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Live Capture and Reuse of Project Knowledge in Construction Organisations

ABSTRACT

It is important that the knowledge generated on construction projects is captured and shared between project team members for continuous improvement, to prevent the 're-invention of the wheel' and to avoid repetition of previous mistakes. However, this is undermined mainly by the loss of important insights and knowledge due to time lapse in capturing the knowledge, staff turnover and people's reluctance to share knowledge. To address this, it is crucial for knowledge to be captured 'live' in a collaborative environment while the project is being executed and presented in a format that will facilitate its reuse during and after the project. This paper uses a case study approach to investigate the end-users' requirements for the 'live' capture and reuse of knowledge methodology, and shortcomings of current practice in meeting these requirements. A framework for the 'live' methodology that satisfies the requirements is then presented and discussed.

Keywords: Knowledge management, reusable project knowledge, live capture and reuse, CAPRIKON, knowledge base, post project reviews.

Introduction

The growing importance of KM is often related to the emergence of the knowledge-based economy and the importance of knowledge in providing competitive advantage (Demarest, 1997; Davenport *et al.*, 1997; Drucker, 1998; Bollinger and Smith, 2001) and there is evidence that this has been recognised by the construction industry. A survey of UK project-based organisations shows that about 50% of the respondents (majority were from the construction industry) noted that KM would result in new technologies and new processes that will benefit the organisations (Egbu, 2002). This finding is supported by another survey of construction organisations which reveals that about 40% already had a KM strategy and another 41% planned to have a strategy within a year (Carrillo *et al.*, 2003). Furthermore, about 80% also perceived KM as having the potential to provide benefits to their organisations, and some had already appointed a senior person or group of people to implement their KM strategy (Carrillo *et al.*, 2003). Despite this growing awareness of the importance of KM to the industry, there are limitations in the current practice for the capture and reuse of project knowledge. In particular, there are problems with the loss of knowledge due to time lapse in capturing the knowledge, high staff turnover and reassignment of people (Kamara *et al.*, 2003). To address these issues, it is crucial for the knowledge to be captured ‘live’ (i.e. once it is created or identified) in a collaborative environment during the course of the project. This paper presents the findings from six case studies conducted on the current practice for the capture and reuse of project knowledge in the construction industry. It forms the first stage of work done as part of the research project ‘Capture and Reuse of Project Knowledge in Construction’ (CAPRIKON) which aims to develop an appropriate methodology for ‘live’ capture and reuse of project knowledge in construction. This paper starts with a review of knowledge capture and reuse, and summarises related work. It then makes the case for ‘live’ capture and reuse of knowledge in construction project before presenting the findings of the case studies undertaken. These findings are used to formulate a set of requirements for a KM methodology to address the shortcomings of current approaches.

Knowledge Capture and Reuse

KPMG (1998) defines knowledge management as a systematic and organised attempt to use knowledge within an organisation to transform its ability to store and use knowledge to improve performance. Different researchers have used different terms for the same knowledge management processes or stages (e.g. Soliman and Spooner, 2000; Davenport and Prusak, 2000; Mertins *et al.*, 2001; Bhatt, 2001; Tiwana, 2000; and Rollett, 2003). What differentiates each of these is the difference in perspective, focus and level of detail. Bhatt (2001) delineates the sequence of the knowledge management processes as: knowledge creation, knowledge validation, knowledge presentation, knowledge distribution and knowledge application. However, there is evidence that knowledge management processes may not exist in that linear sequence. Demarest (1997) notes that there can be some iterations between the knowledge management processes such as that between the embodiment (i.e. presentation) and dissemination (i.e. distribution) of knowledge. His study also reveals that some of these stages may exist simultaneously, such as in the case of the construction (the process of discovering and structuring knowledge) and use of knowledge, where people may have put the knowledge into practice while it is being ‘constructed’. The knowledge management process models also differ in the level of detail: some do not take into consideration the issue of knowledge obsolescence in knowledge management (e.g. Demarest, 1997; Soliman and Spooner, 2000; Kululanga and McCaffer, 2001) while others do not address the need to validate the knowledge. Based on the KM process models that are developed within the context of construction (i.e. Robinson *et al.*, 2001; Kululanga and McCaffer, 2001), four main KM processes which have incorporated the notions of knowledge obsolescence and validation (see Table 1) are proposed:

- Capture;
- Reuse;
- Sharing; and
- Maintain.

[Insert Table 1: Relationship between the capture, sharing, reuse and maintenance of knowledge]

(1) Capture

Knowledge capture comprises three sub-processes:

- *Identifying and Locating Knowledge* - This deals with the identification of the types/categories of knowledge to be managed, and the location of learning situations (Kamara *et al.*, 2003) where most of the new knowledge is created and the people with the knowledge required.
- *Representing and Storing Knowledge* - This encompasses indexing, organising and structuring knowledge (Robinson *et al.*, 2002; Goodman and Chinowsky, 2000; Rollett, 2003) into theme-specific knowledge areas (Maier, 2002), and authoring knowledge (Markus, 2001) in the standard or format specified with the details required, adding context to the knowledge depicting where the knowledge was generated and used, where the knowledge may be useful and the conditions for reuse (Hansen and Davenport, 1999).
- *Validating Knowledge* - This is intended to ensure the credence of knowledge captured, and that the knowledge captured is stored with all the relevant contextual details and in the format required.

(2) Sharing

This is about the provision of the right knowledge to the right person at the right time (Robinson *et al.*, 2002; Mertins *et al.*, 2001) or within the shortest time possible. This process can be passive (e.g. publishing a newsletter or populating a knowledge repository for users to browse), or active (e.g. 'pushing' knowledge via an electronic alert to those who need to know) (Markus, 2001). Although the tools and methods used are dominated by ICT applications (Mertins *et al.*, 2001), effective knowledge sharing are also underpinned by a supportive organisational culture and trust between the people involved (Newell *et al.*, 2002).

(3) Reuse – Adapting and Applying Knowledge

This covers the reuse of knowledge through the re-application of knowledge, such as the re-application of best practice as mentioned by Szulanski (2000), and the reuse of knowledge for innovation with necessary adaptation or integration (Majchrak *et al.*, 2004;

Egbu *et al.*, 2001). The reuse of knowledge through adaptation involves re-conceptualising the problem and searching for reusable ideas (i.e. knowledge), scanning and evaluating reusable ideas, analysing the ideas in-depth and selecting the best idea, and developing fully the reused idea, which may ultimately lead to innovation (Majchrak *et al.*, 2004).

(4) Maintain – Archiving and Retirement of Knowledge

Knowledge may become obsolete over time (Pakes and Schankerman, 1979; Rich and Duchessi, 2001) due to the development of a discipline, and the employment new information, rules and theories (Bhatt, 2001). Maintaining knowledge covers reviewing, correcting, updating and refining knowledge to keep it up-to-date, preserving, and removing obsolete knowledge from the archive (Rollett, 2003).

Knowledge Management Research in Construction

In view of the growing interest and recognition of the importance of KM in construction, a number of research projects have been undertaken in this area. The *Cross-sectoral Learning in the Virtual entERprise(CLEVER)* project was aimed to derive generic structures for KM practices and to develop a framework for the transfer of knowledge in a multi-project environment in construction (Kamara *et al.*, 2002). The framework developed assists construction firms in articulating their KM problems and in selecting an appropriate strategy for knowledge transfer (Kamara *et al.*, 2003). Meanwhile, another KM research project entitled *Knowledge Management for Improved Business Performance (KnowBiz)* was conducted to establish the relationship between KM practices and business performance in construction firms (Carrillo and Anumba, 2000). To enhance organisational learning between construction project partners, the *Building a Higher Value Construction Environment (B-Hive)* project developed the Cross-Organisational Learning Approach (COLA), which is an IT-supported innovative process for review, evaluation, feedback and organisational learning (B-Hive, 2001). CIRIA also contributes to KM research by conducting the *Business case for knowledge management: guidance & toolkit for construction* to provide good practice guidance and a supporting management toolkit for practitioners to develop business plans and metrics for KM within

their company (CIRIA, 2005). Through benchmarking, the *Benchmarking Knowledge Management Practice in Construction* project attempted to provide a deeper understanding of successful knowledge management programmes and the approaches used to successfully overcome the challenges, and to identify effective ways to improve both the short and long-term competitiveness of participating companies (Dent and Montague, 2004). Cooperating with BAE Systems, the *Sharing Knowledge between Aerospace and Construction* project investigated the extent to which managerial practices can be shared between the aerospace and construction sectors. It also sought to develop an approach to knowledge sharing that could be implemented as part of a knowledge management initiative within individual companies (Green *et al.*, 2004). Furthermore, there are some projects conducted to explore the potential of IT in KM and specific areas. For the former, the examples are the *Knowledge and Learning in CONstruction (KLICON)* project (KLICON, 2001), and the EU-funded *Methodology, tools and architectures for electronic COnsistent knowledGe maNagement across prOjects and between enterpriSes in the construction domain (e-COGNOS)* project (Whetherill *et al.*, 2002). For the latter, the examples are:

- *An Approach to Knowledge Management for SMEs*, which aims to improve KM in SMEs in construction industry (Boyd *et al.*, 2004);
- *Creating, Sustaining and Disseminating Knowledge for Sustainable Construction: Tools, Methods and Architecture (C-SanD)*, which focused on the development of a mechanism, which includes a software tool, to facilitate the capture, retrieval and creation of knowledge pertaining to sustainability in construction (C-SanD, 2001);
- *A Knowledge Transfer Approach to Continuous Improvement on PFI Projects*, which focused on identifying the scope for improvement and knowledge transfer in Private Finance Initiative (PFI) projects (Robinson *et al.*, 2004); and
- *Knowledge Management for Sustainable Construction Competitiveness*, which investigated the associated challenges and effectiveness of the strategy adopted in managing knowledge resources and capabilities for construction, and how the strategy contributes to the project success and sustained organisational competitiveness (www.knowledgemanagement.uk.net).

The literature reveals that the aforementioned research projects are focused at either:

- Strategic and business perspectives (CLEVER, KnowBiz, ‘Business case for knowledge management: guidance & toolkit for construction’ and ‘Benchmarking Knowledge Management Practice in Construction’);
- Specific types of knowledge, i.e. knowledge pertaining to sustainability (C-SanD, 2001), PFI projects (Robinson *et al.*, 2004), management practice (Green *et al.*, 2004) and sustainable competitiveness (www.knowledgemanagement.uk.net);
- Specific project phases, i.e. KLICON which focused on the transfer of knowledge from early design to detailed design stages and to the contractor (McCarthy *et al.*, 2000); or
- Specific type of construction organisation, e.g. SMEs in Boyd *et al.* (2004).

The need for an approach which is capable of capturing project knowledge, irrespective of the type of project, the type of construction organisation and project phases, and particularly capturing the knowledge ‘live’ (Kamara *et al.*, 2003), has not been adequately addressed. The importance of a ‘live’ methodology proposed by Kamara *et al.* (2003) to address the limitations of current practice is discussed in detail in the next section.

The Importance of ‘Live’ Capture and Reuse of Project Knowledge Approach

The imperative of ‘live’ capture of knowledge is supported by the recent survey of organisations involved in PFI (Private Finance Initiative) projects where the ‘live’ capture of knowledge is noted as crucial by 76% of construction organisations and 70% of client organisations (Robinson *et al.*, 2004). Furthermore, the need for ‘live’ capture of knowledge is also being indirectly addressed by Whetherill *et al.* (2002). They assert that a construction organisation’s only sustainable advantage lies in its capability to learn faster than its competitors and the rate of change imposed by the external environment, and that there is a need to ‘integrate learning within day-to-day work processes’. Kamara *et al.* (2003) have outlined the potential benefits of ‘live’ capture and reuse of project knowledge as follows:

- Facilitate the reuse of collective learning on a project by individual firms and teams involved in its delivery. More insights are likely to be captured in the collaborative

environment, as each of the members in the project team knows only bits of the whole story about the project (Kerth, 2000);

- Provide knowledge that can be utilised at the operation and maintenance stages of the assets' lifecycle;
- The 'live' methodology for knowledge capture proposed by Kamara *et al.* (2003) involves the members of the supply chain in a collaborative effort to capture learning in tandem with project implementation, irrespective of the contract type used to procure the project from the basis of both ongoing and post-project evaluation;
- Benefit the client organisations with enriched knowledge about the development, construction and management of their assets; and
- Benefit the construction industry as a whole. Project teams would be enabled to manage better the subsequent phases of a project, to better plan future projects and to collaborate better with other organisations through the capture and transfer of learning from a previous phase or projects.

Other potential benefits identified include:

- Prevent knowledge loss due to time lapse in capturing the knowledge. This is supported by Ebbinghaus's (1885) and Linton's (1975) findings which reveal that the percentage of human memory retained on a set of data depletes over time and that the probability of forgetting an event (and knowledge) increases as time elapses;
- Maximise the value of reusing the knowledge captured through 'live' reuse. The true benefit of capturing knowledge comes only when the knowledge is being used (McGee, 2004), particularly if the knowledge is being reused 'live' after it has been captured. This is obvious when the benefit accrued through reusing the knowledge is time-related (e.g. leading to a saving of £x per day); and
- Enable the knowledge to be disseminated for reuse as soon as possible (i.e. 'live') before the opportunities for reusing the knowledge diminish. This helps to seize every knowledge reuse opportunity.

Research Methodology

A case study approach was selected because it provided an in-depth insight into the current approaches for the capture and reuse of project knowledge within the case study companies. The case studies involved identifying suitable persons in each organisations and conducting semi-structured interviews. A total of 18 senior staff from six companies were interviewed to ensure that a comprehensive view was obtained. Their job titles included: Group Knowledge Manager, Director of Business Development, Knowledge Researcher, IT Manager, Procurement Manager, Head of Research and Development, Company Partner and Managing Director. Each interview lasted one to two hours and was supplemented by presentations of the IT tools used for managing knowledge and sample documents showing the format used for capturing knowledge. Background information on the case study companies is presented in Table 2:

[Insert Table 2: Background of Case Study Companies]

Case Study Findings

The case studies explored the various types of reusable project knowledge which are important to be captured from construction projects, the learning situations/events from which reusable project knowledge is created (Kamara *et al.*, 2003) and can be captured, current approaches for the capture and reuse of project knowledge, and the requirements for 'live' capture and reuse of project knowledge. However, this paper focuses on the findings about the latter area and an assessment of the capability of current approaches to facilitate 'live' capture and reuse of project knowledge.

Shortcomings of Current Approaches

KM tools used for the capture and sharing of knowledge can be categorised as KM techniques (non-IT tools) and KM technologies (IT tools) (Al-Ghassani, 2003). Various KM techniques and technologies were being used by the case study companies (see Table 3). Some of the KM techniques, such as Communities of Practice, were also aided by KM technology.

[Insert Table 3: KM techniques and technologies adopted by the case study companies]

As knowledge management in the UK construction is still at an embryonic stage (Carrillo, 2004; McConalogue, 1999; Robinson *et al.*, 2001), it is therefore not surprising to find shortcomings in the current approach, particularly in terms of the capability to facilitate the 'live' capture and reuse of project knowledge. These shortcomings include:

- Post Project Reviews (PPR)

PPR are normally time-consuming and slow. The time lapse between the discovery and creation, and the capture and sharing of knowledge leads to the loss of important insights and does not allow the current project to be improved by incorporating the knowledge gained as the project progresses (Kamara *et al.*, 2003). Two major shortcomings of current PPR practice were identified in the case studies: first, in three out of the five cases, the learning captured was not being shared effectively and there was no established way to locate the learning embedded in reports for reuse. Secondly, the current practice of distilling the key learning captured in PPR into point form is too brief for understanding and efficient sharing of the knowledge captured. Company B attempted to overcome this problem by involving non-project participants in the PPR so that they would have a better understanding of the learning which was captured in point form. However, the effectiveness of this method is restricted by the number of people that can join the PPR.

- Communities of Practice (CoPs), Groupware and Forums

Whilst powerful as a knowledge sharing tool, the shortcoming of CoPs, groupware and forum is their passive nature (i.e. if a question is not asked in the forum, the knowledge pertaining to the question is less likely to be shared). In addition, as Company A's forum was restricted to senior members of the company (mainly partners and associates), other members of staff who were excluded from the forum failed to benefit directly from the practice.

- Recruitment

Recruitment is more a practice for getting new people to fill existing and future anticipated knowledge and skills gaps (Harman and Brelade, 2000) than for the capture

and reuse of project knowledge. Other than this, it is also a lengthy process undermined by the difficulties in finding and assessing experts with the required knowledge (Harman and Brelade, 2000) and the scarcity of experts (Maier, 2002).

- Training, Team Meetings, Road Shows, Presentations and Workshops

The time lapse between the capture of knowledge from a project to the sharing of the knowledge through these knowledge sharing mechanisms also suggests that they do not adequately facilitate the ‘live’ capture and reuse of project knowledge. Furthermore, the scope of knowledge available for sharing through the aforementioned practices are also constrained to those captured by the trainers and participants, and are normally topic-specific.

- Succession Management and Mentoring

Succession management was only used to transfer a specific type of project knowledge in the case studies. It was found not very successful due to the reluctance of people to confine their learning to a specific area. For mentoring, it is primarily focused on ‘career development’ (Tabbron *et al.*, 1997) and developing necessary transitional competencies for people to take up new tasks and challenges (Von Krogh *et al.*, 2000). This practice is influenced by the number of protégés that a mentor can handle at any point in time, the distance between the mentor and potential protégé, issues related to cross-gender mentoring (Clawson and Kram, 1984), time constraints (Tabbron *et al.*, 1997) and the ability of the mentor to transfer his/her knowledge to the protégé (Megginson, 2000; Carrillo, 2004).

- Documentation of Knowledge

Companies A and D’s checklist-based design handbook and case studies of project undertaken were criticised by their employees for lack of detail and reuse value. Companies C and F’s practices (i.e. the creation of feedback notes which were accessible online and the maintenance of a knowledge base) were very mature and tested tools of documenting knowledge. However, there is no mechanism to ensure that the knowledge is captured ‘live’ or within a short time frame after its creation or generation. Furthermore, the knowledge captured by Company C’s feedback notes is limited to that created or

identified by the company while the views of other project team members are not captured.

- Partnership Arrangement and Research Collaboration

Attempts to facilitate the sharing of knowledge between construction organisations through partnership arrangements and research collaboration cannot guarantee that critical or key knowledge will be shared. This is because:

- a) The construction organisations collaborating in one project may actually be competing in another project (Kamara *et al.*, 2003); and
- b) Corporate security restrictions imposed on posting of information/knowledge have further added to the problem (Ardichvili *et al.*, 2003). People have been indirectly discouraged from sharing their knowledge especially where the boundary of such restrictions is not made clear.

- Knowledge and R&D teams

The nature of work done by the knowledge and R&D teams seemed to be more relevant to knowledge creation and innovation than the capture of reusable project knowledge. Moreover, there was no established way to share the knowledge created.

- Preparation of the Standard Reusable Details

This practice is probably only economically viable for companies with a high proportion of similar projects. Furthermore, for people other than the creator of the documents or drawings, the reuse may pose some problems as the rationale for the design and changes made might not always be clear to them.

- Reassignment of People

The success of reassignment of people for knowledge capture and reuse depends heavily on: (1) the staff turnover rate (Kamara *et al.*, 2003), which is 20.2% in 2003 (CIPD, 2004), and (2) the individual's ability to capture the learning from his/her previous project and then reuse the knowledge in another project or share the knowledge with others.

- External Sources of Knowledge

The external sources of knowledge may lead to time and cost savings for the capture of knowledge, particularly those that require a relatively long time to capture (such as knowledge on whole life costs). However, what the companies obtained from the external sources was general project knowledge, rather than detailed reusable project knowledge.

- Project Extranets

Currently, the role of project extranets is more significant in the sharing of documented or explicit knowledge (such as the reusable project documents) rather than tacit knowledge. In addition, there is no specific template or mechanism specifically designed for the capture of project knowledge.

- Expert Directory

Expert directory was used for the capture of knowledge on ‘who knows what’ only. It is a crucial tool for connecting the people who need a knowledge to the people with the knowledge, but not appropriate for the capture and creation of knowledge.

- Custom-designed Software

Tan *et al.* (2004) have identified various types of reusable project knowledge in construction, which need to be managed. Custom-designed software used for the capture of project knowledge were, however, narrow in scope and focused on specific types of project knowledge only. For instance, Companies B and D’s custom-designed software targeted only costing knowledge and knowledge about the performance of suppliers.

The findings from the case studies revealed that although there are various KM techniques and technologies available for different KM sub-processes, none of the KM technologies or techniques represents a complete solution. The findings further revealed that both KM techniques and technologies have their strengths and shortcomings, and in fact complement each other.

Requirements for ‘Live’ Capture and Reuse of Project Knowledge

The companies identified the following requirements for the ‘live’ capture and reuse of project knowledge:

- (1) Cost – The general consensus among the case study companies was that the methodology used for the capture and reuse of the reusable project knowledge should not incur significant additional cost to the companies. Furthermore, one of the companies pointed out that the cost incurred should be justifiable by the benefits (such as increase in profitability and reduction in production cost) brought about through the reuse of the knowledge captured;
- (2) Workload – The companies emphasised that any methodology developed should not create significant additional workload to members of staff in view of their existing heavy workload. They also pointed out that the additional workload might not be covered by the worker’s current job description or employment contract;
- (3) Legal Issues – An interviewee mentioned that some companies prohibit their members of staff and collaborating companies from disclosing the information and knowledge learned to other organisations which are not involved in the project. A solution is required to ensure that the sharing, capture and reuse of knowledge from a project is not in breach of the copyright and the conditions of contract;
- (4) Accuracy – Any methodology developed must be capable of capturing and representing the knowledge accurately; and
- (5) Representation of knowledge – The companies’ main requirements for knowledge representation are summarised in Table 4. Companies C and F recommended their practice for representing the project knowledge.

[Insert Table 4: Companies' practice and requirements on knowledge representation]

Addressing the Requirements for ‘Live’ Capture and Reuse of Project Knowledge

A methodology for the ‘live’ capture and reuse of project knowledge can be developed based on the various requirements identified from the case studies. The main requirements identified include: (1) Cost and workload; (2) Legal issues; (3) Accuracy of knowledge captured; and (4) Representation of knowledge.

(1) Cost and Workload

There are three cost components for the development and running of a KM system (Robinson *et al.*, 2004) which have to be managed and taken into consideration in the development of the methodology:

- The *staff costs* (KM team component) associated with the roles and skills required for knowledge transformation;
- The *organisational or (re)organisational costs* (KM process component) associated with core and supporting business processes enabled, affected or re-engineered; and
- The *KM infrastructure component costs* associated with information and communications technologies (hardware and software), setting up or maintaining people sharing networks, systems or techniques to provide knowledge creation and sharing capability and to facilitate knowledge transformation.

The following recommendations can help to reduce and to prevent additional cost in the aforementioned cost components:

- To keep the staff cost low, the ‘live’ knowledge capture and reuse methodology should avoid the need for additional staff and the creation of significant additional workload for existing staff. Cost and workload are in fact interwoven as Robinson *et al.* (2004) have shown that staff cost is associated with the role or workload for knowledge transformation. Therefore, to resolve this matter it is suggested that most, if not all, of the relevant tasks and additional workloads created are handled by ICT, i.e. through the application software developed;
- To reduce the *organisational or (re)organisational costs*, the methodology developed should build on existing practice if possible (i.e. integrated into something that people already do, such as meetings and reviews) for the capture of knowledge. This can help to prevent significant additional costs due to the need to re-engineer the current processes and the creation of additional workload; and
- To reduce the *KM infrastructure component costs*, the application software developed as part of the ‘live’ knowledge capture and reuse methodology should be capable of running on existing ICT systems and platforms which are commonly used by construction organisations or that are readily available in the market. Otherwise, it could lead to significant additional cost and render any plan to implement the methodology commercially unfeasible.

(2) Legal issues

To overcome the client's potential restriction on sharing information and knowledge with parties not involved in the project, the knowledge to be shared can be limited to those captured from the current project. The sharing of knowledge captured from other projects should be voluntary. An appropriate legal framework for 'live' knowledge capture and reuse needs to be developed and agreed between the project team members.

(3) Accuracy

A validation mechanism is required to ensure that the knowledge entered is accurate and valid. Company F's practice can be used as a reference, as the new knowledge captured has to be validated by a panel of experts before it is published on the company's intranet for reuse.

(4) Representation of Knowledge

A standard format for representing the reusable project knowledge captured was proposed and subsequently validated in the workshop conducted. This covers:

a) *Background information on the project* – These include:

1. Project title;
2. Location;
3. Sector;
4. Type of project;
5. Type of contract;
6. Start and completion dates;
7. Duration;
8. Companies involved; and
9. Date on which the knowledge is captured, which is included as an attempt to address the knowledge obsolescence issue.

b) *Abstract* – This is a short description of the knowledge captured.

c) *Details* – This is the detailed explanation of the knowledge so as to help others to understand and hence reuse the knowledge. This was identified as a crucial part of knowledge representation by most of the case study companies. The textual details of knowledge can be supplemented by video clips which capture the detailed explanation made by the provider of the knowledge, as well as relevant images and photos. Apart

from this, the benefits of applying and reusing the knowledge, such as cost saving, can also be mentioned in this section.

- d) *Conditions for reuse* - This spells out the condition(s) for reusing a particular knowledge entry.
- e) *Reference* - This contains the reference to other relevant knowledge captured in the system, project documents, publications (e.g. books and reports), Websites and people, where further details may be obtained.

In addition, a knowledge map and an index should be provided to give users an overview of the knowledge available as suggested by Maier (2002).

Enabling Technologies and Techniques

The essence of the 'live' capture and reuse of project knowledge methodology lies in allowing users at different locations to enter and access the knowledge captured in real-time. Given the main strength of Web-based KM technologies (such as groupware, expert directories and knowledge bases) is their capability to connect distant offices together, provide fast access and location of knowledge captured, facilitate sharing of knowledge, and provide huge knowledge storage space, they are an integral element of the methodology for the 'live' capture and reuse of project knowledge. Among the KM technologies available, a web-based knowledge base seems to be the current practice closest to meeting the requirements identified by the case study companies. The reasons are as follows:

- *No significant additional cost*: A Web-based knowledge base can run on existing systems and platforms commonly used by most of the construction organisations. This eliminates the chances of incurring significant additional cost for the implementation of the methodology;
- *No significant additional workload created*: The only requirement is the need to enter project knowledge into the knowledge base;
- *Accuracy of knowledge ensured*: A mechanism can be built into the knowledge base for monitoring the validation of knowledge submitted as a means of ensuring its accuracy;

- *Legal framework for solving knowledge's copyright issues:* The legal framework used in project extranets for the sharing of project documents amongst the project team members can be adapted for the use of this methodology. As this is an adaptation of an existing practice (i.e. for the users of project extranets), it may receive lesser resistance from the users; and
- *Allowing a standard format for representing project knowledge to be specified:* Another built-in mechanism can be created to ensure that project knowledge is entered in accordance with the format developed.

A web-based knowledge base can be supplemented by PPR. Post project reviews are the most common approach used in the construction industry for the capture and reuse of project knowledge (Orange *et al.*, 1999). PPR provides an opportunity for project team members from different organisations to share and even explicate their tacit knowledge through the face-to-face interactions facilitated before the team dissolved. In addition, the discourse amongst the project team members in PPR may lead to innovation and better idea than that can possibly be captured from an individual. This is crucial as everyone only knows bits of the whole story about a project (Kerth, 2000). Therefore, PPR can help to ensure that a more complete set of project knowledge is being captured than through knowledge base alone. The main shortcomings of the PPR identified from case studies are: (1) its susceptibility to knowledge loss problem due to time lapse in capturing knowledge, and (2) the lack of an established format for the representation and a mechanism for sharing knowledge captured. The former shortcoming can be addressed by the attempts to capture project knowledge from routine project meetings (which are conducted at weekly or bi-weekly basis) and project reviews conducted at various project stages in addition to PPR. As the knowledge capture mechanism is built on existing practices, it avoids the creation of new practice which may lead to resistance from the users. For the latter shortcoming, it is resolved by using the web-based knowledge base for the representation and sharing of knowledge captured from PPR.

A Methodology for the ‘Live’ Capture and Reuse of Project Knowledge in Construction

Based on the findings from the case studies, a methodology for the ‘live’ capture and reuse of project knowledge has been developed. The proposed methodology attempts to capture reusable project knowledge generated from the various learning situations once the knowledge is created or identified (i.e. ‘live’) through project reviews/meetings and individuals. The methodology comprises:

- A Web-based knowledge base – This is where the Project Knowledge File (PKF) of a project is stored. The knowledge base will run in the project extranet environment where only designated users from organizations collaborating in a project can gain access into the system;
- A Project Knowledge Manager (PKM) – This is a role, normally charged to a planning supervisor, project manager or other designated person, to manage the knowledge base (i.e. the development of a Project Knowledge File for a project) and the Integrated Workflow System (IWS); and
- An Integrated Workflow System (IWS) – This delineates, executes and monitors the mechanism for the capture, validation and dissemination of the project knowledge captured. A Project Knowledge Manager (PKM) may configure the IWS to suit individual requirements of the project.

The details of the ‘methodology for the ‘live’ capture and reuse of project knowledge, and how the PKM, IWS and knowledge base interact with each other, are depicted in Figure 1. A template is developed to ensure that the project knowledge is captured in the stipulated format of the knowledge base. This is followed by a validation process, which is essentially the review of the knowledge captured by a group of designated people, before the knowledge can be shared and reused. The knowledge is disseminated once it has been validated (i.e. ‘live’) via email, although users can also access the knowledge from the knowledge base. All the project knowledge captured from a project will be recorded in a designated file, i.e. the Project Knowledge File (PKF). For accessibility and security reasons (as it provides access to more than one organisation involved in a project), the knowledge base will run on a project extranet instead of a intranet.

[Insert Figure 1: Methodology for the 'live' capture and reuse of project knowledge in construction]

Implementation of the Methodology

The methodology for the 'live' capture and reuse of project knowledge will be encapsulated into a software application. The implementation of the methodology therefore involves the followings:

1. Installation of the software application;
2. PKM customises the system to suit the requirements;
3. Conduct training for the users on how to use the system;
4. Capture of project knowledge through:
 - Mode 1 - Project meetings/reviews; and
 - Mode 2 - Individual learning;
5. Project teams to browse through the Project Knowledge Files for relevant knowledge prior to the commencement of new project;
6. Project teams to apply the relevant knowledge with necessary adaptation; and
7. Project team members contributes their knowledge into the system, and the whole process repeats again.

This would allow vital knowledge from construction projects to be captured 'live' using different mechanisms to allow a greater chance of reuse at a later date.

Conclusions

This paper has established the importance of the 'live' capture and reuse of project knowledge approach in construction. It has also identified the shortcomings of current approaches for the 'live' capture of knowledge and the end-users' requirements for the development of the 'live' methodology through the case studies conducted. The major shortcomings of the current practices identified are:

- KM techniques (such as post project reviews and meetings) are mainly good in capturing project knowledge from people but are inadequate in facilitating 'live' sharing of the knowledge across distant offices. They mainly depend on face-to-

face interactions among people for knowledge transfer and are vulnerable when there is high staff turnover;

- Some KM technologies (such as Web-based knowledge base and extranets) are important in enabling ‘live’ sharing of project knowledge, but they still either lack an established mechanism to ensure that knowledge is captured ‘live’ from a project or an appropriate format for representing the knowledge captured; and
- Some tools are narrow in scope and only focused on the capture of specific type of project knowledge (e.g. the custom-designed software).

The various end-users’ requirements for the development of the ‘live’ methodology identified are as follows:

- The methodology should not create significant additional cost and workload to the companies;
- An appropriate legal framework is required to overcome the client’s potential restriction or copyrights problem on the sharing of knowledge;
- A validation mechanism is required to ensure the accuracy and correctness of knowledge before it is shared; and
- A standard format for representing the knowledge which contains the background information on the project, abstract, details, conditions for reuse and reference is required.

The paper has revealed that a combination of KM technology and KM technique will be the most pragmatic option in fulfilling the requirements for the ‘live’ capture and reuse of project knowledge methodology. A methodology was developed to assist companies in capturing and reusing their knowledge ‘live’, i.e. as it occurs and not at a time lapse. It comprises mainly a knowledge base (which runs on a project extranet), a format for representing reusable project knowledge captured, and a workflow depicting how reusable project knowledge is captured from project meetings/reviews and individuals, and how knowledge is validated and shared subsequently.

In this paper, the author had introduced the concept of ‘live’ capture and reuse of project knowledge in construction, and presented a detailed methodology on how this can be achieved in construction context. This is expected to bring tremendous benefits to the

construction industry because it helps to address the shortcomings of current practices in the capture and reuse of project knowledge, and also provides a methodology to enhance the cross organisational capture and sharing of project knowledge. Some of the key elements are generic and also applicable to other project-based organisations in other industries.

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Table 1: Relationship between the capture, sharing, reuse and maintenance of knowledge

CAPRIKON		Robinson <i>et al</i> (2001)	Kululanga & McCaffer (2001)	Bhatt (2001)	Rollett (2003)
Capture	<ul style="list-style-type: none"> • Identifying • Locating 	<ul style="list-style-type: none"> • Discovering • Locating • Capturing 	<ul style="list-style-type: none"> • Acquiring • Creating 	<ul style="list-style-type: none"> • Creation 	<ul style="list-style-type: none"> • Planning • Creating • Assessing • Integrating • Organising • Transferring
	<ul style="list-style-type: none"> • Representing • Storing 	<ul style="list-style-type: none"> • Organising • Storing 	<ul style="list-style-type: none"> • Storing 	<ul style="list-style-type: none"> • Presentation 	
	<ul style="list-style-type: none"> • Validating 			<ul style="list-style-type: none"> • Validation 	
Sharing	<ul style="list-style-type: none"> • Sharing 	<ul style="list-style-type: none"> • Sharing • Transferring 	<ul style="list-style-type: none"> • Sharing 	<ul style="list-style-type: none"> • Distribution 	
Reuse	<ul style="list-style-type: none"> • Adapting • Applying 	<ul style="list-style-type: none"> • Modifying • Applying 	<ul style="list-style-type: none"> • Utilising 	<ul style="list-style-type: none"> • Application 	
Maintain	<ul style="list-style-type: none"> • Archiving • Retirement 	<ul style="list-style-type: none"> • Archiving • Retirement 			<ul style="list-style-type: none"> • Maintaining

Table 2: Background of Case Study Companies

Company	Company background	Number of employees	Annual revenue (£)
A	Design Consultant	80	£4.3M
B	Design Consultant	850	£250M
C	Engineering Consultant	7000	£403M
D	Management Consultant	1200	£61M
E	Project Extranet Service Provider	31	£2M
F	Water Company	18000	£1860M

Table 3: KM techniques and technologies adopted by the case study companies

KM technique	Case Study Companies					
	A	B	C	D	E	F
Post project reviews	√	√	√	√	√	√
Communities of Practice		√	√			√
Documentation of knowledge	√		√	√		
Training	√			√		√
Forum	√		√			
Recruitment			√			√
External source of knowledge	√	√				
Reassignment of people		√	√			
Research collaboration				√		√
Partnership-like arrangements					√	
Preparation of standard reusable details		√				
Research & development				√		
Team meetings, road shows, presentations and workshops				√		
Knowledge team				√		
Succession management & mentoring	√					
KM technology	A	B	C	D	E	F
Groupware		√	√	√		√
Custom-designed software		√		√		√
Expert Directory		√	√			√
Project extranet		√				

Table 4: Companies' practice and requirements on knowledge representation

Company	How project knowledge is represented
A	a) General headings are provided on the type of project knowledge b) Case studies or detailed explanation of the knowledge to help others to understand and hence reuse the knowledge c) The conditions for reusing the knowledge must be made clear to the users d) Checklists to show: <ul style="list-style-type: none"> ▪ The issues relevant to the particular project ▪ The characteristics of the project that are related to the context for the reuse of the knowledge
B	Sharing the bullet-point learning in a Web environment, each with a short description prepared to give the audience basic background information. This is supplemented by video clips to capture the detailed explanation from the originator of the learning.
C	Establishing convenient means, such as people's personal profile and knowledge network aided by custom-designed IT-systems, for people to communicate with each other and share their knowledge. Some knowledge of technical and contractual issues are represented in the form of 'feedback notes' in accordance with the format specified. The 'feedback notes' are made available to the members of staff over the company's intranet.
D	A standardised approach is required. The knowledge captured must be organised and represented in a logical and simple to understand way, and readily accessible to others within the organisation. Knowledge on know-how to perform a specific task (such as how to approach difficult situations) can be captured in the organisation's standard procedures.
E	The methodology developed for capturing or representing the knowledge should avoid the introduction of excessive additional workload to people. The additional workload created should be integrated into daily job functions and be carried out within normal working hours.
F	Knowledge represented comprises two sections: <ul style="list-style-type: none"> ▪ Context of the knowledge such as the type of project and project stage, where the knowledge is concerned, and an explanation of how to reuse the knowledge; and ▪ The financial impact, such as the cost saving if the suggestion is implemented. Some process knowledge can be represented in the form of interactive process maps.

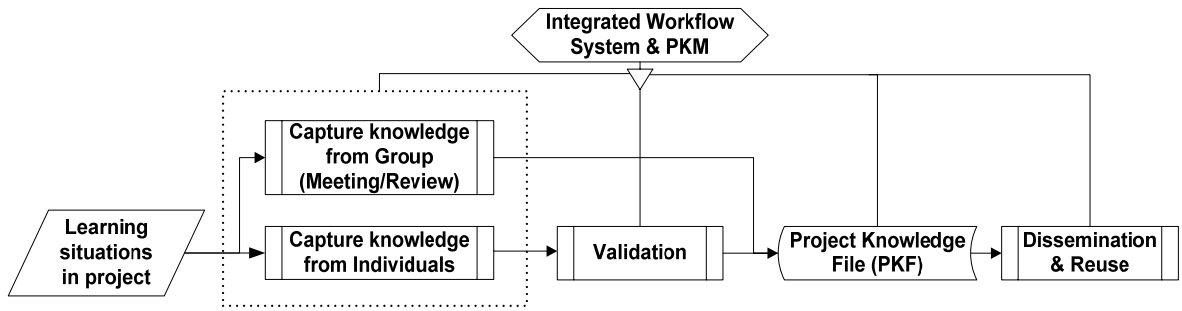


Figure 1: Methodology for the 'live' capture and reuse of project knowledge in construction

Tables

Table 1: Relationship between the capture, sharing, reuse and maintenance of knowledge

Table 2: Background of Case Study Companies

Table 3: KM techniques and technologies adopted by the case study companies

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Figure

Figure 1: Methodology for the 'live' capture and reuse of project knowledge in construction