THE APPLICATION OF KNOWLEDGE MANAGEMENT PRACTICES IN THE PROCUREMENT AND CONSTRUCTION OF CLEANROOM PROJECTS

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Many of the world's largest biotechnology, pharmaceutical and medical device companies have established production facilities in Ireland in recent years. The country's leading contracting firm, Sisk have developed an expertise in constructing these facilities through the management contracting procurement route. Identifying the sector as a major growth driver, the company has established a bio-pharmaceutical division as part of their corporate strategy within the past year. The procurement of these facilities is complicated, highly regulated and knowledge-intensive. The identification and sharing of this knowledge within Sisk has been hindered by a lack of interaction between members of live projects. The proposed research concentrates on the application of knowledge management (KM) practices to one aspect of such projects; the procurement of cleanrooms through the management contracting route. This paper focuses on a review of literature related to cleanroom construction, management contracting, and KM. In order to identify the key issues related to the procurement of cleanrooms, action research has been adopted as the research strategy. The proposed methods include interviews with members of Sisk's bio-pharma division, a pilot knowledge exchange seminar within a focus group framework and an evaluative questionnaire. In terms of contribution to the current body of KM in construction, the development of a framework for sharing knowledge across simultaneous construction projects is a key objective of the research. The intention is that this exercise shall highlight the benefits of a formal KM approach, in addition to the potential for applied academic research in industry.

Keywords: action research, knowledge management, knowledge sharing, management contracting.

INTRODUCTION

The project-based, fragmented and unstable nature of the construction industry has led to chronic knowledge loss compared with other industries (Orange *et al.* 2003). Recognized as highly knowledge-intensive, construction firms now need to formally manage their knowledge in order to meet current and future challenges (Payne and Sheehan, 2004). The ever-increasing need to innovate and improve business performance has led to the promotion of knowledge management (KM) as a means of addressing these challenges, yet uncertainty still remains about how to approach KM in construction organizations (Kamara *et al.*, 2002, Salisbury, 2003).

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John Sisk & Son, who are the leading contracting firm in Ireland, have gained considerable experience in the delivery of complex projects for clients in the biotechnology, pharmaceutical and medical devices sectors. As a result, the company has established a special bio-pharma division to address this growth sector. Typically, Sisk are retained on many of these projects in a management contracting role, allowing them to bring their experience to bear earlier in the design phase. Within these projects, the design, construction, commissioning, and validation of cleanroom facilities are significant challenges for all involved. Constantly caught in a dilemma of budget and schedule constraints, companies have to deliver a quality building that complies with relevant codes and regulations (Wrigley, 2004). Despite these challenges, Sisk do not have any formal approach to managing their knowledge of cleanrooms, which if implemented, could potentially improve their effectiveness as management contractors. The purpose of this paper is to present the aims and objectives of ongoing research within Sisk, a review of literature relating to cleanrooms, management contracting, KM and a proposed methodology for the application of KM within Sisk's bio-pharma division.

RESEARCH AIMS AND OBJECTIVES

The overarching aim of the research is to improve the delivery of cleanrooms by Sisk's bio-pharmaceutical division by actively sharing knowledge between projects. In order to achieve the stated aim, the following objectives have been formulated:

6. To develop a critical understanding of the current body of literature relating to management contracting, cleanroom construction and knowledge management.
7. To analyse the effect of lack of scope and design at early stages in a project and the importance of early supply chain involvement.
8. To identify problems related to the procurement and validation of cleanroom facilities through the management contracting route within Sisk's Bio-Pharmaceutical division.
9. To assess the effectiveness of KM techniques for sharing knowledge and experience between projects within Sis's Bio-Pharmaceutical division.
10. To make recommendations for the implementation of KM activities in order to improve the delivery of projects within Sisk's Bio-Pharmaceutical division and the wider organization.

The hypothesis which shall be tested by the research is as follows: *"If Sisk wish to achieve a high level of project performance in the procurement and construction of clean rooms, then a more structured, formal approach to sharing knowledge between projects should be adopted."*

BACKGROUND

The Irish government has targeted the biotechnology, pharmaceutical and medical devices sectors as key drivers of industrial development in Ireland in recent decades and the industry has made a very significant contribution to the economy in the country. This is reinforced by the fact that thirteen of the top fifteen global pharmaceutical firms have located in Ireland and are involved in continuous reinvestment programmes. With over eighty facilities employing more than 17,000 people, six out of ten of the world's top selling drugs are produced in Ireland for

export. In 2002, €34 billion worth of pharmaceutical products were exported, making Ireland one of the world's largest exporters (Wallace, 2006).

Founded in 1859, John Sisk & Son Ltd. had a record turnover exceeding €1 billion in 2005, employing over 1500 people directly, making them the leading construction company in Ireland. The company have a number of regional offices throughout Ireland as well as operations in the United Kingdom and South Africa. With continued growth in the bio-pharmaceutical sector in Ireland, Sisk have completed numerous projects for some of the world's leading companies including Johnson & Johnson, Pfizer, Takeda, Wyeth, Guidant, and Abbott. Having developed an expertise in delivering bio-pharmaceutical projects, Sisk have been retained by a number of these clients for repeat projects in a management contracting role. In 2005, such projects accounted for approximately €250 million of the company's overall turnover, making it a key area of business. Traditionally, projects have operated on a regional basis, however last year the company restructured, establishing new divisions which specialize in Civils and Transportation, Bio-Pharmaceuticals and Residential. The new bio-pharmaceutical division is led by a director and two senior contracts managers with many years experience in the sector. At present there are three major, multi-million euro cleanroom projects underway, managed by experienced project managers.

CLEANROOMS

Cleanrooms form an essential part of the production process across a range of industries, such as electronics, micromechanics, optics, bio-technology, pharmaceutical, medical devices and food and drink (Whyte, 2001). A cleanroom is defined by Whyte (2000: 6) as *"a room in which the concentration of airborne particles is controlled, and which is constructed and used in a manner to minimize the introduction, generation and retention of particles inside the room and in which other relevant parameters e.g. temperature, humidity and pressure, are controlled as necessary."* Cleanrooms are intensively serviced and consume large amounts of power and other kinds of energy, which is critical in maintaining a proper environment. The heating, ventilation and air circulation accounts for over 60% of the power needed to operate a cleanroom (Yang and Gan, 2005).

The design and construction of cleanrooms are based on a set of standards, developed by ISO (the International Organization for Standardization). The most common classification of cleanrooms is based on air cleanliness, which differs depending on the task performed in the room, the level of air cleanliness increasing from ISO Class 8 down through to ISO Class 1. In designing a cleanroom it is necessary to consider the anticipated use of the room, equipment arrangement, flow diagrams, HVAC zoning and room classifications, budget, quality, scope of work, a realistic project schedule, and relevant regulatory authorities for which the facility will have to be validated (Smith, 2005). The complexity of the buildings structural requirements and the magnitude of mechanical and electrical services makes the construction of cleanrooms difficult. According to Whyte (2000: 184): *"the correct selection of construction materials and finishes depends on first establishing the four main performance criteria that are required for the cleanroom to be constructed,"* these are functionality, durability, cleanability and maintainability. Essentially, there are three elements requiring consideration, floor, wall and ceiling finishes. Floor finishes must be able to resist the impact of any chemicals spilled on it in addition to withstanding static and dynamic stress and possibly provide a shunt for static discharge (Whyte,

2000). There are four basic types of walls used, blockwork, plaster and epoxy paint; studwork, plasterboard and epoxy paint; solid core panel monoblock and factory applied finish; and hollow core system factory panel system. The type of wall construction must be defined early in a project as it will have an effect on the total project cost, schedule and detailing (Pearson, 2005). False ceilings are typically used in cleanroom construction to accommodate the extensive amount of services required to maintain a clean environment (Ardmac, 2006). Two types of ceiling systems are most commonly used: a panel system which interlock together and are sealed with a mastic joint and a grid system which consists of a light metal framework which have fastenings for light installations and filters (Whyte, 2000).

Air filtration is an important aspect of cleanrooms, as the supply of air must be filtered to ensure the removal of particles and micro-organisms that would contaminate the process being carried out in the room (Anghel and Chetwynd, 2002). Control of air movement is extremely important and considerations include filtration standards, allowable contamination levels, pressure relationships between adjacent spaces, air flow patterns and distribution (Croome and Roberts, 1981). The introduction of building management systems (BMS) has improved the monitoring and control of a cleanroom environment, including air supply and return, water temperatures, humidification, water flow and failed compressors (Wood, 1999). With the benefits derived from a BMS, it is also important to note that such systems have contributed further to the complexity of cleanrooms, from design, through to operation and maintenance (Wood, 1999).

Once the cleanroom has been physically completed, it must be subjected to rigorous commissioning and validation procedures. Typically commissioning involves design review, installation verification, proper system start-ups, functional performance tests, operations and maintenance training, and complete documentation of the HVAC system. For the best possible results, commissioning should be included in all phases of the design and construction process and involve all relevant consultants and contractors (ACG, 2007). The process of validation requires that it complies with specific regulations for current good manufacturing practice (cGMP) which is dependent on the location and jurisdiction of the cleanroom/production facility. There are a number of regulatory organizations in existence, including the European Agency for the Evaluation of Medical products (EMEA), the American Food and Drug Administration (FDA), the Japanese Ministry of Health, Labour and Welfare (MHLW), the World Health Organization (WHO) and the International Society for Pharmaceutical Engineers (ISPE). Depending on the client's organization and their intentions for exporting finished products, the validation process may be subject to one or a number of these regulatory bodies. There now appears to be a global effort happening to make all of these bodies more consistent in their approach to validation (Bonanomi, 2006).

MANAGEMENT CONTRACTING

There are a number of options available to a client in procuring a construction project, for the purposes of this paper the focus shall be on management contracting. In this route, the contractor is engaged by the client to manage the whole of the building process and is paid a fee for doing so. The management contractor may carry out some self performed works or provide some of the common site services. In a pure management contracting situation such works are let as a self contained work package (Morledge et el., 2006; Franks, 1998). Management contracting is considered to be a

'fast track' strategy, which is achieved by overlapping the design and construction which helps to achieve a reduction in project time (Morledge *et al.*, 2006; Cooke and Williams, 2004). This route allows for early contractor involvement in the design development process, the contractor being incorporated into the design team or an equivalent basis to all the other consultants (Walker and Hampson, 2002). It has been found that by involving the contractor from the start of the project, on average expedites the project delivery since it prevents delays caused by bidding and by unfamiliarity with the design (Gil *et al.*, 2004). Due to this overlapping of design and construction, together with the management contractors experience with buildability and technical issues, considerable time can be saved that other procurement methods cannot achieve (Morledge *et al.*, 2006).

Competition between management contractors is created at appointment stage. Presentations are given by management contractors on their proposals to the client and the design team. These proposals are then assessed based on programme, financial soundness, technical ability/buildability considerations, safety performance, reputation, the procurement of work packages, and the control of information flow (Cooke and William, 2004; Hatush and Skitmore, 1987). With management contracting the subcontract packages are issued to tender and are issued a contract first prior to commencement of work. This means that accurate tenders can be attained and that changes can be accommodated provided there is not effect to the packages that have been let (Morledge *et al.*, 2006, Franks, 1998). However, as the design is being done on a phased basis in agreement with the management contractor, work packages are being let in the same manner. Cost certainly is not achieved until all the work packages have been appointed (Turner, 1997; Morledge *et al.*, 2006). The greatest degree of uncertainty is encountered at the earliest stages of a project. Decisions taken during the earliest stages of a project can have a very large impact on its final cost and duration (Mills, 2001).

Being part of the client's team, the contractor takes a less adversarial approach. Communication improves as the contractor is working for a fee and is working with the design team and the package contractors (Cooke and Williams, 2004; Walker and Hampson, 2002). Risk and uncertainty can potentially have damaging consequences for some projects. The client's main objectives are time, cost and quality and risk can effect greatly all of these requirements if it is not planned properly. Indeed according to Hughes (1991: 8) *"the most significant risk in a management contract is that related to the price to be paid by the employer for the works"*. The client has to pay whatever the management contractor spends, plus the management fee. However, one method of controlling this risk is getting the management contractor to sign up to a guaranteed maximum price during the contract. To keep control over the quality of the design may be important for the client. The issue is that the design risk remains with the client (Cooke and Williams, 2004). Any financial risk being absorbed by the management contractor may result in the price being put up or passing down the risk to the sub-contractors who are least able to bear the risk (Hughes, 1991). The former may lead to claims due to a strain on management relations. It may also have an adverse effect on package contractor performance on site. As discussed previously management contracting is designed to overlap the design and construction and also to incorporate client changes during the process. If the project duration extends over the agreed time frame, the client is entitled to liquidated damages from the management contractor, as in other forms of procurement (Cooke and Williams, 2004).

KNOWLEDGE MANAGEMENT

There are two options for KM in the construction industry, at inter-organizational level; between organizations involved in temporary project organizations and at intra-organizational level; within individual organizations (Kamara *et al.*, 2002). Taking the intra-organizational approach, Jashapara (2004: 12) defines KM As: *"the effective learning processes associated with exploration, exploitation and sharing of human knowledge (tacit and explicit) that use appropriate technology and cultural environments to enhance an organization's intellectual capital and performance."* Early research into KM focused on the use of technology to manage explicit knowledge, however it is now more widely recognized that the management of tacit knowledge and socialization is more valuable (Nonaka and Takeuchi, 1995, Egbu, 2004). Organizational knowledge-sharing practices for the sharing of tacit knowledge within construction organizations are identified in Table 1 (Carrillo, 2004, Egbu *et al.*, 2004).

Table 1: Organizational Knowledge-Sharing Practices

Informal knowledge workshops	Knowledge exchange seminars
Departmental meetings	Site visit programme
Summary Reports	Project award scheme
Coaching and mentoring	Brainstorming
Face to face interactions	Training

In attempting to manage knowledge in construction organizations, there are three key areas requiring consideration (Egbu and Robinson, 2005, Kamara *et al.*, 2002):

1. Product/project: technical knowledge of design, materials, technologies etc.
2. Process: procedures, statutory regulations and standards
3. People: identifying people with specific skills, the abilities of suppliers and subcontractors, knowledge of clients business

A major two-year research study on KM in construction in the UK found that people rely heavily upon communication to solve problems; the construction industry values experience very highly; and the industry finds it very difficult to capture knowledge gained form experience (Egbu *et al.*, 2004).

PROPOSED RESEARCH METHODOLOGY

As part of a wider study, the director of the newly established bio-pharma division was interviewed regarding a number of issues related to managing and sharing knowledge within Sisk. The following is a summary of some of the most relevant points:

- The management contracting procurement allows Sisk to use their experience to influence the design process through earlier involvement in a project, *"it gives you the opportunity to make a name for yourself, to prove that you have something to bring to the table. Where we find this useful is in repeat business because we get clients, when you offer the service, they like it, they see they're getting value for money and they come back to you."*
- *"There's a huge amount of knowledge out there, but a lot of it is staying in individual's heads or even within the project teams."* The company recognizes the need to manage knowledge and is *"something that we're trying to do, but possibly would need more structuring."*

- Despite not having any knowledge sharing platform within the bio-pharma division, the director believes that *"getting people together is very good"* for sharing knowledge. Particularly small groups comprising key people, *"if you get the knowledge in to the guy leading a project team, the contracts manager, it then filters down. But we probably have a fair bit to go yet, until we crack that one."* A lack of time for busy construction managers was cited as one of the biggest impediments to getting people together.

The need to identify and share knowledge is particularly relevant to Sisk, especially in the management contracting route, where the exploitation of experience is crucial to winning work. In order to address the current challenges faced by Sisk in the procurement and construction of cleanrooms through management contracting, it is intended to adopted action research as the overall research strategy. This approach has been chosen as it is based on a collaborative approach between the researcher and the practitioner with the aim of solving a problem and generating new knowledge. It is viewed as a significant strategy for organizational research in commercial organizations, community work, education and healthcare (Coghlan and Brannick, 2001). Robson (1993: 438) identifies action research as involving *"a spiral of cycles of planning, acting, observing and reflecting."* According to Denscombe (2003) it is normally associated with 'hands-on', small-scale research projects where practitioners wish to use research to improve their practices, who identifies the following characteristics:

- *Practical:* aimed at dealing with real-world problems in organizational settings.
- *Change:* specifically geared to changing current practice.
- *Cyclical process:* a process of research in which the application of findings and an evaluation of their impact on practice become part of a cycle of research.
- *Participation:* practitioner's active participation in the research process is crucial.

The participants in the action research shall comprise members of the Sisk bio-pharma management team to include the divisional director, two senior contracts managers and three project managers, all of whom are presently engaged in the construction of multi-million euro cleanroom projects throughout Ireland. The research will be conducted jointly by the authors, one of whom is a project manager in the bio-pharma division, the others being academics. A three-stage approach for the first cycle of research will be adopted as follows:

1. **Interviews:** prior to the acting stage of the research, interviews will be conducted with all practitioners on an individual basis. The aim of these interviews is to identify the key areas surrounding the procurement and construction of cleanrooms through management contracting. The design, construction, commissioning and validation of cleanrooms will be explored with particular emphasis on project and process knowledge. Management contracting will be evaluated in terms of its effectiveness and how its delivery can be improved.
2. **Knowledge Exchange Seminar:** the findings of the interviews will form the basis for a knowledge exchange seminar where all aforementioned members of Sisk's bio-pharma management team will meet in a face-to-face environment. This will be the first time that such a session will have been attempted within the company, with a focus group being used as a framework for this seminar. According to Litosseliti (2003: 1), focus groups *"are small structured groups with selected*

participants, normally led by a moderator. They are set up in order to explore specific topics, and individuals' views and experiences, through group interaction." The focus group shall be moderated by the academic researcher, who in consultation with the practitioner will devise a suitable agenda based on the interview findings. To generate discussion, the practitioner will make a presentation about his current cleanroom project to the other participants. This seminar shall be video-taped to allow observation by the practitioner at a later stage for more detailed analysis.

3. **Questionnaire:** all participants will then be given an opportunity to reflect upon their learning at the knowledge exchange seminar by completing a questionnaire. The purpose of this is two-fold, firstly to consolidate learning from the focus group and secondly, to evaluate the effectiveness and future potential of the knowledge exchange seminars.

Based on this first iteration of action research, the need to follow-up with further knowledge sharing activities will be assessed, hopefully leading not only to change, but a cyclical process of improving knowledge sharing within the bio-pharma division.

CONCLUSIONS

Having explored issues related to the procurement and construction of cleanrooms there are a number of conclusions which can now be drawn:

1. The biotechnology, pharmaceutical and medical devices sectors are significant growth areas for the Irish construction industry, all of which require the procurement and construction of cleanrooms.
2. Cleanrooms are complex facilities presenting significant challenges to contractors at all stages from design and construction through to commissioning and validation.
3. John Sisk and Son, the leading building contractors in Ireland have recently established a bio-pharma division to consolidate their position as leader in the area, yet interaction between its projects is somewhat limited.
4. The management contracting procurement route, which is popular with many of Sisk's clients provides the opportunity to bring their experience to bear at the early stages of complex cleanroom projects.
5. The application of knowledge sharing practices within Sisk's bio-pharma division has the potential to consolidate the learning and experience of its management team, thus improving the delivery of such projects, and indeed the opportunity for repeat business.

While the proposed research is very narrow in focus, it is hoped that the adoption of action research will lead to change in addressing the sharing of knowledge within Sisk's bio-pharma division. Furthermore, the outcomes of the research will add to the growing body of knowledge on KM practices in construction organizations.

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