"KNOWLEDGE AND INFORMATION EVALUATION PRACTICE – AN EXPLORATORY STUDY IN A CONSTRUCTION FIRM"

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ABSTRACT

There are a number of challenges associated with managing knowledge and information in construction organizations delivering major capital assets. These include the ever-increasing volumes of information, losing people because of retirement or competitors, the continuously changing nature of information, lack of methods on eliciting useful knowledge, development of new information technologies and changes in management and innovation practices. Existing tools and methodologies for valuing intangible assets in fields such as engineering, project management and financial, accounting, do not address fully the issues associated with the valuation of information and knowledge. Information is rarely recorded in a way that a document can be valued, when either produced or subsequently retrieved and re-used. In addition, there is a wealth of tacit personal knowledge which, if codified into documentary information, may prove to be very valuable to operators of the finished asset or future designers. This paper addresses the problem of information overload and identifies the differences between data, information and knowledge. An exploratory study was conducted with a leading construction consultant examining three perspectives (business, project management and document management) by structured interviews and specifically how to value information in practical terms. Major challenges in information management are identified. An through-life Information Evaluation methodology (IEM) is presented to reduce information overload and to make the information more valuable in the future.

KEY WORDS

construction, information evaluation, information management, knowledge management.

INTRODUCTION

Information has its own intrinsic value and can be viewed as an asset of a corporate body when its invisible value is leveraged. In this information age, individuals and corporate bodies acquire ever increasing amounts of information, and it is becoming necessary to understand the value of information. This is not solely for the obvious financial reasons (e.g. too much investment in information and communication technology, and high maintenance and storage

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costs), but also because of limitations in storage capacity (especially paper storage), restricted processing capabilities and lack of scanning facilities. Through-life activities have the propensity to generate large amounts of information and knowledge, and either too much or too little information can be damaging to the performance of individuals, organisations and systems. This can result in low productivity and stress leading to information fatigue syndrome (Oppenheim 1997). In particular, there is a failure to learn from previous experience because the information has not been captured or it is not readily retrievable in a meaningful context. The latter may be confounded by being lost amongst all the less useful and valuable data and information. Besides the information overload problem, 70% of the working population will retire within the next 4 years in most developed countries (Douglas 2003). In the design of future information systems and knowledge management tools, it is important to be able to classify what is essential to retain.

This paper identifies current approaches to information evaluation. This follows a review of information overload and the differences between data, information and knowledge. An exploratory study within a leading construction consultant is presented examining three perspectives (business, project management and document management) and specifically how to value information. We describe the lessons learnt in a number of areas, including information systems, information sources, information criterion, information evaluation, information storage, knowledge management techniques and technologies and knowledge transfer. Finally, knowledge and information (KIM) research questions are outlined in relation to the development of a through-life Information Evaluation Methodology (IEM) based on a value trade-off of "what you get" and "what you give" in which each stakeholder has a unique perspective (Thomson et al. 2006).

INFORMATION OVERLOAD

Construction industries are becoming more dynamic in nature due to the diverse and complex nature of work tasks, trading relationships, environments, as well as the temporary and transitory nature of workplaces and workforces. At an operational level appropriate and timely information is critical to the success of a project, and in particular the design process. Typically, a design process uses as well as generates large amounts of information during its execution (Thomson et al. 2003). However, the approach of many organisations has been to gather all information regardless of cost; much is often not useful, leading to information waste and a cost burden. A survey (Inc. Staff 2003) revealed that 80% of information filed has never been used. Another survey found that knowledge workers spend 60 % of their time looking for information (McCampbell 1999). The problem of information overload is becoming crucial as technologies such as search engines develop apace (Feather 1998) and personal, organisational and customer issues (Edmunds and Morris 2000). Furthermore, it has been widely reported that the performance of an individual or an organisation can be detrimentally affected by too much information (Butcher 1995, Elpper and Mengis 2004).

In the UK construction industry, there are a number of challenges associated with managing information and knowledge in delivering major capital assets. There are the ever-increasing volumes of information and knowledge, the loss of people because of retirement or competitors, the changing format of information, lack of methods for eliciting useful knowledge, development of new information technologies, and changes in management and innovation practices. These sit alongside a shift from product delivery to through-life service support most notably as a result of the government's private finance initiative (PFI). Information is rarely recorded in a way that facilitates the valuation of a document, when it is either 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. There is thus 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. An effective evaluation method should help to avoid information overload, retain the right information for reuse, and identify the necessary history and context in order to give information subsequent meaning.

UNDERSTANDING DATA, INFORMATION AND KNOWLEDGE

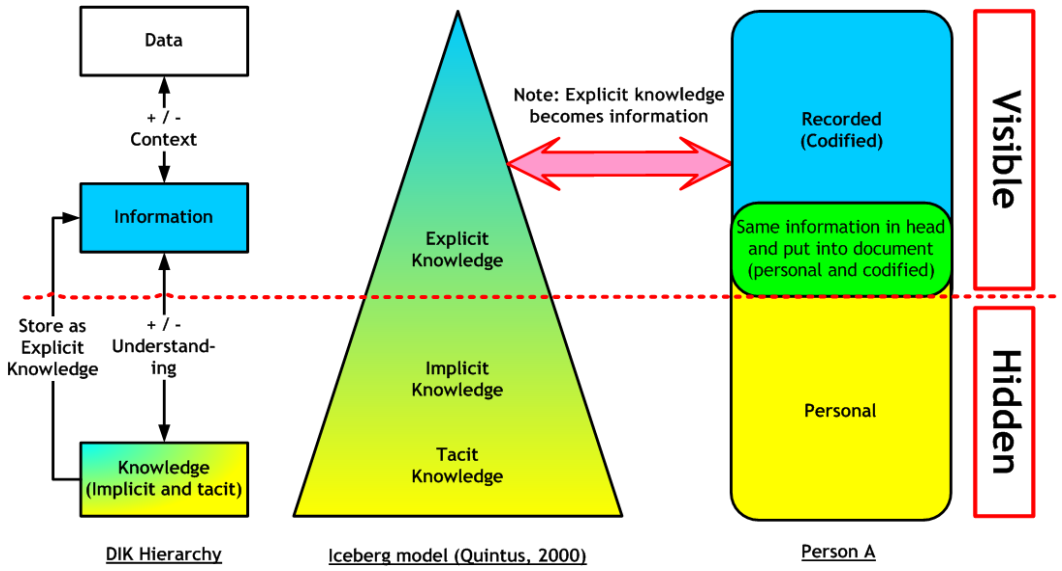
In the literature, there are many definitions to distinguish data, information and knowledge (call a DIK hierarchy). Data is "facts, statistics, that can, frequently, be analysed to derive information" (British Standards Institution 2003). Information is "the descriptive content of a message which allows a change in through interpretation". The message may be transmitted via any of the senses (Bruner 1990). Wiig (1993) defined information as structured fact to express a situation while knowledge is truth, belief, perspective, concept, judgement and expectation. Nonaka and Takeuchi (1995) defined information as a flow of a meaningful message while knowledge is commitment and belief produced from a message. Choo et al. (2000) defined data as facts and messages, information as meaningful data and knowledge as true belief which is justified. Hicks and Culley (2002) undertook an extensive review on the relationship between the data, information and knowledge in the engineering design domain. For that purpose, "data is considered to be structured and represent a measure such as quantity; and information is defined in two classes: formal information (provides a specific, structured context and measure) and informal information (encompass unstructured); and knowledge is combined with knowledge inferred from information through a knowledge process". Polanyi (1966) defined tacit knowledge as personal, context-specific and rooted in an individual's actions, values and insights and defined the knowledge dimension as tacitness and explicitness. Knowledge is a cumulative understanding of the information and data in the specific context of an application (British Standards Institution 2003). Anumba et al. (2005) suggested that experiences of construction professionals are based on a balance between explicit and tacit knowledge in different phases of a project and they are interchangeable by different kinds of codification methods. However, there is no single agreed definition of knowledge since the emergence of knowledge management a decade ago. It is commonly referred to Plato's "justified true belief" (Plato 1953) or the appropriate collection of information, such that its intent is to be useful.

Figure 1 shows a DIK hierarchy. The hierarchy consists of three stages (Tang et al. 2006): data can be numbers, characters, symbols or images (statements taken at face value), information (interpreted data or data with context that inform) and knowledge (information with understanding that may be facts, feelings and truths that make up what is known). Knowledge can be explicit (recorded in some way), tacit (in the mind) or even implicit (cannot be recorded and codified in any format). Explicit knowledge can be stored as information.

An iceberg model (Quintus 2000) further illustrates their differences. The model divides knowledge into explicit, implicit and tacit. Explicit knowledge (above the surface) is visible while both implicit and tacit knowledge (under the surface) are hidden. The iceberg may be 'raised' exposing some of the 'implicit' knowledge, but not the tacit. In the context of the research presented herewith, techniques to 'surface' implicit knowledge of a person (e.g. person A in figure 1) include after action reviews, in which he/she may express learning that has taken place but which previously they have not expressed, or even acknowledged formulated internally. Explicit knowledge that is codified (recorded in some medium; paper, electronic for instance) is available therefore as information. It contains the same information partly in the head of person A, flows through messages to other people and can be formalised in databases, books, manuals and documents. The evaluation of explicit knowledge is in a

corporate level carried out on an recorded information or knowledge asset of the company. Implicit knowledge is uncodified (not expressed) but could be. It cannot flow between minds but can be articulated selectively by abstraction and codification. Tacit knowledge that is inherently difficult or impossible to codify, especially knowledge requiring experiential learning, cannot be communicated to others (shared) from person A to the other person. The evaluations of these kinds of knowledge are in personal levels carried out on a piece of information in respect of a current or predictable information need.

Figure 1: Understanding Data, Information and Knowledge



In a construction organisation, data can be for instance structural, material or cost data. Information can exist on a paper or be stored electronically (such as emails, building regulations, specifications, standards, manuals, costs, contracts, minutes, reports, variation orders, programmes and drawings) or in what can be thought of as an intangible state (such as decision-making process and judgment, or even processing to knowledge stored in people's brains - first called tacit knowledge in 1970 (Kuhn 1970). During concept design much knowledge stays in people's head, whilst in detailed design much implicit/even tacit knowledge is transformed to information in detailed drawings and specifications.

AN EXPLORATORY CASE STUDY - A CONSTRUCTION CONSULTANT

The research identified current approaches to information evaluation. This followed an extensive literature review of information value, classification and valuing methodologies from different viewpoints including supply chain management, Value of Information in risk analysis and decision-making support in project, business management, financial, accounting and librarian domains. A number of exploratory studies have been conducted with four construction and three engineering organisations examining three perspectives (business, project management and document management) and specifically how to value information. A total of 25 structured interviews were conducted with a template of 35 questions.

This paper presents the exploratory study of a construction consultant. The case study firm was established over 90 years ago and is a leading global company providing professional services in quantity surveying (QS), building surveying, project management, building surveying, management consultancy, software development and facilities management in the real estate, infrastructure and construction sectors. It has 40 wholly owned offices in over 20 countries employing over 3,000 people with an annual Group turnover in excess of £200

million. The first person was a quantity surveyor mainly in contractors, now works as a cost consultant in this firm for 5 years. The second person, who worked for construction consultants mainly, has been now a senior cost consultant in the firm for 3 years. The last person worked in a company involved in the public sector using traditional QS practice to deliver school and hospital for 14 years, now is a partner to deal with clients, the market and team management in order to deliver better services to the clients after being a Project Manager and an Associate in the firm.

CURRENT KIM PRACTICE

Tables 1 and 2 summarise the current practice in KIM in the construction consultant. In the table, a number of systems are used includes a cost planning system, spreadsheet, programming software and an Intranet called the Service Delivery System (SDS). SDS includes British standard templates, valuation certificates, practical completion certificates, meeting agendas in various stages of the project, technical indexes, construction programmes and information standards that are provided to the clients and users. The Intranet supports many of their project processes. The company wishes to extend it to a global system. In general, three main high-level systems and online collaborative working tools that the firm is using are:

(i) a '_on' series that fits individual client's requirement and manages the process from inception to completion;
(ii) the Internal Intranet (SDS); and
(iii) a Residential Efficiency Database (RED) which is available on the Intranet, used to capture various stages of cost information, supports design work and maximise the value for the client.

Table 1: A Summary of Information Management in the Construction Consultant

	Information Management (IM)				
	System	**Source**	**Criterion**	**Evaluation**	**Storage**
Document Management	Intranet called Service Delivery System (SDS), Cost planning and other software	Emails, cost research database and other materials (e.g. building magazine)	Accuracy, Relevance, Trust level, Up-to-date	Judged by an individual when projects end, clean up and send necessary information to archive	Paper in archive, electronically stored for 6-12 years. Cost issue remains an unknown
Project Management	SDS	Word of mouth, Intranet and Internet	Accuracy, Up-to-date, Location	Internal issue: trustful	Scan all signed hardcopies for 12 yrs. Cost is increasing
Business	'_on', SDS, Residential Efficiency Database (RED)	RED, Word of Mouth	Accuracy	Maintain standard input consistently when generating information; use gateway keeper	Cost is increasing

Table 2: A Summary of Knowledge Management in the Construction Consultant

	Knowledge Management (KM)		
	Technique	**Technology**	**Knowledge Transfer**
Document Management	Cost Research Department obtains cost for various tasks and locations	Building Cost Information Service (BCIS)	Learning and discussion
Project Management	Capturing knowledge when every project ends, making input someone who is in charge of RED	Forums	Discussion
Business	Make it as a rule that everyone makes his/her contribution to RED from each project	RED where it is updated every 6 months, a cost information booklet	RED, Meeting

From a document management perspective, employees use daily email for questions and responses (personal but mainly at a corporate perspective). They also use cost research databases such as building cost information services (BCIS) (personal but mainly at a corporate perspective) and information from building magazines (personal perspective but some useful information is extracted for the corporate perspective). Staff do not have any training on using the Intranet (SDS), but learn from the job and colleagues. In general, everyone has the responsibility to enrich the Intranet. There is a Cost Research Department obtaining the cost per square metre for various tasks and locations and the data are presented in a booklet. Building cost information services (BCIS) and the booklet are major information sources. However, it is difficult to capture all the relevant information as people are "workshopped" out after the project and knowledge is lost.

From a project management perspective, most information comes from the Intranet, email, word of mouth and internal discussions through a residential sector forum that has a KM function, maintained by IT people in London. There are also forums for cladding materials and mechanical installations. The top three information sources, identified by the interviewees are: word of mouth to find out the solution or the people who knows the answer; the Intranet; and the Internet. They were viewed as equally important at both the personal and the corporate perspectives. Information is captured and classified based on the information type (for example, cost information). Everybody in the residential sector has to manage the cost database (i.e. RED), by inputting information such as the nature of the tendering process and the market environment. It is assumed that new staff have the knowledge to manage a cost database. Everybody has access but only a few authorised people have to check and authorise the information. This is one of the main KM techniques. It is often difficult to interpret information because the context or history is unknown. Knowledge is transferred by word of mouth, when intangible and contextualize information can be transferred. The firm has one expert in each sector to capture and store information and they meet once a quarter to enrich the database in England. There is no difficulty in accessing the RED cost database by the offices outside the UK.

Similarly, from a business perspective, it was believed that RED enables comparisons of the market price for a particular building, presented in a graphical format and thus the history of the price fluctuation could be shown and compared. The practice of assuming that everybody will capture relevant information and update the appropriate database appears to be a common key strategy. The electronic archive (it is still easy to access) is updated every 12 months and the Intranet is updated every quarter, which is the same as the BCIS service.

INFORMATION EVALUTION AND STORAGE

Document manager perspective: The legal obligation of the firm is to keep project data for 12 years. In document management terms, staff use the following criteria to judge the quality of information (in descending order): *accuracy, relevance, trust level and up-to-datedness*. It is notable that accessibility was not perceived to be an issue.

The storage cost of information was unknown. Papers and files are stored in an archive outside the office. However, the firm does not have a person to make judgements on the things that are worth retaining. Normally, each person decides after the projects, cleans up the files and sends the useful information to archive that is then available for the next project. Contingencies are adopted in a cost planning process that was good enough to deal with intangible things such as the uncertainty of a decision-making process.

Project manager perspective: The firm does not have a proper library but all signed hardcopies are scanned and kept for 12 years. From a project management perspective, the following criteria are used to judge the quality of information (in descending order): accuracy, up-to-datedness, location (newly added), relevance and context. It was explained that cost information had to be up to date. Also, trust was not an issue as they assumed that the internal database was trust-worthy; however, it would be an issue for an external one. If a project requires specialised information, historical information is likely to be reused. Investment would be needed to develop a sophisticated database in which the storage of valuable information is governed by the user. It was believed that storage and acquisition costs were increasing and intangible things such as uncertainty would be solved by trusting the providers of information to produce accurate data.

Director perspective: At a business level, it was extremely important to collect all the necessary knowledge and information from a project to improve the company's knowledge database. The only information characteristic that was taken into account was accuracy. Regarding the quality of information, the firm requires and trains staff to have a standard input format to achieve consistency of data. This is the first quality filter. A gateway keeper checks the information to be put on RED, the second quality filter. Before finalising the cost, a senior person goes and talks to a suitable person who is an expert in a sector on cost data. It would be worthwhile employing people to build a user-friendly prototype system to deliver information in the short term but the cost of maintaining the system would be substantial. It was believed that uncertainty is not a concern given the factual nature of information that the firm produced.

Valuable information is unique and one cannot capture everything, especially in the construction industry in which a project is dynamic in nature. It is not easy to change the nature of the raw data. Based on the feedback from staff who have used the data, it is easier if staff change the way valuable data is made available for different levels of use for instance. Clients change and the firm has to keep a step ahead, otherwise, useful information will be captured by competitors who may have high-level information and knowledge capture technologies or strategies However, there is no strategy (e.g. by rewarding people) to turn information into a capital asset. It was suggested that valuable ideas could be found by sharing experiences in a 1-2 hour meeting, from which papers could be published on things that could affect construction cost and regulations.

OVERALL KIM CHALLENGES

From the document and project management perspectives, the biggest challenge in KIM is capturing the right knowledge in the right format to support reuse. The case study's firm knowledge management strategy is not totally compatible with capturing valuable information to support future projects. There is also insufficient time to go undertaken the

KIM process thoroughly. From a business perspective, the greatest challenge would be to resource the creation of a global knowledge system to capture every piece of valuable information for all the sectors (e.g. residential and commercial) in a quick and efficient way. This would need to address the key issues of context and history, information storage and disposal and the loss of knowledge as people leave the firm.

The IT infrastructure, information storage and archiving policies in these types of construction organisations result in the following unanswered questions:

1. Context and history - Are these currently captured effectively by word of mouth, community of practice (e.g. users provide feedback, experts in sectors meet regularly) or Information and Communication Technology systems (e.g. Intranet, Extranet, a database)?
2. The "Workshopped out" problem - relying upon individual judgement to make decisions about retention of valuable information is risky. How much data should he/she store and how much information and knowledge can he/she capture and transfer? How much information and knowledge can a newcomer receive (assuming that the archiving works well on data storage)? What is lost at the same time?
3. The long term problem – this is the biggest challenge. 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 information and maintaining it in a sophisticated ICT system are increasing. An overall solution proposed by the firm is to use technology to drive the company and to accompany any transition from product to service or vice versa by capturing the right knowledge in the right format to support reuse. A global 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 is not solved by ICT systems alone.
4. What will be the KIM road map in the future (say after 12 years of the legal liability)? To "keep everything" appears not to be the solution to KIM. How can the firm best communicate with the people in the future in order to establish an 'immortal' system?

INFORMATION EVALUATION METHOD AND ONGOING RESEARCH

This research has raised a number of research questions that impact on the design of an information evaluation method:

1. It is noted that documents are stored for legal reasons, for up to 12 years (perceived now to be low value despite its intrinsic value).
2. 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 legal does?
3. The introduction of 'tags' might 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?
4. The automated addition of some value criteria (e.g. length of use/viewing of a document) by a search engine or database. Should a firm identify major search engines to see how they may identify these criteria and search electronic information?
5. Should a person or a firm increase the amount of recorded and/or shared information (e.g. context, rationale) e.g. a lessons learnt database by recording details of events across all the phases of a project from development, construction/manufacturing, operations and maintenance? If so, what is perceived now to be high value?

Information characteristics can represent the nature of the information and assist the measurement of information quality or value. Zhao *et al.* (2007b) have introduced an

approach to identify the key information characteristics, in which a set of common evaluation criteria were derived from the literature, namely: *Accessibility* • *Usability* • *Currency* • *Context* • *Accuracy* • *Availability* • *Relevance.* Information value can be defined as a trade-off between benefits of having information, i.e. "what you get" and costs spent on creating, storing and retrieving, i.e. "what you give". An information evaluation process model under development using a Bayesian Network Model (Zhao et al. 2007a, 2007c) which can help address some of these questions.

CONCLUSIONS

This paper addresses the problem of information overload and provides a basic understanding of data, information and knowledge in the construction industry. An exploratory study was conducted in a major construction consultant examining three perspectives (business, project management and document management) and specifically how to value information. From the case study, it can be concluded that the IT infrastructure, information storage and archiving policies in these types of construction organisations result in the following overall challenges in KIM:

1. It is difficult to interpret information when the context and history currently are unknown because they are not captured effectively by word of mouth, community of practice or Information and Communication Technology systems.
2. Relying upon individual judgement to make decisions about retention of valuable information is risky. Relevant and valuable knowledge is lost when the project team dismisses after the project or the knowledge worker retires within the next few years.
3. Even if storage costs are decreasing (per GB), the costs of acquiring relevant information and maintaining it in a sophisticated ICT systems are increasing. Besides, accessibility to relevant information/explicit knowledge is not solved by ICT systems alone.
4. To "keep everything" appears not to be the solution to KIM. How can the firm best communicate with the people in the future in order to establish an 'immortal' system?

Finally, information evaluation research questions are outlined in relation to the development of a through-life information evaluation approach based on a value tradeoff of "what you get" and "what you give" for individuals and corporate bodies, not only to avoid information overload but also to make information more valuable in the future.

ACKNOWLEDGMENTS

The contribution of the KIM project team and its industrial collaborators to the development of the research programme and thus to this paper is gratefully acknowledged. The project is funded by the UK Engineering and Physical Sciences Research Council (EPSRC) and the Economic and Social Research Council (ESRC) under Grant Numbers EP/C534220/1 and RES-331-27-0006.

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