

IT support for knowledge management in designer and contractor briefing

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ABSTRACT | This paper describes the activities and findings of an EPSRC project examining the role of IT in Knowledge Management and Organisational Learning in Construction – KLICON. The research, which is nearing completion, has explored the use of IT in supporting knowledge management in construction briefing, both for designer briefing in unstructured situations, and in contractor briefing in design-build bidding situations. Specifically it examined, from first principles, the choice of appropriate knowledge transfer mechanisms and the challenge of searching for knowledge without a well-formulated ontology. Though the research findings are still preliminary the indications are that:

- 1 structured knowledge areas benefit from more formal structuring of knowledge space and content (lessons, data, contacts, etc.) while, conversely, less structured areas benefit from free search capabilities;
 - 2 ontology may not be the challenge that it has seemed in the past;
 - 3 many users still find IT support unattractive.
- All these represent areas of important further research.

1 Introduction

Over the past few years, organisations have become increasingly conscious of the importance of knowledge as an asset. Many companies now recognise that much of their effectiveness lies in the way they manage, and use, knowledge –knowledge here being defined as the ability to use information in a predictive manner. Construction firms should in principle be no different: much of their work is information intensive, with the ability to predict and make judgements being central to most everyday activities. Yet the industry faces particular challenges in managing knowledge, not least in the fragmented, project-based and multi-company nature of most firms' activities.

Information Technology based tools have been rapidly developing our ability to capture, classify, transmit, retrieve and assess information. KLICON [“*The Role of IT in Capturing and Managing Knowledge for Organisational Learning on Construction Projects*”] is an EPSRC funded project [IMI/C/05/03] being conducted by UMIST's Centre for Research in the Management of Projects [CRMP], in partnership with Kvaerner Construction Ltd (now Skanska), Ove Arup & Partners, BRE, the University of Manchester, and the University of Salford. It has been examining the role of computing and information technology in aiding knowledge management and organisational learning in construction, particularly from a projects' orientation, and particularly with respect to briefing and design management.

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This paper reports findings from the research as it stands at about the 90% complete position. It reviews first the challenge of knowledge management in construction. It then describes initial work performed by the research in positioning IT support for knowledge management in construction. In this it became clear that any evaluation of IT support, as with any usage itself, has to take account of the organisational context in which the tools are applied: context is critical to IT effectiveness in knowledge management. It then describes two research studies undertaken within KLICON (there were four all together⁵):

1. creating a web-based knowledge management tool for a structured knowledge situation – contractor briefing for design-build⁶;
2. using an intelligent search engine to identify best practice from a lesson-learned database on design without the existence of a pre-defined ontology.

2 Knowledge Management in Construction

Knowledge is an elusive term to define. Laudon and Laudon defined knowledge management as the process of systematically and actively managing and leveraging the stores of knowledge in an organisation [1]. The Butler Group defined knowledge management as the framework for discovering, capturing, transmitting, and reusing knowledge to gain competitive advantage [2]. Warwick University's Business Proc-

esses Resource Centre defines knowledge management as "the acquisition, sharing and use of knowledge within organizations, including learning processes and management information systems" [3]. One of the best definitions in a business context is probably that by the Yankee Group: "knowledge management involves efficiently connecting those who know with those who need to know, and converting personal knowledge into organisational knowledge" [4].

KLICON took as a working definition the ability to use information to predict off a cognitive base. KLICON distinguished between data, information and knowledge as follows.

- Data is un-interpreted material on which a decision may be based.
- Information is data interpreted in a given context. Different information may be gleaned from a single data source if the context is different.
- Knowledge is a body of information, coupled with the understanding and reasoning about why it is correct. Knowledge is thus the cognitive ability to generate insight based on information and data.

In practice the distinction between information and knowledge is a lot less clear than that between both of these and data. For what is information to one person may be knowledge to another; and what was knowledge in one context may only be information in another. (Literature, like life, is replete with examples of predictions being made on mistaken assumptions.)

5. The other two were as follows.

- The formal modelling of project information flows to identify areas of improved knowledge representation. EXPRESS was used to model the information generated and used during the geotechnical operations of a construction project. The EXPRESS model was linked to an IDEF0 activity model of the site investigation and other Geotechnical activities. A simple ontology was applied using Virtual Hyperglossary (VHG) format related to soil sampling, thereby allowing terminology to be represented in an XML format in an interpretable manner. The information model was developed to be compatible with the AGS Standard (data model for boreholes) and the end application was delivered via the web in XML. By adhering to formal modelling techniques, KLICON was able to generate translators automatically between the EXPRESS model and XML and use automatic tools to check the consistency of the result. A prototype browsing system was developed to examine all levels of the IDEF0 model. In addition, where appropriate, inputs or outputs from the model were linked into the relevant part of the VGS site investigation glossary or to the formal specification of the data semantics as represented by the EXPRESS model of AGS. The initial findings showed that the system allows the user to understand the context of the work (the activity model), the meaning of the information carried in the AGS file (AGS information model), and see related data taken from site investigations. The extra effort required to model information with standard formalisms has, through this work, been seen to lead to benefits in that standard computer tools can be used to improve functionality. There are benefits both in the process of creating the model and then using it in new contexts. This work was carried out by the University of Manchester Computer Science Department under the leadership of Professor Hilary Kahn working with Ove Arup and Partners.
 - A survey of knowledge management practices in 12 leading construction companies. This showed that most companies (10) were only at a relatively early stage of developing an enterprise-wide approach to Knowledge Management. Two were advanced in IT KM terms.
6. This is now being extended to a full contractor Knowledge Management System.

Nevertheless the fact remains that people use knowledge, and value it, in making day-to-day decisions. Organisations too draw on knowledge in performing as effective institutions. To some, knowledge is always people based (“knowledge has two legs”), but people come and go: the challenge for the organisation is to be able to capture and use knowledge without having necessarily to rely on people.

Knowledge Management, as a formal area of management activity, is relatively recent emerging from the early to mid 1990s. Knowledge Management seems to reflect a constellation of changes - some profound, some more cosmetic - in the business environment. These include:

- Long-run shifts in advanced industrial economies which have led to the increasingly widespread perception of knowledge as an important organisational asset.
- The rise of occupations based on the creation and use of knowledge.
- The convergence of information and communication technologies, and the advent of new tools such as Intranets and Groupware systems.
- Theoretical developments – for example, the resource-based view of the firm – which emphasize the importance of unique and inimitable assets such as tacit knowledge.

Nonaka and Takeuchi, in a pioneering work, claimed in 1995 that Japanese companies have been successful and maintained competitive edge because of their skills and expertise at organisational knowledge creation [5].

Polyani in 1966 distinguished between tacit knowledge and explicit [6]. Tacit knowledge is personal knowledge embedded in individual experience; it involves intangible factors such as personal belief, perspectives, and values. Explicit knowledge is 'readily available'; it can be codified and structured in a way that makes the knowledge easily transmissible.

Most organisations begin Knowledge Management with some kind of ‘who knows what’ programme (a

Yellow Pages), and then encourage people to contact those with relevant knowledge (chat rooms, cafés, Communities of Practice, Subject Matter Experts). Even at this basic level, note, Information Technology is being used to aid in Knowledge Management.

Knowledge has long been recognised as central in construction. Engineering and architecture are recognised as ‘learned’ professions. Knowledge of construction practices and processes is widely recognised as a constructor’s core competence. Commercial know-how permeates the contracting side of the industry.

Construction knowledge is thus both explicit (engineering principles etc.), and tacit (in one’s knowledge of organisations, or location). But knowledge is by no means always easily captured or effectively shared amongst industry players. It is generally recognised that there is much knowledge wastage and often considerable difficulty in accessing important information. There are four basic reasons for this.

1. The industry is large and complex, with a high proportion of companies being small. (The construction industry in the UK consists of about 200,000 companies. The top 95 companies are about 0.05% of the total yet they generate 21% of the industry output. Small firms account for 93% of all firms yet they only generate 28% of the output.)
2. The many different players in the industry typically do not share a common educational base. As a result, cognitive frameworks are not always easily shared.
3. Historically the contractual forms which underpin the way firms and resources are selected, and indeed the traditional strategy of contracting (late entrant of the constructor; tendency to select the cheapest bidder rather than necessarily the best, etc.), has encouraged adversarial relationships to grow too easily. These have exacerbated the differences in thinking between firms working together on projects and have often inhibited the effective exchange of information.

4. The project nature of the industry – with a frequently reconfigured set of supply chain partners, non-repetitive nature of work, pressure to complete, and lack of incentive to appraise performance or pass learning on to others, or to improve overall project delivery – means that information is too often not collected.

These factors have not merely inhibited effective knowledge management: they have inhibited the industry's ability to learn on a consistent basis and improve performance. Though there have been many changes in construction practice over the last few decades, until recently there has been little formally attempted in Knowledge Management, or Organisational Learning, in construction.

Recent changes in the industry, led, though not exclusively, by the Latham and Egan initiatives, have however created new climates for innovation and development [7]. Knowledge Management and Organisational Learning have been one of several management areas that construction firms have begun to look at. Much of the early initiative was Information Technology led. The 1995 report 'Construct IT – Bridging the Gap', for example, stated that "an industry-wide online knowledge base should be set up to allow systematic capture and distribution of information around the industry" [6] and a subsequent set of reports reviewed the practical implementation of this and other recommendations.

A 1997 research project addressed on-line information requirements and examined the procedures that contractors used relating to products, product-related software, codes, standards and regulations, safety and health, design guidance, on-line databases, technical papers and databases, supplier/vendor registration forms and pricing information [8]. Among the findings of the research were that knowledge-based solutions

are needed to ensure that results obtained from online searches are appropriate, correct and derived from a suitable source. (This is an issue directly addressed in KLICON via its work on *Extractor*.)

Meanwhile during the late 1990s developments in IT were continuing to push our ability to manage knowledge, in construction as elsewhere, more effectively. The most important development undoubtedly was the growing ubiquity of the web. As a result, the speed and scale of interconnectivity grew enormously. Though a common complaint was the resulting tendency to information overload, IT tools increasingly addressed these (one of the most successful, *Autonomy*, a form of search engine⁷, actually entering the FTSE100 in December 2000 – and leaving it in March 2001!). With the consequent growth in IT functionality and power came a significantly increased potential in management capability: e commerce, collaborative working, process re-engineering, and knowledge management being leading examples.

It was slightly in advance of this explosion in interest in Technology, in fact in February 1998, that KLICON was launched to review the role of IT in Knowledge Management and Organisational Learning⁸ in construction.

3 Evaluation of Information Tools for Supporting Knowledge Management

One of the first tasks of KLICON was to place current IT KM tools and research in the KLICON research context – largely design and design-build.

Laudon and Laudon evaluated the role and support of IT tools for managing knowledge in terms of creating, distributing, sharing, capturing and codifying knowledge [1]. Table 1 portrays the types of IT tools which

7. *Autonomy* uses high-performance pattern matching algorithms, based on Shannon's principles of information theory, Bayesian probability, and on neural networks to identify patterns in text and to look for patterns in similar sources. It helps identify similar 'key concepts'. www.autonomy.com

8. Organisational learning has throughout been closely associated with knowledge management, as the references above show. In fact the early writings in this area tended to emphasise the organisational and learning aspects more than the knowledge aspects [8]

Table 1. Aspects of Knowledge Management & IT Tools Support

Aspects of Knowledge Management	IT Domain	IT Tools
Creating knowledge	Knowledge Work Systems	CAD; Virtual Reality; Investments Workstations
Distributing knowledge	Office Automation Systems	Word Processing; Desktop Publishing; Imaging and Web Publishing; Electronic Calendars; Desktop Databases and Spreadsheets
Sharing knowledge	Group Collaboration Systems	Groupware; Intranets
Capturing and codifying knowledge	Artificial Intelligence Systems	Expert Systems; Neural Nets; Fuzzy Logic; Genetic Algorithms; Intelligent Agents

Table 2. Examples of commercially available knowledge management software systems.

Type of IT Tool	Examples of Commercial Software
Knowledge-Based Systems	ART*Enterprise, Clips 6.0, Flex, KnowMan, CommonKADS; Rete++, Eclipse, Comdale Suite, G2, Netica, ILOG Rules 4.0, EXSYS 5.0, ICIAS, ALICE, M.4; Vidwan, Fault Expert, LPA, Elements Expert, XperRule
Cased-Based Reasoning	ART*Enterprise, Case Advisor 3.1, ICIAS
Object-Oriented Databases	Object Design (Objectstore), Objectivity/DB, Versant, O2 Technology; DOORS, Gemstone, Ontos, Mjølner, Poet Software
Neural Networks	Process Insights, NeuroShell, NeuroWindows, Nestor, Neurogon; NeuroSolutions, Domain Solutions, Atree 3.0 ALN, NN Utility/2, NeuroLab; Matlab NN toolbox, ABM, Attrasoft Predictor, Neural Bench, NeuroLution, BioNet Simulator
Fuzzy Logic	FLINT, DataEngine, Fuzzy Control Manager, NeuroModel EVO, Fuzzy Expert, WIN-ROSA, Partek, FLDE, FUZZLE, Matlab fuzzy logic toolbox, LFLC, Neuframe, Genetica/ NeuroForecaster
Knowledge Management & Search Engines	LiveLink, Autonomy, grapevine, Excalibur, Wincite, PC Pack, InternetKnowledge Manager, KnowledgeX, Muscat Empower, Sovereign Hill, Meta Pack
Knowledge Discovery/ Data Mining	Data Mining Workstation (DMW), CASSIOPEE, CRAYON, FARCAST
Data Warehouses	Influence Knowledge Warehouse (IKW), Prism Data Warehouse, Ardent Data Mart
Genetic Algorithms	Evolver, OOGA, XperRule GenAsys
Group Decision Support Systems (GDSS)	GroupSystems, Negotiator Pro, VisionQuest, GENIE, SAMM, NSS; Lotus Domino/ Notes, TCBWorks, BrainWeb, InterAction, MEDIATOR
On-Line Analytical Processing (OLAP)	BrioQuery, Pilot Internet Publisher, Business Objects, WebOLAP, Commander DecisionWeb, DataFountain, DSS Web, Focus Fusion, InfoBeaconWeb, Oracle Express Server

are designed to provide support at different levels in the organisation.

- Knowledge Work Systems support the activities of highly skilled knowledge workers and professionals

as they create new knowledge and try to integrate it into the organisation.

- Office Automation Systems help disseminate and co-ordinate the flow of information in the organisation.

- Group Collaboration Systems support the sharing of knowledge among people working in groups.
- Artificial Intelligence Systems provide codified knowledge that can be reused by others in the organisation.

Within each category of course there is a plethora of tools. Table 2 represents just a few identified by the KLICON research team.

KLICON undertook structured interviews to explore where users were finding value from forms of knowledge management tools. A significant finding was how constrained practitioners' interests were by the company culture and supply chain configuration they were operating under. Specifically we found that:

- access to many of the tools was in many cases limited – the most important instance of this was access to the Internet which in several companies was proscribed during working hours (a finding also of the 1997 Construct IT report [9]);
- contractual constraints [supply chain configurations] also had a marked impact on the ability of construction practitioners to derive value from knowledge management tools – if the supply chain was relatively fragmented, important corporate knowledge could be assessed; with the contractor not coming in until the design was relatively complete for example, the value of the tools was substantially diminished.

In short, we found that it is hard, and not necessarily always very useful, to try and evaluate IT [knowledge management tools] independently of their organisational and cultural context. A key finding was therefore that to be effective, technology has to be applied appropriately in its organisational context. (A theme to emerge consistently in KLICON's work). IT/KM support should be flexible, easy to use, cost effective, and supportive of relevant people.

4 Briefing

Knowledge in fact is ubiquitous. Many familiar construction systems are in effect knowledge management systems. Procurement databases for example contain information [corporate knowledge] on suppliers; estimating databases and risk registers contain project performance knowledge; technical standards and project appraisals represent technical and project management knowledge. An early challenge therefore was to decide where KLICON should focus in its exploration of the use of IT in knowledge management in construction.

The research team decided to focus as far as possible on the briefing and definition stages of a project. There is increasing acceptance that briefing and project definition represent vital yet inadequately well-managed areas of project performance [10]. Poor definition of what is required will, not surprisingly, often lead to poor provision of what was wanted [11].

In fact the research identified two general areas of briefing that it felt should be studied: front-end definition by the design team; and 'briefing' of the constructor as he enters the project – (a) in bidding and (b) in briefing the construction team after the bid is awarded. [12].

The research team thus investigated examples of IT-based knowledge management tools in two differing situations:

- creating a web-based bidding knowledge management tool for a contractor's bid team in design-build for Liquefied Natural Gas (LNG) tanks⁹;
- using an intelligent search methodology to identify best practice from a broad lesson-learned 'design notes' database on design.

9. Liquid Natural Gas: most LNG facilities start at about £30 million each.

5 A Framework for Defining an Appropriate Knowledge Management System

The work attempted to design, and evaluate, from first principles, how a knowledge management system should best be designed to support a contractor in his bidding process.

Following our initial findings on the importance of user needs and organisational context, we sought a broader framework in which to set the Knowledge Management System. We therefore turned to the work of MIT's Centre for Organisational Learning [13], and specifically to the work of Dixon [14], as the theoretical base for selecting the most appropriate form of 'knowledge transfer' mechanism.

Dixon has shown that knowledge transfer can be categorised into five different types, namely, serial transfer; near transfer; far transfer; expert transfer; and strategic transfer. Table 3 categorises these types of knowledge and suggests, following Dixon, appropriate transfer methods for each type.

5.1 LNG knowledge familiarisation

Applying Dixon's research findings in the LNG case, it was seen that three out of the five kinds of knowledge transfer are appropriate and match the design processes of an LNG project. They represent serial transfer, far transfer and expert transfer.

- Serial – because, for instance, the design team acquires knowledge from designing a specific LNG project and transfers this experience to a future project.
- Far – when a specialised designer, from one office, passes on his tacit knowledge to another colleague, in a different office, doing a similar component design.

- Expert – that is where a junior designer seeks the expertise of others to solve a technical design issue.

Dixon suggests that these kinds of knowledge transfer are best served by:

- meetings (Serial);
- reciprocal exchange: "source team knowledge is translated; people carry the knowledge across the organization" (Far);
- and electronic forums aggregated by topic: "electronic format are monitored and supported; different levels of participation are encouraged; knowledge is pulled" (Expert).

Applying Dixon's research findings to the more general 'design notes' case, it was seen that two¹⁰ out of the five kinds of knowledge transfer are appropriate and match the characteristics of the general design search situation. These are:

- Near – where explicit knowledge that a team has gained from doing a frequent and repeated task is reused by others doing very similar work.
- Expert – where a junior designer seeks the expertise of others to solve a technical design issue.

Dixon suggests that these kinds of knowledge transfer are best served by:

- "electronic dissemination supplemented by personal interaction; users specify content and format; knowledge is pushed; a limited number of items is pushed; brief descriptions are adequate; the data base is targeted" (Near);
- and "electronic format are monitored and supported; different levels of participation are encouraged; knowledge is pulled" (Expert).

With these characterisations in mind, the KLICON team began the development of the Knowledge Management System for use in briefing bidding teams for the design and construction of the LNG tanks.

10. The transfer could occasionally be Serial too – because while knowledge is being transferred from one situation to another, in which the task is being done in a different setting, it is not really the same team that is doing the task (though it just might be).

Table 3. Types of Knowledge transfer mechanisms

Knowledge Transfer	Definition	Nature of Task	Type of Knowledge
Serial Transfer	The knowledge a team has gained from doing its task in one setting is transferred to the next time that team does the task in a different setting.	frequent & non-routine	tacit & explicit
Near Transfer	Explicit knowledge a team has gained from doing a frequent and repeated task is reused by other teams doing very similar work.	frequent & routine	explicit
Far Transfer	Tacit knowledge a team has gained from doing a non-routine task is made available to other teams doing similar work in another part of the organisation.	frequent & non-routine	tacit
Expert Transfer	A team facing a technical question beyond the scope of its own knowledge seeks the expertise of others within the whole organisation.	infrequent & routine	explicit
Strategic Transfer	The collective knowledge of the organisation is needed to accomplish a strategic task that occurs infrequently but is critical to the whole organisation.	infrequent & non-routine	tacit & explicit

6 The LNG Bid Briefing Knowledge Management System¹¹

LNG storage tanks are very sophisticated types of projects. They have high technical requirements, especially within their insulation systems. Discussing and evaluating these characteristics within the contracting organisation, the research team concluded that there is a limited opportunity for knowledge transfer by face-to-face meetings and hard copy documents. Ultimately, however, it was concluded that an IT support tool that the design, bidding and executing teams could rely on to feed them with useful information would be the most appropriate means of effective knowledge transfer.

In this instance, we chose to create and trial an approach for developing a knowledge management tool that could be used generically by a contractor for bidding. Features of the approach we took included:

- developing a sound rationale for selecting the type of knowledge transfer mechanism appropriate to the type of knowledge and the intended audience;
- developing a knowledge management process;

- building and evaluating the knowledge management tool.

This portion of the research was conducted primarily by a team led by UMIST on data supplied by, and with the support of, Kvaerner [now Skanska] Technology Ltd. Given the obstacles and difficulties experienced to date in creating effective knowledge management systems in construction, the research team decided to focus on where:

1. there would be clear potential business benefits from the use of a knowledge management system,
2. the knowledge was more stable, reproducible and accessible.

The Liquid Natural Gas (LNG) domain was selected from among Skanska’s work areas for the knowledge system because it was considered as a new market and a potential growth business stream for Skanska. The insulation systems of an LNG tank were chosen as the knowledge domain because of their requirements’ complexity during the design, construction and operation stages.

11. This system has subsequently been extended into a broader LNG Knowledge Management System.

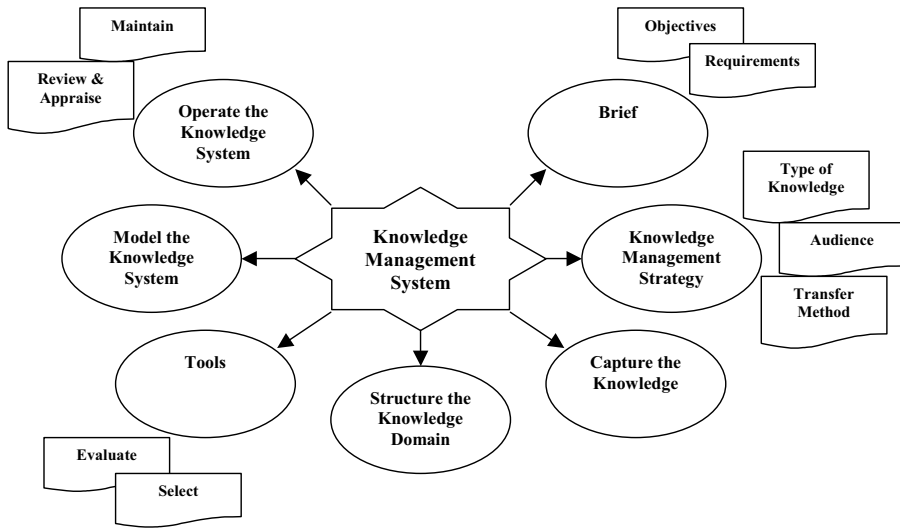


Figure 1. Sequence for the development of a Knowledge Management System.

Furthermore, the form of the LNG knowledge system is anticipated to be applicable to a range of other project types such as buildings. The ultimate aim is to consider the LNG Knowledge Management System (KMS) as a standard to develop similar systems for other types of projects having similar transfer needs across the organisation.

6.1 LNG Project Knowledge Management System

The LNG KMS resides within an already existing corporate Knowledge System. The hosting IT environment, which is an intranet-based company system, suffered difficulties in the past in that the information it held was not always seen as sufficiently targeted, or relevant, to the needs and requirements of staff [vide Dixon!]. To avoid the same dangers, the proposed LNG system was therefore designed to furnish specific information relevant to a major business area, and was designed to utilise the most appropriate knowledge transfer mechanisms.

The development of the Knowledge Management System followed a systematic process developed by the team. This is summarised in Figure 1. An activity flowchart was established to develop the LNG Knowledge System. Figure 2 illustrates the activities undertaken.

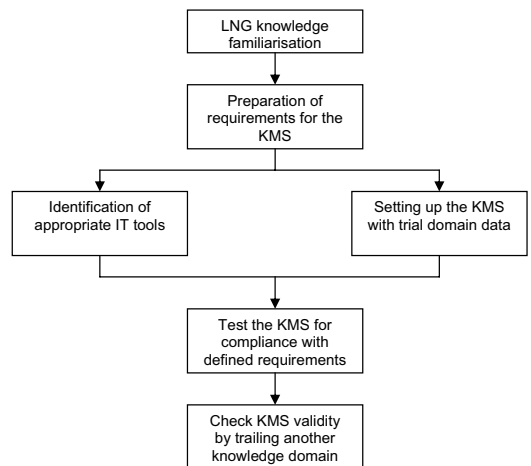


Figure 2. A Flowchart for LNG Knowledge Management System Development

- The first step was LNG knowledge familiarisation, which included meetings; interviews; and inspections of documents.
- The second stage was to prepare the requirements for the knowledge system. This consisted of setting out the needs for capturing the knowledge; mapping out a data structure to fit the needs; and setting out tool selection criteria.
- The third process was to identify IT tools that meet the agreed requirements.
- The fourth phase was to set up and populate the knowledge system with trial domain data – the design of the base insulation system.
- The fifth activity was to test the knowledge system for compliance with defined requirement criteria.

Once the system was built, its flexibility, validity and appropriateness will be checked by trialing another knowledge domain within the LNG projects – e.g. procurement, operation, etc.

Specific requirements for the selection and use of the most appropriate tools were suggested and discussed by the project team. They included the ability to deliver the system brief; fit with the company's IT environment; low initial and maintenance costs; and ability to improve process efficiency and performance at different stages of the LNG project. Based upon these requirements an evaluation framework for the proposed IT tool was developed and agreed. This is shown in Table 4.

Most of the IT tools shown in Table 2 were discarded because they were seen not to be appropriate for the type of the LNG information being dealt with, and therefore did not meet most of the evaluation criteria shown in Table 4.

The following candidate IT tools were assessed: a relational database (*MS Access*); an object oriented database for requirements management (*DOORS*); the

creation of a simple bespoke web-based system; or the option of combining any of the databases with a web-based environment. (A Requirements Capture and Management tool was proposed because of the complex nature of briefing and requirements involved within an LNG project across all its components and phases).

Workshops and interviews were conducted to evaluate and rank these proposed options; the results are presented in Table 4¹².

A web-based knowledge system was developed using FrontPage 2000. The primary components of the LNG KS consist of a tank base, walls, roof, insulation systems, process plant and nickel steel components. The KMS captured information and knowledge across total project life cycle including design, procurement, planning, estimation, construction and operation for each LNG component.

The information made available for the knowledge system consisted of tender documents; typical drawings; technical specifications; method statements; and technical submission documents. Additional explicit knowledge and tacit knowledge were also captured through interviews and workshops, as well as working closely with designers who regularly provided feedback and criticism regarding the development of the knowledge system.

6.2 Findings and Future Developments

The knowledge system has been formally evaluated by over 50 users, 24 of whom provided structured feedback and commentary. Table 5 depicts the evaluation criterion against which the knowledge system was assessed by potential users within Skanska.

The feedback results of the evaluation exercise are portrayed in Figure 3. Respondents view the knowledge

12. A scoring system was used ranging from high (3), medium (2), and low (1) for each evaluation criterion. The exceptions for this scoring system include three criteria, namely, the initial cost, the maintenance cost, and the training cost. The ratings for these criteria are in a reverse mode, because they all represent costs, and they are represented as follows: high (1), medium (2), and low (3).

Table 4. Evaluation Framework for IT Tools

Evaluation Criteria	Web-Based			MS Access			Doors		
	High	Medium	Low	High	Medium	Low	High	Medium	Low
Effectiveness / Efficiency: <i>The ability of the proposed IT tool to work and meet the knowledge system requirements</i>	3				2		3		
Maintenance and updating: <i>Ease of maintaining information input/output after initial setup</i>	3			3				2	
Integration: <i>Reliability to be used across different platforms and fit within the organisation IT environments</i>	3				2				1
Speed: <i>to identify, locate and transfer information</i>	3				2			2	
Capital/initial cost: <i>Price of hardware, software and licenses</i>			3			3	1		
Support/Running Cost: <i>Costs for IT manager and software support</i>			3			3		2	
Training requirements and costs: <i>should be minimal for IT manager and should be negligible for users and should be easy and quick to learn</i>			3		2		1		
Business benefits: <i>revenue/cost achieved directly or indirectly by using the proposed IT tool</i>									
Access control: <i>Availability of different access permissions at different levels of information</i>		2			2			3	
Data/Information security: <i>Ability of copying and downloading restrictions, read only, printing, amending, and field specific information</i>		2			2			3	
Search engine facility: <i>Ability of word-search within all levels of the knowledge system</i>	3				2			3	
Traceability and activity links: <i>Facility to apply links between different objects and to trace the links forwards and backwards</i>			1			1		3	
Disaster recovery: <i>Precautions to recover information removed directly or accidentally</i>		2			2			3	
History recording and users hits: <i>Ability to record contributors/users, their data input and the timing of information updates</i>		2				1		3	

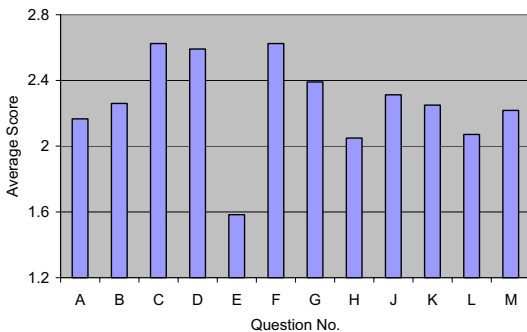


Figure 3. Results of the Evaluation Process for the LNG Knowledge System

Table 5. Evaluation Criteria for the LNG Knowledge Base

ID	Criteria	High (3)	Medium (2)	Low (1)
A	What is the ability of the proposed system to enhance your effectiveness and efficiency			
B	Is the information clear and valuable			
C	Would the system enhance sharing knowledge and experience			
D	Is the system easy to use and intuitive to navigate through			
E	How frequently would you use this system			
F	Would it be useful if there were expert help available in addition, e.g. via e-mail			
G	How quickly the system is in identifying, locating and transferring information			
H	Does the system meet your needs			
J	How easy the system is to update and maintain after initial setup			
K	Does the system fit within the organisation IT environments			
L	How do you rate the cost of developing the system			
M	How do you rate the potential business benefits			

system as valuable; easy to use; quick; and meet most of their needs. The lowest scoring criterion is the frequency of using the knowledge system, which to an extent contradicts the overall findings.

This might be because bidding for LNG projects is in itself an infrequent activity, or it could reflect a wider lack of interest in IT support tools specially within a certain age range of project teams.

More general findings of this part of the research, which stemmed out from workshops and interviews within Skanska, include the following:

- Knowledge Management System (KMS) platforms should use industry standard software as far as possible;

- a KMS should be developed against a well defined brief;
- it should be intuitive with minimum training;
- knowledge should be easily accessible: two clicks away, three phone calls away;
- there are no standard knowledge transfer structures [vide Dixon];
- the KMS must deliver value to users - there have to be rewards for using it;
- it is easy to capture explicit knowledge: tacit is often more valuable and harder;
- process mapping is of more value where diverse data [bases] are present;
- culture [often driven by procurement as well as attitudes] is a huge constraint;
- top management support is essential.

7 Development of a [Web] Site Extraction and Classification Tool¹³

The other aspect of briefing support investigated by KLICON concerned the perusal of vast amounts of design ‘notes’ – basic design information fed back over many years which potentially represent an invaluable source of knowledge to the designer when beginning to respond to a brief. How could IT tools support the user scour this information source?

Information retrieval is an important but frustrating aspect of knowledge management. Previous work by BRE [15] has shown that while almost all processes in the overall construction project life cycle could benefit from electronic capture, there is still on-going serious difficulty in agreeing the ‘language’ needed to deal with construction concepts. While there have been several attempts to create vocabularies, classification systems and thesauri, ontologies offer the prospect of a much richer method of relating information. The reality however is that “in spite of the huge amount of research in computer-aided construction to date, there is no large-scale machine-readable ontology for construction” [16].

The main difficulties in generating a common ontology are:

- agreeing a common representation
- using a large enough vocabulary
- avoiding the problems of meanings changing over time.

While an agreed formal ontology for the construction industry may well therefore be a chimera, it would still seem possible that language [sub]sets can usefully be developed and agreed for specialised domains while

general terms would be used at a high level for general construction concepts.

KLICON tested a methodology developed by BRE to generate [subset] language classifications semi-automatically. The methodology uses a web based site extraction and classification tool (*Extractor*) [17]. The tool provides classification of contents of an information web site. It links this to a thesaurus for broadening the search terms (the Canadian Thesaurus of Construction Science and Technology). The tool also links to construction specific search engine (in this case, *Signpost*).

Extractor is essentially a ‘spider’ which retrieves all accessible pages from web sites and automatically creates an initial site-specific classification system. The pages are parsed for links and these links are then followed. It also includes additional capabilities which allow links containing specified strings to be followed. It can also understand ‘frames’ and extract information from databases. Table 6 shows the *Extractor* data structure.

The Automatic Site Classification program builds a tree structure from the *Extractor* output¹⁴. The initial keyword ordering ensures that the most important keywords are classified first. The majority subset condition provides a natural way of structuring words, producing a balance between a broad flat tree and a narrow deep one. The percentage similarity parameter (initially 50%) can be altered to deepen or flatten the tree.

The Site Navigation tool enables quick and easy construction of a relevant classification system, avoiding the more usual problems of:

13. This aspect of the research was conducted primarily by a team led by David Bloomfield of BRE, with support from the UMIST research team, on data supplied by, and with the support of, Arup & Partners. Text for this portion of the paper comes from this team.

14. It does so in the following manner.

- Keywords (kw1) are ordered according to score.
- Each keyword (kw1) is compared against the URL list of all keywords (kw2) currently assigned a classification.
- If over half of kw1’s URL references are also in kw2’s list (i.e. refer to the same documents) the keyword is deemed to be similar in meaning to the first or kw1 is a *majority subset* of kw2.
- kw1 is placed in a classification tree.
- If there are many possible majority subsets, the word is placed as a subset of the deepest nested majority subset in the tree.

Table 6. The *Extractor* data structure

Automatic classification number	Total score for the Keyword	No of occurrences	Comma delimited list of synonyms	Comma delimited list of tripples [URL, Title, Score]
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1. full text searching – too much information;
2. classification systems –
 - standard classification systems providing too high a level to be useful,
 - bespoke classification systems being time consuming to devise.

The methodology offers three kinds of classification systems:

- Automatic Classification - machine derived as described above;
- Site Specific classification - devised by domain experts on the basis of the extracted keywords;
- Uniclass – enables users to use a more standard classification system.

At the 90% complete point of KLICON, we are at the stage where Arup’s design best practice guides have been reviewed using *Extractor* and testing by Arup of the search methodology is at an advanced stage. The initial findings suggest that the *Extractor* approach is certainly less expensive than contemporary third generation knowledge management tools, and as such more appropriate to Small and Medium Enterprises. There are also indications that *Extractor* works without a predefined taxonomy, although testing and evaluation of this aspect is not yet completed.

If such techniques can be shown to permit new and improved ways of locating information based on their semantic content alone, rather than having to create taxonomies and ontologies, low cost, easy-to-use tools could be built and applied that would obviate the need for the more expensive systems currently on the market. Not only would the IT be less costly but the human-intensive activities of classification and description of documents and web pages would be avoided. Pre-defined ontologies would not be the pre-

requisite to successful knowledge management that they have seemed in the past to be.

8 Evaluation of the Two KMS in Terms of Dixon’s Framework and the Implications on Ontology

Both the Skanska and the Arup Knowledge Management Systems appear to be working well, yet they were quite different in their structure. What does this tell us about the type of IT support that is appropriate for Knowledge Management in briefing?

The Arup knowledge management support required a system that worked in an unstructured data set. There are multiple application domains, and many different gatekeepers. The relevant data set is almost impossible to predict *a priori*. In such a situation one would expect an ontology to be important. Without at the least a taxonomy the meaning of terms is questionable and the resulting information (let alone knowledge) probably meagre at best.

The key points of the Arup exercise are that:

1. the domain search area is unstructured
2. *Extractor* appears to be able to obviate the need for a predefined ontology (or taxonomy) to a significant degree.

The Skanska domain on the other hand is a highly specific, structured one. It refers only to the specific knowledge needed for the ‘design-build’ bidding of the LNG tanks. (Other possible applications are contemplated in the future but these too are seen as highly domain specific and structured, comparable to the LNG tanks.) There are few gatekeepers, and the domain is highly repeatable. Here a formal ontology

was found to be less critical (a) because of the compactness of the knowledge set, (b) because of the ready identification of 'knowledge owners' and the ability to bring their tacit knowledge quickly into play.

In neither case was Dixon's schematisation really applicable. Both delivered explicit information. (Skanska's gave quicker access to relevant tacit). But the issue was not the relevance of routineness or frequency in the sense that Dixon described the 'Nature of the Task'. It is the degree of structure in the data set, together with the degree of tacit knowledge readily available in support of the explicit knowledge, that would appear to be the determining factors.

9 Conclusions

Information Technology is relentlessly changing our ability to manage, in construction as elsewhere. But as many researchers and managers have found, it is not necessarily the Technology that is the determining factor in applying IT successfully so much as culture and organisation. This is as true of Knowledge Management as of other applications. These are certainly findings echoed in KLICON where organisational

culture has been seen to influence IT applications significantly.

To design an effective knowledge management system it is important to have a proper understanding of the context in which the knowledge transfer is to take place, particularly the type of knowledge and the target audience [Dixon]. Modelling formalisms offer efficiency gains in information use/ knowledge re-use but care has to be given to content design and to the cost/benefits of the proposed application [the LNG case]. The challenge, for the industry, is less the development of new technology – of which there is plenty [Table 2 etc.] – than the proper application of what is available [LNG].

Information overload is a major problem. Good content design is important and can help reduce overload [LNG]. Taxonomies and ontologies help give meaning to data but are expensive and not always fully effective. The extraction tool developed by BRE would appear to offer particular promise in that relationship categories are created automatically and at very low cost, thereby substantially obviating the need for more expensive taxonomies. Pre-defined ontologies may therefore not always be the essential requirement to effective knowledge management that they have seemed in the past.

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