Overload of Information or Lack of High Value Information: Lessons Learnt from Construction

Llewellyn C.M. Tang[1], Yuyang Zhao[2], Simon Austin[1], Mansur Darlington[2] and Steve Culley[2]

[1]Department of Civil and Building Engineering, Loughborough University, Loughborough, Leicestershire, LE11 3TU, United Kingdom

[2]Department of Mechanical Engineering, University of Bath, Bath, BA2 7AY, United Kingdom

C.M.Tang@lboro.ac.uk
y.zhao@bath.ac.uk
S.A.Austin@lboro.ac.uk
ensmjd@bath.ac.uk
enssjc@bath.ac.uk

Abstract: Information and knowledge are strategic assets, processed to attain objectives, perform actions and make decisions. However, technological innovations can 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. Current systems have little or no regard for the value of the information they contain. As projects draw to a close, some organisations are now asking what information is worth retaining and how might it be reused. This paper addresses the problems of information overload and value in the construction industry. Exploratory studies compared two major consultants in the UK from three perspectives (business, project management and document management). Major challenges in the current information evaluation practice in the industry were identified. Information overload does exist in the industry and is getting worse because of the heavy but often inappropriate use of search and collaborative technologies. Loss of high value information due to staff leaving is a major problem, but the companies are reluctant to evaluate recorded information (before or after storage) for future retrieval. 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. Based on these findings, a through-life Information Evaluation Methodology (IEM) has been proposed to allow high value information to be easily retrievable in the future in order to support through-life knowledge and information management (KIM) practice.

Keywords: construction, information evaluation, information management, knowledge management, value of information

1. Introduction: 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, 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. In a Reuters's survey in 1998, amongst 1,072 executives in 16 countries, 59% thought that time restricted them from obtaining the information they require. 60% did not know how to find it and 42% said they have information overload (Reuters 1998). Other 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). 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.

Long-life products have the propensity to generate very large amounts of information, 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 useful stuff being lost amongst all the less valuable data and information. 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 is captured and recorded, it can be difficult to retrieve relevant elements. Koniger and Janowitz (1995) examined the causes behind complaints made in the business world about lacking relevant information and at the same time suffering from a surfeit of information. They believe that information is only valuable to the extent that it is structured. On top of this, 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. Figure 1 shows a modified relationship from Eppler and Mengis (2004) between the value of information and overload, where the later results in a nett decrease in the quantity of valuable information that a person or system can deal with.

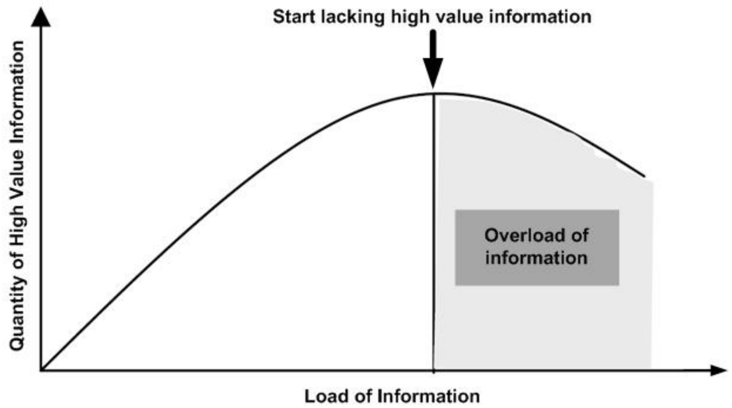

Figure 1: Information overload phenomenon

Construction companies are becoming more dynamic due to the diverse and complex nature of work tasks, trading relationships and 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, which generates large amounts of information. Information and knowledge management tools generate yet further communications. 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 due to 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 in some markets 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, 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.

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. However, decision-makers may find it difficult to value a piece of information, especially if it has no intrinsic value and is highly time-dependent. 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.

This paper identifies current approaches to information evaluation. This follows a review of information overload and the differences between data, information and knowledge. Two exploratory studies within leading construction consultants are presented and compared 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. The findings of the case studies provide answers to the following research questions:

a. Is there any information overload in the industry? And why?
b. Is there enough high value information? And why?

Finally, knowledge and information research questions are outlined in relation to the development of a through-life Information Evaluation Methodology (IEM).

2. A hierarchy of data, information and knowledge

In the literature, there are many definitions to distinguish data, information and knowledge (call a DIK hierarchy). Data can be defined as “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” (British Standards Institution 2003). Knowledge is a cumulative understanding of the information and data in the specific context of an application (British Standards Institution 2003). 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 et al. (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 (encompassing unstructured); and knowledge is inferred from information through a knowledge creation 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. 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 codification methods. However, there is no agreed definition of knowledge since the emergence of knowledge management a decade ago. It is commonly referred to as Plato’s “justified true belief” (Fowler 1953) or the appropriate collection of information, such that its intent is to be useful.

The authors’ position is that the hierarchy consists of three stages in two main levels: recorded and personal (figure 2). Table 1 shows some dimensions of this information hierarchy where: data can be numbers, characters, symbols or images (statements taken at face value); information is interpreted data or data with context that inform; and knowledge is 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.

Table 1: Some dimensions of an information hierarchy

Dimension	**Data**	**Information**	**Knowledge**
Nature	A statement taken at face value.	Interpreted data that informs.	Facts, feelings and truths that make up what is known.
Form and location	Numbers, characters, symbols, images. Formalised in a databases and documents.	A received message. Data which is structured, analysed and given meaning. Recorded in some medium and be formalised in databases and documents.	Knowledge can be explicit (recorded in some way) or tacit (in the mind). It cannot flow between minds but can be articulated selectively by abstraction and codification.
Origin	From observations, measurements and imagination.	Data is organised, filtered, presented and given context.	Using information for action. Gained from experiences (learning, perception) or reasoning (association, synthesis).
Examples in construction perspective	Structural data, material data, cost data.	Emails, word of mouth, customer requirements, tendering documents, design information, cost plan, building regulations, brief, specifications and construction programme.	Explicit: Project manager gathers and combines knowledge from the team by brainstorming and project reviews. Tacit: Carpenter’s craftsmanship is built up by observation and practice and transferred by demonstration.

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 knowledge. In the context of the research presented herewith, techniques to 'surface' implicit knowledge of a person (e.g. person A in figure 2) include after-action reviews, in which he/she may express learning that has taken place but which previously they have not expressed. Explicit knowledge that is codified (recorded in some medium; paper, electronic for instance) is therefore available 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 at a corporate level can only be carried out on recorded information or knowledge. 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. The evaluation of these forms of knowledge at a personal level is carried out on a specific piece of information in respect of a current need.

In a construction organisation, data can be for instance geometric, materials or cost data. Information can exist on paper, 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 described as an intangible state (such as a decision-making process and judgment, or processed to knowledge stored in people's brains - first called tacit knowledge in 1970 (Kuhn 1970). During concept design much knowledge remains in the mind of a person, whilst in detailed design much implicit/even tacit knowledge is transformed to information in detailed drawings and specifications.

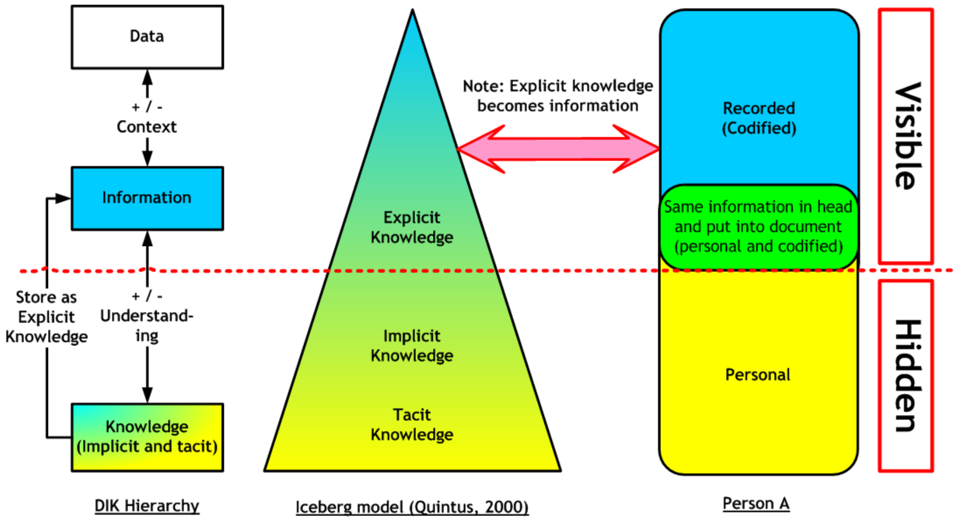

Figure 2: A hierarchy of data, information and knowledge (DIK)

3. Case studies in UK construction consultants

This research identified current approaches to information evaluation. It presents exploratory studies of two cost/project management consultants from three perspectives: business, project management and IT/document management. A total of 6 structured interviews 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;
e. Final considerations: the biggest challenge in knowledge and information management the interviewee is facing.

Studies have also been conducted in three other construction companies and three engineering organisations, involving a total of 28 interviews, but the data is not presented here. Table 2 details the two case studies, including the history, nature of products and services provided, scale of offices and number of employees, and annual group turnover.

Table 2: Company background of the case study

Company	**Company X**	**Company Y**
History	Established over 90 years ago	Established over 100 years ago
Nature of Products and Services	A global company providing professional services in Quantity Surveying (QS), Building Surveying, Project Management, , Management Consultancy, Software Development and Facilities Management in the Real Estate, Infrastructure and Construction Sectors	An international company which started in Scotland and then moved south providing professional services on cost management, project management, consultancy and building surveying. The company does many PFI projects around the world and in the UK
Scale of Offices and Employees Number	40 wholly owned offices in over 20 countries employing over 3,000 people	There are offices around the UK employing over 750 people
Annual Group Turnover	In excess of £200 million	In excess of £50 million

4. Cross company analysis of current KIM practice

This section analyses and discusses the findings of the interviews with the professionals in both companies summarised in table 3. 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 based on the three perspectives.

4.1 Overall KIM practice

Figure 5 shows the overall KIM practice in companies X and Y. 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 and personal PCs, whilst typical software tools support document management, intranets, extranets, protocols, share point, wikis, blogs, and intelligent decision support systems. The remaining part is the people, which includes auditors, knowledge managers, librarians, communities of practice, brainstorming, face-to-face interaction, and post-project review.

Figure 5: Overall KIM practice in both companies

Table 3: Summary of knowledge and information management in the construction consultants

Company X								
KIM	**Information Management (IM)**					**Knowledge Management (KM)**		
Dimension / Perspective	**System**	**Source**	**Criterion**	**Evaluation**	**Storage**	**Technique**	**Technology**	**Knowledge Transfer**
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, electronical stored for 6-12 years. Cost issue remains an unknown	Cost Research Department obtains cost for various tasks and locations	Building Cost Information Service (BCIS)	Learning and discussion
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	Capturing knowledge when every project ends, making input someone who is in charge of RED	Forums	Discussion
Business	A software called '_on', SDS, Residential Efficiency Database (RED)	RED, Word of Mouth	Accuracy	Maintain standard input consistently when generating information; use gateway keeper	Cost is increasing	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
Company Y								
KIM	**Information Management (IM)**					**Knowledge Management (KM)**		
Document Management	Information Technology (IT) and shift to more on Information System (IS)	Emails (PDA), Phone calls	Relevance, Accuracy	Rework cost is much more higher	Soft copies (e.g. up to 2.5TB), No document management system, never dispose information. Cost of maintenance is high	Auditor for PATD	Knowledge database	Timesheet in Intranet
Project Management	Intranet, Life cycle cost assessment	Experience, Emails, Technical data, Phone calls	Relevance	Experience based, Information filtering (Line management system, Secretary)	80% in paper work. Never reuse, In J: drive	Managing people	Technical training	A people to people transfer
Business	Intranet, Project Audit Tracking Database (PATD)	Memory or experience, Emails, Purchase from a recognised body	Trust level	Experience based, Cost of gathering, Filtering (Secretary)	No formal procedure for softcopy	3-6 months notice before leaving the company	Communities of Practice (CoP)	A people to people transfer (e.g. minutes, report, discussion)

4.2 Information sharing and storage

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.

Archiving orientated strategy: In Company Y, soft copies are up to 2.5TB in size and the cost of maintenance is high. Information filtering is conducted by individual judgement based on criteria such as relevance, accuracy and trust level. However, staff do not have a culture of storing information on shared drives or disposing of useless information. Sometimes staff misdirect information such as the misuse of a 'REPLY ALL' button in email. Whilst the Company Y Archiving Policy gives sensible guidance on how to identify what should be kept, it is often not followed. Only the electronic documents volunteered by staff are captured and the printed to be physically archived.

Accessibility inclined strategy: In Company X, relying upon individual judgement based on criteria such as accuracy, relevance, trust level, currency and location to make decisions about retention of valuable information is considered risky. Therefore, the project manager is in charge of the database and makes decisions and checks on what to keep that is most likely to be useful. The information is put on the intranet, creating an electronic archive that is subsequently more accessible. The electronic storage cost is thus increasing. Only signed documents are kept as paper documents, minimizing physical storage. In terms of the number of employees and annual turnover, Company X is four times more than Company Y. The ICT infrastructures are more complicated and their offices are more geographically dispersed. That is why location is included when the project manager in Company X accesses information. As a general observation, Company X is less worried about the problem of information overload as they are quite confident in their current ICT system.
(It is noted that the project managers from both companies did not think that they had the information overload problem, whereas the directors and IT managers did. This could be due to the fact that they have more information channels to transfer and redirect information no matter they are useful or not.)

"Storing everything" culture in both companies: The "storing everything" culture exists in both companies, but 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. The evidence also indicates 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). Both 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.

4.3 High value information/explicit knowledge

Knowledge creation mechanism: The "embedded knowledge" is one of the biggest assets of these two construction consultants. 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 archieved by discussion in both 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 by meeting and project reviews in Company X and by PSP and CoPs in Company Y;
c. explicit knowledge is transferred and stored as implicit knowledge by internalisation (e.g. knowledge databases, E-learning, visualisation) through training and databases in both companies; and
d. explicit knowledge is transferred by combination (e.g. abstracting, classification and clustering) using company intranets, software and personal PCs in both companies.

Losing valuable knowledge: However, current strategies are not sufficient to tackle the problem of losing knowledge. 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, the knowledge of these staff is rapidly lost. 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/information storage)? What is lost at the same time? Interviewees in both companies confirmed that knowledge loss is a major problem. As discussed above, information evaluation is solely based on individual judegment and there is no scientific tool to increase the quantity of high value information for future reuse and to support through-life products. 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.

An overall solution proposed by Company X 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. 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 cannot be solved by ICT systems alone. ICT and improving staff retention (e.g. by reward) are proposed by Company Y 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, what should be sent to archive, and what should be kept in a document management system? One possible solution, (being investigated by both companies), is to use SharePoint from Microsoft Corporation to manage, share, and archive all information generated in their work. This software has not been implemented fully yet not only because of its functionality but also the cost (as most companies especially the SMEs cannot afford to buy it). But another way may be to put a value tag on information in order to reduce the information overload.

5. Further research on an information evaluation methodology (IEM)

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. It seems that storing everything is the approach taken by these two construction consultants. The storage cost is low especially for the electronic documents but the maintenance cost is increasing rapidly. Also companies (as reflected in these two case studies) are scanning documents and storing for a certain number of years (typically 12 years) mainly for legal reasons. It thus can be seen that better organization on storage would be a solution to the information overload problem. However with business search engines improving, like Google business search (Google Corp.), Autonomy (Autonomy Corp.), FAST search (Fast Search & Transfer ASA.), and other search tools, based on relevance of the documents, finding information in storage is easier than it used to be. However, putting a value tag on searched information would increase the usefulness of the information found.

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 “what you get” and “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 (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?

6. Conclusions

It is clear that, if these companies are representative of the construction 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 addresses the problem of information overload, the lack of high value information and provides a basic understanding of data, information and knowledge in the construction industry. An exploratory study was conducted in two major construction consultants examining three perspectives (business, project management and document management) and specifically how to value information.

The case studies show that an overall KIM practice (including hardware, software and criticalware is being adopted in these companies. Different information storage strategies were adopted; one company is archiving orientated while the other is high accessibility inclined. Information overload exists in both companies because of the current ICT infrastructures, ‘storing everything’ culture, legal reasons and the nature of business. 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.

What will be the KIM road map in the future (say after 12 years of legal liability)? To "keep everything" appears not to be the solution to KIM. Can/should these ompanies increase the value/future value of information today in order to best communicate with the people in the future in order to establish an ‘immortal’ system? Further studies are needed on managing information in engineering contexts, and in particular the problems associated with the ever-increasing volume of information, the continuously changing nature of information, and the value of information. A good built-in search engine for all archived information, together with a tool that can give some form of information value tag, during archiving or storing information, or after search, would be important to increase the quantity of high value information and to reduce the information overload problem. This is key to the development of a through-life information evaluation approach.

Acknowledgements
The work presented herein was undertaken under the aegis of the Knowledge and Information Management Through-Life Grand Challenge Project (www.kimproject.org) funded primarily by the Engineering and Physical Research Council (Grant No EP/C534220/1), the Economic and Social Research Council (Grant No RES-331-27-0006) and Loughborough University's Innovative Manufacturing and Construction Research Centre (Grant Nos EP/C534220/1 and RES-331-27-0006). The support of the collaborating companies is gratefully acknowledged.

References

Al-Hakim, L. (2007) *Information Quality Management: Theory and Applications*, Idea Group Publishing, US.
Anumba, C., Egbu C. and Carrillo, P. (2005) *Knowledge Management in Construction*, Blackwell Publishing, Oxford, UK.
British Standards Institution (2003) *Knowledge Management Vocabulary, BS PD7500*, British Standard Institution, London, UK.
Bruner, J. (1990) *Acts of Meaning*, Harvard University Press, Cambridge, MA.
Choo, C.W., Detlor, B. and Turnbull, D. (2000) *Web Work: Information Seeking and Knowledge Work on the World Wide Web*, Kluwer Academic Publishers, Dordrecht, London, UK.
Douglas, H-EB. (2003) *Boomers' Retirement Prospects: An Overview*, D.C., Washington.
Eppler, M.J. and Mengis, J. (2004). “The Concept of Information Overload: A Review of Literature from Organization Science, Accounting, Marketing, MIS, and Related Disciplines”, *The Information Society*, Vol 20, No. 5, pp 325-344.
Hicks, B.J., Culley, S.J. Allen, R.D. and Mullineux, D. (2002) “A Framework for the Requirements of Capturing, Storing and Reusing Information and Knowledge in Engineering Design”, *International Journal of Information Management*, Vol 22, No. 4, pp. 263-281.
INC. (2003) “Data Data - How Much Time People Waste Looking for Lost Information, How Fast the World Wide Web is Growing, and Other Statistics from the Front Lines of the Info Glut”, [online], INC Magazine, New York, http://www.inc.com/magazine/19990101/715.html.
Koniger, P. and Janowitz, K. (1995) “Drowning in Information, but Thirsty for Knowledge”, *International Journal of Information Management*, Vol 15, No. 1, pp. 5-16.
Kuhn, T.S. (1970) *The Structure of Scientific Revolutions*, University of Chicago Press, Chicago.
McCampbell, S.A., Clare, L.M. and Gitters, S.H. (1999) “Knowledge management: the new challenge for the 21st century”, *Journal of Knowledge Management*, Vol 3, No. 3, pp. 172-179.
Nonaka, I. and Takeuchi, H. (1995) *The Knowledge-Creating Company*, Oxford University Press, New York.
Oppenheim, C. (1997) “Managers' use and handling of information”, *International Journal of Information Management*, Vol 17, No. 4, pp. 239-248.
Quintas, P. (2000) *Managing Knowledge: A Big Picture, presented at Routes into Knowledge Management*, City Information Group, Baltic Exchange, London, 11 October.
Fowler, H.N. (1953) *"Phaedo"*, in Fowler, H.N. (Transl & Eds). *Plato I*. Harvard University Press/The Loeb Classical Library, Cambridge, MA, pp. 117-124.
Polanyi, M. (1966) *The Tacit Dimension*, Doubleday, New York.

Rao, M. (2004) *Knowledge Management Tools and Techniques: Practitioners and Experts Evaluate KM Solutions*, Elsevier, UK.

Reuters Ltd. (1998) *Out of the Abyss: Surviving the Information Age*, London, UK.

Tang, A. and Nicholson, A. (2007) “Using Bayesian Belief Network for Change Impact Analysis in Architecture Design”, *The Journal of Systems and Software*, Vol 80, No. 1, pp. 127-148.

Thomson, D.S., Austin, S.A., Devine-Wright, H. and Mills, G.R. (2003) “Managing Value and Quality in Design”, *Building Research & Information*, Vol 31, No. 5, pp. 334-345.

Thomson, D.S., Austin, S.A., Root, D. S. and Thorpe, A. (2006) “A Problem-solving Approach to Value-adding Decision Making in Construction Design”, *Engineering Construction and Architectural Management*, Vol 13, No. 1, pp. 43-61.

Wiig, K.M. (1993) *Knowledge Management Foundations: Thinking About Thinking-How people and Organisations Create, Represent, and Use Knowledge*, Schema Press, Arlington, TX.