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Information in engineering and construction organisations: what is it worth?

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SYNOPSIS

The management of information in engineering and construction organisations is facing a challenge due to the ever-increasing volume of information needs to be dealt with**.** This paper addresses the problems of information overload and value in the construction and engineering industries. Based on some exploratory studies on major engineering and construction organisations in the UK, major challenges in the current information evaluation practice in these two industries were identified. A through-life Information Evaluation Methodology (IEM) is proposed at the end to allow high value information to be easily retrievable in the future in order to support through-life knowledge and information management (K&IM) practice.

1. INTRODUCTION

The UK construction industry has more than 250000 firms employing 2.1 million people. Its output is the second largest in the EU and contributes about 8.2% of the nations GVA (Gross Value Added) (BERR – formerly the DTI 2007). The UK aerospace industry has more than 3000 companies employing around 150000 people directly and 350000 indirectly through some of their contractors and consultants in the UK and adding about £8 billion annually to the value of economy in the UK (DTI 2003). The UK construction industry is set to capitalise on the 2012 London Olympics. The Aerospace Innovation and Growth Team's vision is that by 2022 "The UK will offer a global Aerospace Industry, the world's most innovative and productive location, leading to sustainable growth for all its stakeholders". (DTI 2003). These long-life products (e.g. a building or an aircraft) have the propensity to generate very large amounts of information and knowledge within their life cycles. Besides, the life cycles are actually extending because of several reasons such as:

a. product to service shift, e.g. the emergence of fleet service agreement from Rolls Royce that reduces the risk and cost of long term service and maintenance events by a fixed cost per flight hour and this in turn increases the chance for an engineer to track the history of a similar design;
b. the influence of different contracting system such as private finance imitative (PFI). It repositions the supply chain and produces an invisible pressure to deliver better solutions to the clients and the customers; and
c. technological innovations. They change the format of information and often result in more complicated project information or knowledge management tools whilst this can provide information to an individual more easily and quickly (e.g. Web 2.0, emails on Blackberry, RSS feeds, instant messaging, collaboration tools, content management portals, e-library). Also, the diversity of understanding of the use, capture and reuse of information, information system and knowledge management creates a culture that inhibits employees' capability and full functioning of the adopted systems in an organisation.

Obviously, either too much or too little information can be damaging to the performance of individuals, organisations and systems. What people are really look for are the value of information but not the information itself. Current systems have little or no regard for the value of the information they contain. Information is rarely recorded in a way that facilitates the valuation of a document, either when it is produced or subsequently retrieved and re-used. In addition, there is a wealth of tacit personal knowledge that, if codified into documentary information, could prove valuable to operators of the finished asset or future designers. From the strategic point of view, there is a lack of information evaluation tools that quantify the benefits and costs of performing information evaluation activities and the effects on storage (e.g. how they save time and money from a business point of view). As projects draw to a close, some organisations are now asking what information is worth retaining and how might it be reused.

This paper identifies current approaches to information evaluation. This follows a review of information overload and the differences between data, information and knowledge. We highlight the overall knowledge and information practice and its associated challenges from a number of engineering and construction organisations and specifically how to value information. In particular, the findings of the case studies provide answers to the following questions:

a. How do engineering and construction organisations organise information storage and retrieval?
b. Do they keep the most valuable stuff?
c. Is knowledge being lost as fast as it is acquired?
d. Can an evaluation strategy help and what might it look like?

1.1 Information and its Value

Information has its own intrinsic value and can be viewed as an asset of a corporate body when this value can be leveraged. In this information age, the approach of many organisations is to gather all information regardless of cost; much is often not useful, leading to information wastage, traffic, and a cost burden. It is becoming necessary to understand the value of the ever increasing amounts of information acquired by individuals and corporate bodies. This is not solely for the obvious financial reasons (e.g. excessive investment in information and communication technology, and high maintenance and storage costs), but also because of limitations in storage capacity (especially paper), restricted processing capabilities and lack of scanning facilities. Surveys revealed that 80% of information filed has never been used (INC. 2003) and that knowledge workers spend 60 % of their time looking for information (McCampbell et al. 1999). A study reported that 73 per cent of construction projects are over budget and 50 per cent of errors are due to bad information (CIO 2007). More recently, an online survey that is done by 1,009 managers at U.S. and U.K based companies to get the insights on the way they collect, use and evaluate information. The report said

> '……managers spend up to two hours a day searching for information, and more than 50 percent of the information they obtain has no value to them…...' (Accenture 2007)

Figure 1 shows a modified relationship from Eppler and Mengis (2004) between the value of information and overload, where the later results in a net decrease in the quantity of valuable information that a person or system can deal with.

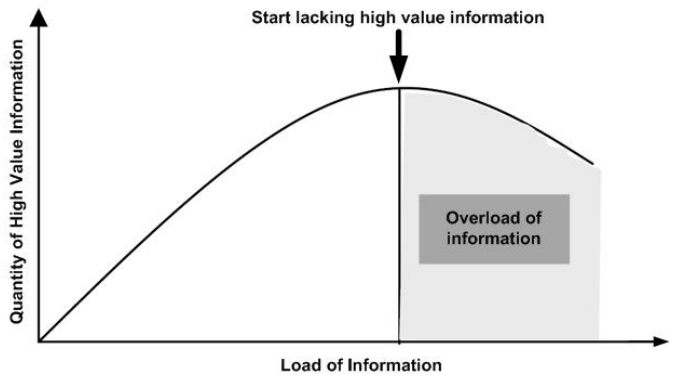

Fig. 1 Information overload phenomenon

Besides the problem of information overload, valuable knowledge is being continually lost as staff leave - 70% of the senior working population will retire within the next 4 years in most developed countries (Douglas 2003). Even when information and knowledge are captured and recorded, it can be difficult to retrieve relevant elements. It has been recognised (Al-Hakim 2007) that effective methods are needed to value information characteristics (e.g. accuracy, completeness, timeliness, currency and trust level) at appropriate stages in the information cycle. A variety of metrics and empirical methods may be required to avoid information overload, to retain the correct information for reuse, and to identify the history and context to give it subsequent meaning; that is to maintain high value information especially in the design of future information systems and knowledge management tools. All this begs the inevitable question of what we mean by value. Thomson et al. (2003) argued for clarity, especially when a variety of stakeholders are involved. They developed the VALiD approach

to help deliver stakeholder value, especially in the design stages, in which the ***trade-off between benefits, sacrifices and resources is considered***. There is a need to be able to value information, including its contribution to, and consumption of, an organisation's resources, i.e. its potential benefits and the cost of acquiring and maintaining it.

2. SITUATIONS IN UK CONSTRUCTION AND ENGINEERING COMPANIES

This research identified current approaches to information evaluation. Studies have also been conducted in five construction companies (annotated as C1, C2, C3, C4) and three engineering organisations (annotated as E1, E2 and E3), involving a total of 28 structured interviews from three perspectives: business, project management and IT/document management that were carried out with a template of 35 questions covering:

a. Demographics: including questions about the background and position of the interviewee;
b. Information definition and classification: including questions about the types of information the interviewee deals with and information systems the interviewee uses on an everyday basis;
c. Information evaluation methods: including questions about the methods, procedures, criteria, and other aspects of information evaluation that the interviewee uses to make judgement on information value;
d. Knowledge management approaches: including questions related to knowledge sharing, management, and transferring from the interviewee's perspective; and
e. Final considerations: the biggest challenge in knowledge and information management the interviewee is facing.

However, the details of data are not presented here. This seminar paper highlights the overall knowledge and information management (K&IM) practice and the major challenges on information evaluation practice based on an overall observation on the case study companies.

2.1 Current K&IM Practice

Figure 2 shows the overall K&IM practice in the case study companies. A common framework can be drawn from their current ICT infrastructure, systems, culture and the way that people work on a day-to-day basis. IT tools form two parts of the time, effort, and money that is required to develop and use the KIM infrastructure. The hardware includes databases, networks, servers, communication systems, phone and PDA, personal PCs, shared drives and physical archive, whilst typical software tools support data and document management system, process management system, intranets, extranets, protocols, share point, wikis, blogs, email, yellow page, web 2.0, SharePoint, XML tools, and intelligent decision support systems. The remaining part is the people, which includes auditors, project leader (for most of the time, he/she makes decision to evaluate the value of a document after project finishes), knowledge / IT managers, collaboration tool champion, document controllers, librarians, archivists, everyone's responsibilities (enforced by official guideline such a an archiving policy and self-motivation), face-to-face interaction, brainstorming, post-project review, lessons learnt, and communities of practice including discussion, meeting, and team working.

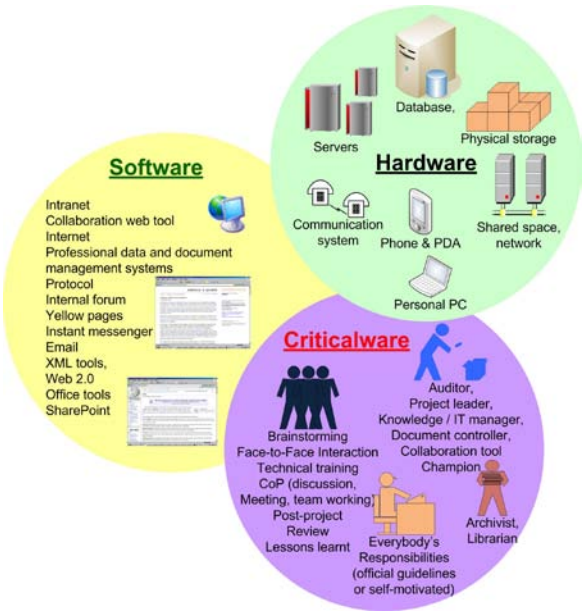

Fig 2 Overall K&IM practice in both industries

2.2 Information Storage and Retrieval Strategy

Information sources are multi-dimensional and scattered in both companies. The current ICT infrastructure, information storage and archiving policies in these types of construction organisations lead to the following storage, disposal and retrieval phenomenon. Based on the overall KIM practice, all the companies have three strategies: accessibility inclined, people networking and archiving oriented. It is an ad hoc approach that depends on whether people have got the time to do it. Because of the nature of business, nature of products, scale, culture and history of the organisation, scatterness of offices, and their resources on investing ICT and knowledge management, they are mostly having their own inclined information storage and retrieval strategy out of these three strategies at the time of the study (figure 3).

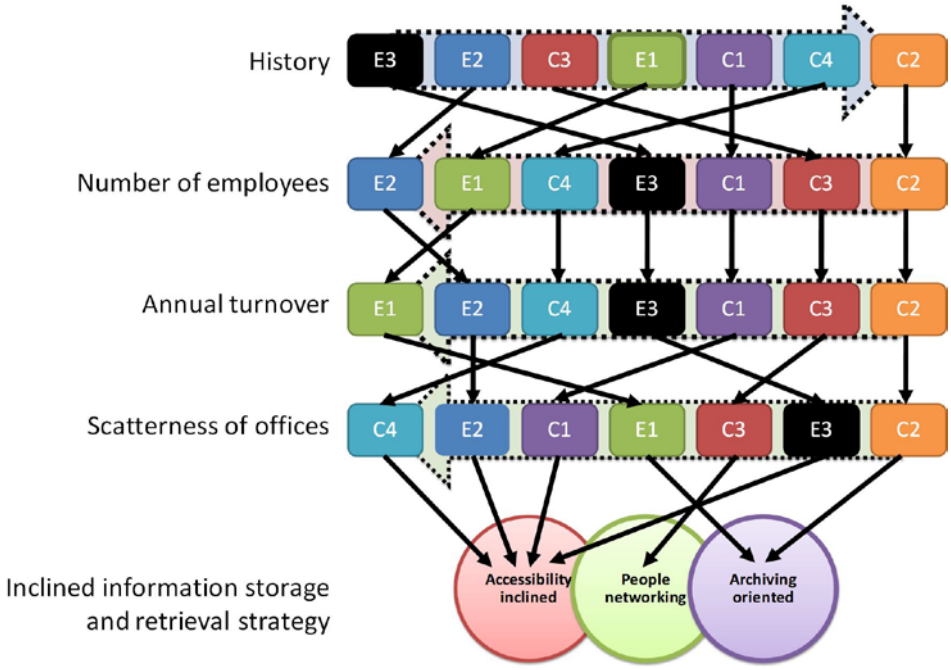

Fig 3 Information storage and retrieval inclined strategy in the companies and their backgrounds comparison

2.3 "Storing everything" Culture

In construction organisations, based on legal obligations, company archiving policy, only signed documents are kept as paper documents for a period of time (e.g. 12-20 years), minimizing physical storage (see table 1). After this period, the legal responsibility is handed over to the other party so that the documents are no longer needed. Even every construction project is unique and the possibility of reusing information (e.g. a design of a building) is low, some interviewees also claimed that they do reuse information for cost forecast and tendering. In engineering organisations, the life time of physical storage is up to forever because of the nature and life time of the products (e.g. the failure of an airplane may cause fatal accident that the engineering company cannot bear the risk). For example, with the biggest annual turnover and second largest number of employees, Company E1 is scanning all old paper documents and scanning work has been scheduled in for the next ten years. In both industries, the storage cost is low especially for the electronic documents but the maintenance cost is increasing rapidly.

Most case study companies are questioning how much data and/or information they should store, capture and transfer, and how much investment should they make in creating and storing information by the use of IT. Based on these observations, instead of keeping the most valuable stuff, the "storing everything" culture exists in all the companies. This culture leads to the following issues in the future:

a. Most of the companies reveal that context and history are not being captured effectively by word of mouth, community of practice or an ICT system (e.g. Intranet, Extranet or a database).
b. When the evaluation activity is down to everyone's responsibilities, this self-motivated culture is not being established in most of the companies as it has been replaced by the ad hoc strategy that people tend to do it when they have got the time. Besides, it is questionable whether the storage of electronic documents on personal hard drive should be continued in the future because relying on individuals to identify information worth storing appears to be very unreliable.

c. Moreover, there may be information that is captured because of legal reasons with little value. On the other hand, there may be high value information that is not captured because it is not stated in the contract or the archiving policy.

Table 1 Physical and electronic storage situations in the case study companies

Company	Life time of paper storage	Life time of electronic storage	Reason(s)	OVERALL storage & maintenance cost
C1	Keep signed copies for 12 years	Keep everything for 6-12 years	Trust, contract and legal obligations	Increasing
C2	Keep signed contracts for 12 years	Keep everything, no formal procedure	Archiving policy & Law	Increasing
C3	Keep everything for 12-20 years	Keep everything for 12-20 years	Legal requirements	Increasing
C4	Keep contractual information for 5-10 years	Keep everything for 5-10 years	Contractual agreements, company practice	Increasing
E1	Keep everything (mostly signed documents) for 'product life time+6 years' to as long as possible (e.g. 99 years)	Keep everything for 'product life time+6 years' to as long as possible (e.g. 99 years)	Law & life time of the products	Increasing
E2	Keep everything (mostly signed documents and final reports) for 5 years to forever	Keep everything for 5 years to forever	Law & life time of the products	Increasing
E3	Keep versions for legal, product and financial information for more than 30 years	Keep versions for legal, product and financial information for more than 30 years	Law & life time of the products	Increasing

2.4 Losing Corporate Memory

Knowledge creation mechanism: The "embedded knowledge" is one of the biggest assets of these companies. There have been discussions that high value information creates more useful knowledge (Tang and Nicholson 2007). According to the theory of knowledge creation (Nonaka and Takeuchi 1995; Rao 2004), there are four ways of transferring implicit (refer to tacit in the original model) and explicit knowledge, namely:

a. by socialisation, implicit knowledge of an individual can be transferred to implicit knowledge of another individual (e.g. webcams, videoconferencing, virtual reality tools) - this is achieved for example by instant messenger, discussions, workshops, start up and project review meetings in the case study companies;
b. by externalisation, implicit knowledge of an individual can be transferred to explicit knowledge (e.g. PSP networks, expert systems, online CoPs) - this is carried out for example by meetings, PSP networks, CoPs, forums, best practice and report sharing in the case study companies;
c. explicit knowledge is transferred and stored as implicit knowledge for example by internalisation (e.g. knowledge databases, E-learning, visualisation) through trainings, lesson learnt databases in the case study companies; and
d. explicit knowledge is transferred for example by combination (e.g. abstracting, classification and clustering) using company intranets, extranets, collaboration tool, SharePoint, data and document management systems, software and personal PCs in these companies.

Losing valuable knowledge: Normally, the interviewees said the IT manager/knowledge manager/collaboration tool champion tries and goes around the sites and company in order to encourage people to capture whatever they see that is different, new or has been done in a way that it is best practice, capture it and they will publish it. However, there are several reasons in these engineering and construction organisations that make the corporate losing knowledge.

a. **Poor knowledge recognition:** Sometimes it is very hard to stand back and capture what they have done as people always forget to do it or do not realise they have got the knowledge.
b. **Knowledge hoarding:** In some companies, people do not want to share as knowledge is power and it is difficult to break down this barrier.
c. **Knowledge walk-out:** Current strategies are not sufficient to tackle the problem of losing knowledge. Knowledge is being lost as fast as it acquired. The project teams are dismantled when a project is

finished and the senior management people will retire one day. If there is insufficient leaving notice and the succession planning does not work well, the knowledge of these staff is rapidly lost.

Interviewees in both companies confirmed that knowledge loss is a major problem. This results in a low corporate memory that slows down its response to the global environment and reduces its competitiveness. As discussed above, information evaluation is solely based on individual judgement and there is no scientific tool to increase the quantity of high value information for future reuse and to support through-life products. How much information and knowledge can an employee capture and transfer? How much information and knowledge can a newcomer receive (assuming that the archiving works well on data/information storage)? What is lost at the same time? Needless to say, the benefits of evaluating information are equal to zero at the points of information creation and storage but the potential benefit could be very large if they could retrieve valuable information in the future.

3. A SUGGESTED EVALUATION STRATEGY

An overall solution proposed by some companies is to use technology to drive the company, and accompany any transition from product to service or vice versa, by capturing the correct knowledge in the right format to support reuse. For example, a global collaboration system for all information for each sector (e.g. residential and commercial) would be a quick and efficient way. However, accessibility to relevant information/explicit knowledge cannot be solved by ICT systems alone. ICT and improving staff retention and knowledge sharing (e.g. by reward, by knowledge sharing facilities such as a knowledge cafe) are proposed also to solve the above issues but this will not necessarily tell them how to evaluate data, information and/or knowledge. Furthermore, what information should be kept in the shared space, should people still use the personal drives to store company information, what should be sent to archive, and what should be kept in a document management system?

These findings raise a number of research questions that affect the design of an information evaluation method possibly based on a ***value trade-off of "benefits - what you get" and "sacrifices - what you give"***, in which each stakeholder has a unique perspective (Thomson et al. 2006):

a. Documents are stored for legal reasons, for up to 12 years normally in construction organisation or forever in engineering organisations (perceived now to be low value despite its intrinsic value).
b. The storage cost of information is decreasing but the management cost is significant. Can/should a person or a firm throw some project information away except where there is a legal obligation?
c. The introduction of 'tags' may make it easier to retrieve valuable information from project information sets. Should a person or a firm tag what is perceived now to be high, and structure it to be easily accessible in the future?
d. The automated addition of some value criteria (e.g. length of use/viewing of a document) by a search engine or database may assist evaluation. Should a firm identify major search engines to see how they may identify these criteria and search for their electronic information?
e. Should a person or a firm increase the amount of recorded and/or shared contextual or rationale information by recording details of events across all phases of a project from development, construction/manufacturing, operations and maintenance? If so, what is perceived now to be of high value in the future?

4. CONCLUSIONS

It is clear that, if these companies are representative of the construction and engineering sector, a common situation facing practitioners is to have either too much or too little information to hand when undertaking many day-to-day activities. This paper presents and highlights some of the main findings of our case studies. It shows that an overall KIM practice (including hardware, software and criticalware) is being adopted in these two industries. Three main information storage and retrieval strategies were adopted while these companies had the preferences for one of the strategies; two companies are archiving orientated, four are high accessibility inclined while the remaining one is people networking inclined. Information overload exists in all the companies because of the current ICT infrastructures, 'storing everything' culture, and the nature of business and products. Too much information leads to a lack of high value information that makes decision-making difficult and reuse in the future highly unlikely. The valuable knowledge of experienced staff is not readily captured when they leave the company because of changing job or retirement.

With the constraints of time and money, the return on investment of collecting additional information cannot be easily quantified and justified. Even if storage costs are decreasing (per GB), the costs of acquiring relevant / high value information and maintaining it within a sophisticated ICT system are increasing. However with business search engines and collaboration tools improving, like Google business search (Google Corp.), Autonomy (Autonomy Corp.), FAST search (Fast Search & Transfer ASA.), Union Square (Union Square Corp.), finding information in storage is easier than it used to be. One possible solution, (being investigated by these companies), is to use SharePoint from Microsoft Corporation to manage, share, and archive all information generated in their work. However, this software has not been implemented fully yet not only because of its functionality but also the cost (as most companies especially the SMEs e.g. companies C2 and C3 cannot afford to buy it). Putting a value tag on searched information would increase the usefulness of the information found. Evaluation strategy is thus useful not only identifying the high value information which contain valuable knowledge, but can also make it more efficient when searching and retrieving information. An overview is an evaluation engine is attached as a part of search engine. The search engine finds the relevant information and value engine gives the value number based on the searcher's profiles and other context metadata.

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