the business. Weber's work was not translated into English until the 1940's, when his ideas were subjected to intensive study and debate, and a whole body of theory has been developed to help understand the nature and operation of organizations. It has been recognized that systems for data and information handling and transmission are essential, and these have been likened to the 'nerves' of the organization. One of the most recent writers to take this view has been Gates (1999), who advocates the use of what he describes as 'digital nervous systems' i.e. electronic systems for data handling and transmission in business organization. However, the creation of such systems is not a straightforward process, and Child (1984) has considered some of the problems that arise if badly structured systems are used. Motivation of workers can be lowered or lost, decision-making may be delayed or reduced in quality, conflict and lack of co-ordination can arise and costs can increase, all because information and data are badly handled or imperfectly transmitted.

The purpose of this paper is to examine the concept of data integration and to report on a small initial project carried out by the authors to explore industry's understanding and use of the concept of data integration.

INTEGRATED DATA SYSTEMS

Before going further, it will be useful to define the term, integrated system. By this is meant a system where the essential operating data is entered once, and each department or function within the company works from the same data. This holds true whether systems are traditional paper-based, or the more modern IT ones. So in construction, a job would be planned, with the correct sequence of operations set out. The same data would be used to allocate resources, both materials and labour, and then the costings would be worked out using the same data again. Issuing of invoices, paying of wages, clearance of payments, etc. would all be done based on the same data. If IT systems were used, all departments would either use the same software or a set of mutually compatible packages able to transfer data seamlessly between one function and the next.

However, integration and electronic data exchange are not always the same thing. Data can be handled and communicated by other than electronic methods, and the authors are currently extending this work by looking at both the data handling needs of construction companies, and at the most convenient ways of doing this in practice.

PROJECT MANAGEMENT TECHNIQUES

Project management techniques are among the best-known recent developments to emerge in the field of management, and software has been produced to enable these methods to be implemented in commerce and industry. A crucial step in the development of Project Management software was the incorporation of a database or repository of operating information. This could then be interrogated by the various job functions, as necessary. Such software provides scope for at least partial integration of data management; using such software work can be planned and scheduled, and labour and material resources can be co-ordinated with the plan. If the software is fully exploited, cost data can be produced, which can then be accessed by the finance and wages sections. The authors have previously investigated the use of computer-aided project management (CAPM) methods and software within the UK construction industry (Sturges *et al.*, 1997), and they found that these methods are increasingly

being taken up. However, the take-up was not uniform; certain sectors, such as house building, were slower to do so than the rest. The authors also found that the implementation of these systems was in most cases only partial, with the complete software package never being used.

Naturally, the reasons for this state of affairs were sought, and the authors shared their findings with colleagues in the industry, who recognized the problem. In a free-ranging discussion, they pointed out that such software was not fully exploited because in their own companies, the different departments used their own local systems with which the CAPM software was not compatible. The result is that the same operating data is entered into several different systems separately, and this makes data transfer and exchange between departments time-consuming and wasteful of effort. In moving from one department to the next, the information must effectively flow through the department head or "gatekeeper". This situation is analogous to a wall or barrier; Peters (1992) refers to it as a 'Himalaya-high functional wall'. How much better would be an integrated system where information flows through the departmental functions without the need for multiple entry.

CULTURAL FACTORS

Cultural factors also play a part. By culture is meant the set of attitudes, modes of operation, corporate values, etc. which pervade all organizations. Certain ways of doing things become the accepted norm over time, and while these systems undoubtedly work, they are not necessarily optimal. The advent of new technology can make alternative, faster and more efficient methods possible; and if, in a company, outdated cultural attitudes are retained, the old methods outlive their time, as operators do not have the knowledge or vision to see what is now possible. This can result in the firm losing competitive advantage. While this can happen in a single firm, it can also be true of a whole industry, where outdated cultural attitudes are retained. This may occur where personnel transfer from firm to firm within an industry, with few people transferring in from other sectors.

The construction industry in the UK undoubtedly has its own culture and style of operation when compared with other industry sectors. It has multi-site operation, (as do others) but the site locations can change from week to week. It employs sub-contract labour in large numbers, and it often has short-term relationships with its suppliers of materials, as well as with some of its sub-contractors. On many jobs, the team of sub-contractors, materials suppliers, quantity surveyors, architects, etc. will be together only for the duration of the current contract, thereafter going their separate ways. This is a culture which makes the effective transmission and handling of data and information both very difficult, and yet at the same time, of crucial importance. The industry has retained some obsolescent ways of handling information in spite of recent, partial adoption of some of the newer, IT-based methods.

This picture describes much, but by no means all, of the UK industry. The authors have investigated the use of computer-aided project management methods by the industry (Sturges *et al.* 1997), and they found that such methods are being increasingly taken up. The take up was not uniform however; certain sectors, such as house building, were slower to do so than the rest. However, they found that implementation of these techniques was in most cases only partial, with the full software package never being used. The planning capability would be used, and perhaps the scheduling ability, but the costing capability was never employed. In

analysing these results, the question naturally arose as to why this state of affairs obtained. Informal discussions with industrial contacts elicited the information that construction firms did not have integrated information and data handling systems.

The authors therefore sought more information in several ways. They embarked on project to investigate the construction industry's views on the use of integrated data handling systems (Sturges *et al.* 2000). Concurrently with these efforts, the authors worked with a firm of housebuilders to implement a Just-in-Time (JIT) system for the delivery of materials to their various sites (Bates *et al.* 1999). The system was developed using CAPM type software, customized to suit the client's needs, and this idea was well received both by the housebuilder and by his materials suppliers. It was when the authors sought to extend the method to the supply of sub-contract labour that another contrast of cultures was uncovered (Sturges and Bates, 2000). The sub-contract labour companies were not at all enthusiastic, and the authors have speculated on some of the possible reasons for this. They also carried out a simple comparison of the construction contracting and aircraft manufacturing industries (Bates *et al.* 1999) in an attempt to compare the respective cultures and also the ways in which the two industries handle information and data. All of these efforts have been fairly small-scale, but taken together, the authors feel that they have illuminated current attitudes and practices in a significant part of the UK industry.

Construction Contracting - Aircraft Manufacturing Comparison
The aim was to compare and contrast the ways in which the two industries make use of CAPM techniques. The aircraft industry regards the development of the new aircraft as the project, which effectively finishes when the plane goes into production (what they referred to as steady-state production). In construction contracting, of course, construction of the building is the project. The work of Bates, *et al.* (1999) showed that the aircraft industry made much fuller use of project management software. This industry also developed much closer, and longer-term relationships with its suppliers. Each new design would involve some element of innovation to give improved performance, and these improvements can only be achieved by a greater sharing of information and data. The manufacturers and their suppliers would recognize their dependence on each other in a way that construction contracting and its suppliers do not. Therefore, a whole set of cultural attitudes are present in aircraft manufacture, that are not usually found in construction contracting.

THE INDUSTRY CLIMATE

The climate under which the industry operates will also have a bearing. The large number of companies operating means that the industry is very competitive; the very low barriers to entry cause the industry to stay competitive. The kind of industry rationalization seen in for example, aircraft manufacture, does not occur because of the steady stream of new small firm entrants. Profit margins remain on the modest side of healthy. Small firms will be reluctant to invest in IT, especially where the firm is essentially being run by one person. In many SME's, the use of IT will depend upon whether or not the firm has recruited a recent graduate with IT skills. The large companies, on the other hand, will invariably have staff with IT skills, and will have invested in the necessary hardware.

THE SURVEY

The survey was a small-scale exercise, using a postal questionnaire, covering small, medium and large companies. For the purposes of the survey, a small firm was defined as one employing 34 people or fewer, a medium firm between 35 and 299 employees and a large firm as having 300 or more. A list of nearly 2800 firms of all sizes was initially compiled, with questionnaires being sent to 5% of them (a total of 141 questionnaires). The break down between various sizes of firms and their responses was as follows:

10 large firms,	6 responded	(60% response rate)
84 medium-sized firms,	17 responded	(20% response rate)
47 small firms,	14 responded	(20% response rate)

The questionnaire was developed and piloted with the help of a number of industrial people. It was divided into three sections; the first section being designed to elicit details of the company and the person responding. Section two covered the main survey information required and section three gave respondents the opportunity to volunteer any comments or anecdotal evidence, triggered by completion of the first two sections.

Two points need to be made; this survey is small-scale and so cannot be truly representative of the UK industry, and secondly, it represents a first attempt at gauging the industry's thoughts on integrated data systems, and that this work continues.

SURVEY RESULTS

The responses in all three categories of size tended to be compiled by contracts managers, managing directors, estimators and surveyors. It was therefore felt that the responses would accurately reflect the industry culture.

In section two, results showed that, as might be expected, larger firms had more departments and well-defined job functions than the smaller firms. In smaller and medium-sized firms, job functions tended to be less tightly defined and more wide-ranging.

With regard to awareness of data duplication, the results showed that large and medium-sized firms were more aware of duplication, with small firms being less so. This is understandable; larger firms will have more well-defined, separate departments to deal with the various organization functions. In small firms there will be more overlap, with one person dealing with more than one function. In terms of an awareness of the problems arising from data duplication, respondents from large and medium-sized firms showed an awareness of problems, although none of them gave any indication of what their own particular problem(s) were.

When asked whether they were familiar with the meaning of the term Integrated Data Exchange (IDE), there were no differences between the groups, between 82 and 86% in all groups were aware of the term in all sizes of company.

Respondents were then asked about the media used by their firm for data handling and transmission. The usual media were listed including; paper-based systems, fax, telephone, e-mail, and other IT-based systems. The replies from all sizes of firm showed that paper-based systems and the telephone were the preferred method of

information transmission by an overwhelming margin. This is an interesting cultural pointer.

Nevertheless, all sizes of firm used computer systems to some extent. To be specific, 66.5% of large firms had fully-networked systems, 59% of medium-sized firms and 35% of small firms had such systems. This may seem to be an encouraging state of affairs; however, replies to the earlier questions indicated that none of them is using their systems to anywhere near their full capacity. However, it did seem that most firms have the hardware required for successful systems integration already installed and in running order.

Firms were asked about the types of software used, and word processing was the most popular, as might have been expected. Spreadsheet and database software were next, with CAPM packages lying in fourth place. CAPM software was used by 83% of large firms, by 70% of medium-sized and by 56% of small firms. Other types of software used included surveying, estimating and costing packages.

When asked about the types of data that were managed electronically, the two most often cited were accounts and wages. 66.5% of large firms, 100% of medium firms and 91% of small firms handled their accounts this way, and 83% of large firms, 94% of medium firms and 91% of small firms dealt with their wages data electronically.

The next question asked about software systems used on-site, if any. Only 6% of large firms said that they used these software systems on site. A lot of the others (47% of medium-sized and 42% of small firms) said that they used none of these on site. Understandably, planning software was the most frequently used type on site. This finding agreed with earlier work (Sturges *et al.*, 1997).

When small firms were asked why they did not use computing facilities on site, 28% said it was not necessary, 21% said that they lacked staff with the required training, and another 21% said that the use of computers would cause problems for the site staff. Staff working on site for a small company would almost always be made up of sub-contract staff, and so these answers were perhaps not very surprising. Formerly, medium and large companies would use their own labour, but increasingly, the trend has been for them to use sub-contract labour.

Firms were reluctant to attribute the non-use of computers on site to a lack of IT trained personnel when asked directly. However, no clear reasons for this could be elicited from questions designed to identify the reasons. None of the firms used all of the software functions on site that were listed on the questionnaire.

The next question centred on awareness of the existence of computer-based, integrated data handling systems, and the majority of firms were aware of these; (83% of large, 94% of medium and 72% of small firms indicating an awareness). They were then asked whether or not they had ever in the past, or were now trying to implement such an integrated system. Only 33% of large firms, 41% of medium firms and 14% of small firms replied affirmatively.

When asked directly whether they would like to adopt an integrated data system, the majority were in favour of doing so, with more (83%) wishing to in large firms than in small firms 65%. This may be because there would be larger scope for savings where contracts were larger and perhaps more complex. The last two questions were designed to find out if respondents were aware of colleagues who had shown interest in integrated systems, and to find out if respondents saw such systems as a way of avoiding duplication of effort. The pattern of replies was similar, with most replying

to both questions in the affirmative; and the larger the firm, the larger the percentage of affirmative replies.

The final section of the survey gave respondents the opportunity to volunteer their own comments, observations, questions, etc. None did so, regardless of the size of company. This was interesting; in a previous survey carried out by the authors (Sturges *et al.*, 1997), similar provision was made for voluntary comments, and on that occasion, many such individual comments and anecdotal evidence were offered. Although not explicitly stated, the impression was given that integrated data handling systems did not form a part of most peoples' vision for the future of the construction industry at this time. While this may not be true, the impression was created.

DISCUSSION

This topic has been the subject of a number of publications and conferences over the past two or three decades. The works of Brandon *et al.* (1995) and of Akintoye and McKellar (1997) are two recent examples. The most recent survey in this area, (apart from the one reported above), was a survey carried out by the Barbour Index (1999). This was a substantial piece of work based on more than 400 interviews and an analysis of 5000 responses from the Barbour Index building product compendium user survey. In addition, 150 construction projects were examined during the first quarter of 1999.

The survey produced some mixed results. On the one hand, access to technical and product information is still largely paper-based; 90% of firms storing project and product information in paper form. Most project information is currently stored using a mix of paper and electronic media, with only one in six projects surveyed using electronic systems as the primary medium for storage. The survey also showed up some variations in the level of IT awareness in different parts of the supply chain.

The Barbour survey, on the other hand, found that construction professionals are increasing their use of computer systems; 60% have increased their use of the Internet. Interestingly, 80% of architects and engineers now have access to information in electronic format, whereas only 40% of project teams have ready access to electronic information at their desks.

This study tended to confirm the Barbour findings in all important respects. The industry continues to increase the IT skills of its workforce, while at the same time lacking a clear vision of the benefits which might accrue from what Bill Gates called a 'digital nervous system'. This lack of vision is the main reason why the industry continues to lag behind the manufacturing sector in the application of integrated data systems.

The materials suppliers would welcome long-term relationships with the construction contractors. They know that they could give improved levels of service to customers who place high levels of repeat business with them, and who keep them apprised of their future plans. In independent discussions with the authors, window manufacturers and brickmakers confirmed this fact as part of their companies’ policy. Their industry culture is similar to that of manufacturing, where long-term supply chain relationships tend to be the norm, with mutual advantage to both parties.

An integrated data system can be implemented in one of two ways. The company can either buy an off-the-shelf solution from a software company or it can develop an in-house, bespoke system. There are advantages and drawbacks to both methods. An off-

the-shelf system should be free from ”bugs” and teething problems. It can be implemented over a pre-determined time; this process will usually involve training sessions, milestone dates, etc. However, the off-the-shelf system will not be exactly tailored to the requirements of a given organization, and therefore it will not exactly "fit". The bespoke system will be developed to meet the organization’s needs, and so it will "fit". However, the development period may be lengthy, and implementation will take time. There will probably be no clean hand-over date, but the final system should suit the organization's requirements exactly. Developing a bespoke system will cause the company personnel to think about and question what they are doing and why. This can be a good thing, and may lead to improved operating procedures.

The authors believe that attitudes in construction contracting will be changed, but that the change will take time, and that it may best be achieved by implementation of successful demonstration projects to show the benefits of more integrated systems.

CONCLUSIONS

A number of conclusions may be drawn from the survey:

- Most of the firms of all sizes claimed that they were aware of the existence of integrated, electronic data handling systems. They were also aware of the benefits of integrated data systems in reducing the duplication of effort in the recording and handling of operating data.
- In most of the companies surveyed, paper-based data systems and the telephone appeared to be the preferred media for data transmission.
- It did appear that factors such as cost, and a lack of trained personnel were real barriers to the introduction of integrated data handling systems.
- Many large firms had the necessary hardware in place with which to run an integrated system, but none had implemented a software package to enable this to be done.
- Despite the industry’s apparent awareness of the benefits of avoiding duplication of effort, little evidence emerged that the management of construction companies had a vision of the potential benefits of integrated systems operation. Such vision appeared to be confined to people outside the industry, such as academics.
- Building materials manufacturers and suppliers share the culture of manufacturing industry, and are very receptive to the notion of receiving and handling data electronically. By contrast, the labour sub-contractors were not so receptive.

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