LIVE CAPTURE AND REUSE OF PROJECT KNOWLEDGE IN CONSTRUCTION – A PROTOTYPE DEVELOPMENT

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ABSTRACT

In construction industry, project knowledge is often lost due to the time lapse in capturing the knowledge, staff turnover, and the disbandment of the project team after the completion of a project. The ability to capture important knowledge from ongoing projects in real-time not only can help to prevent the knowledge loss problem, it also enables construction organizations to get the most out of a knowledge captured through the 'live' reuse of the knowledge in other projects.

This paper describes the development of a prototype application called CAPRI.NET, which is an integral part of a methodology developed to facilitate the capture and reuse of project knowledge on a 'live' basis. The methodology, which comprises a Web-based knowledge base, an integrated workflow system (IWS) and a Project Knowledge Manager (PKM) as the administrator, allows project knowledge to be captured 'live' from ongoing projects. All project team members can retain a copy of the knowledge captured at the end of a project. Future work of the research includes the refinement of the prototype and an evaluation.

KEY WORDS

knowledge management, live capture and reuse, reusable project knowledge, project knowledge file, knowledge base

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INTRODUCTION

Using the term 'information' synonymously with 'knowledge', McGee (2004) states that the capture and presentation of real-time 'information' is crucial so that mishaps may be avoided, opportunities may be seized and unpleasant surprises eliminated. It is envisaged that the capture knowledge in real-time does not only lead to the various aforementioned benefits, it may also help prevent knowledge loss problem due to time lapse in capturing a knowledge. Further more, capturing a knowledge in real-time can also help to exploit the opportunity for reusing a knowledge. This concept is particularly relevant for construction industry which suffers from knowledge loss problem due to the disbandment of project team after the completion of a project, staff turnover and time lapse in capturing project knowledge through post project review.

This paper therefore describes the development of a methodology for the 'live' (i.e. real-time) capture and reuse of project knowledge in construction. This paper starts with a review of knowledge management in construction. It then makes the case for 'live' capture and reuse of knowledge in construction projects before describing the development of the methodology. Case study approach was used to identify the characteristics of reusable project knowledge in construction and the end-user requirements for the development of the methodology. How the various requirements for the development of the methodology identified were addressed are also discussed. Finally, the details of the methodology developed are presented and explained.

KNOWLEDGE MANAGEMENT IN CONSTRUCTION

Most of the knowledge of the construction industry is generated in projects during the process to deliver a custom-built facility in accordance with the client's requirements and business objectives. The ability to manage the knowledge generated from the projects not only can help to prevent the 'reinvention of the wheel' and the repetition of similar mistakes, but also serve as the basis for innovation, overall improvement and sustaining competitive advantage. However, to ability to learning from within and across projects are critical but difficult to achieve. This is often due to the tight timeframe of construction projects, and the lack of sufficient resources and standard work processes for managing project knowledge. Moreover, the fact that the project team either splits up or moves to another project after the completion of a project is also not conducive to the capture, sharing and reuse of knowledge across projects. As a result, knowledge loss is not an uncommon issue. The high staff turnover in the industry has also further aggravated the knowledge loss problem.

In view of the growing interest and recognition of the importance of KM in construction, a number of research projects have been undertaken to help improve the management of knowledge in the construction industry. The examples include CIRIA (2005), KLICON (McCarthy et al. 2000) and C-SanD (2001). The need for an approach which is capable of capturing project knowledge, irrespective of the type of project, the type of construction organization and project phases, and particularly capturing the knowledge 'live', however, has not been adequately addressed. The importance of a 'live' methodology 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 organizations involved in PFI (Private Finance Initiative) projects where the 'live' capture of knowledge is noted as crucial by 76% of construction organizations and 70% of client organizations (Robinson et al. 2004). Furthermore, the need for 'live' capture of knowledge has also been indirectly addressed by Whetherill et al. (2002). They assert that a construction organization'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:

- It facilitates the reuse of collective learning on a project by individual firms and teams involved in its delivery;

- It provides knowledge that can be utilised at the operation and maintenance stages of the assets' lifecycle;

- It encourages 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;

- It benefits client organisations with enriched knowledge about the development, construction and management of their assets; and

- It benefits 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:

- It prevents knowledge loss due to time lapse in capturing the knowledge. This is supported by 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;

- It maximises 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 as soon as possible 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

- It enables knowledge to be disseminated for reuse as soon as possible (i.e. 'live') before the opportunities for reusing knowledge diminishes. This helps to seize every knowledge reuse opportunity.

THE CAPRIKON PROJECT

The CAPRIKON research project was undertaken to develop a methodology for the 'live' capture of reusable project knowledge that will reflect both the organisational and human dimensions of knowledge capture and reuse, as well as exploit the benefits of technology. The specific objectives were as follows:

- To investigate the current practice of knowledge capture and identify the requirements for knowledge reuse by various end users of project knowledge;

- To explore various concepts and techniques that would facilitate the 'live' capture of reusable project knowledge in construction;

- To develop a methodology for the live capture of reusable knowledge on construction projects; and

- To test the methodology on a web-hosted project environment (for easy access to all project participants) and evaluate its effectiveness using live projects.

RESEARCH METHODOLOGY

A case study approach was selected because it provided an in-depth insight into the nature and characteristics of reusable project knowledge and the end-users' requirements for knowledge capture and reuse. The case studies involved semi-structured interviews with 18 senior staff from six companies, whose positions ranged from Group Knowledge Manager to Company Partner to ensure that a comprehensive view was obtained. Background information on the case study companies is presented in Table 1:

Table 1: 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

MAIN FINDINGS

Through the case studies, the nature and characteristics of reusable project knowledge in construction, and the various end-user requirements that impact on the development of the methodology were identified. The details are as follows:

REUSABLE PROJECT KNOWLEDGE

The various types of reusable project knowledge identified include process knowledge,

knowledge about clients, costing knowledge, knowledge about legal and statutory requirements, knowledge about reusable details, knowledge of best practices and lessons learned, knowledge of performance of suppliers, and knowledge of who knows what. It was found that the reusable project knowledge identified often exist as a mix of tacit and explicit knowledge, rather than as distinctive tacit or explicit knowledge alone. For instance, the findings revealed that design knowledge and knowledge about best practices can be made explicit in the form of a design manual and technical notes respectively. However, the case studies companies also acknowledged that there is still part of both knowledge types which is difficult to externalize and hence remains tacit in the head of people. To reflect this, the methodology should be capable of facilitating the capture and reuse of both the tacit and explicit dimension of a reusable project knowledge.

END-USER REQUIREMENTS

The foremost requirement arising out of the concept for the development of the methodology is the ability to facilitate the capture and access of project knowledge 'live', i.e. as soon as possible once knowledge is created or identified, and across geographically dispersed offices. The design of the methodology must reflect the fact that project team members are often pressed for time and not always collocated. To facilitate 'live' capture and reuse of project knowledge, the methodology must therefore allow individual project team member to share and access knowledge at any time without making it compulsory for all project team members to meet face-to-face for the purpose. The case study companies acknowledged that the aforementioned requirements are critical, and had further added the following requirements:

- The methodology should not create significant additional cost and workload to the companies. This requirement can be addressed by building the 'live' methodology on existing practices such as project reviews and meetings;

- 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.

DEVELOPMENT OF THE METHODOLOGY

A methodology for the 'live' capture and reuse of project knowledge was developed based on the end-user requirements and the characteristics of reusable project knowledge identified. The development of the methodology involved the review of various concepts, techniques and technologies that would enable knowledge to be captured and share facilitate the 'live' capture and reuse of project knowledge. This was followed by the selection of the most appropriate technique and technology for the purpose, which ultimately led to the

development of a Web-based tool called CAPRI.NET. The details of these are described in respective sections.

RELEVANT CONCEPTS

Various concepts were explored. Among these concepts, the most relevant ones are:

- Learning histories (Kleiner and Roth, 1996) – Construction is a project-based industry where the projects are handled by different project teams. Therefore, the concept of "learning histories" which was developed to capture and transfer useful knowledge from one team to another team operating in a different context, was studied; and

- Collaborative Learning (Digenti, 1999) – This investigates how a group (which can be a construction project team) can work together to transfer knowledge learned/created to the organisation, or another group of people.

Some useful insights which were very helpful in the development of the methodology for 'live' capture and reuse of project knowledge were obtained. For instance, the review of Collaborative Learning had pointed out that the interactions among the members of a team can help to reveal and share their tacit knowledge. Kleiner and Roth's (1996) "learning histories" revealed how knowledge can be captured and represented in an explicit or written form. This provides an insight on how a standard format for representing the knowledge as required by the case study companies can possibly be designed.

ENABLING TECHNOLOGY

The main challenge for the development of the methodology is to facilitate the project team members to enter and access the knowledge captured in real-time at any place. Regarding this, it was envisaged that information technology (IT) could be an important enabler to realise the concept and methodology for 'live' capture and reuse of project knowledge. Therefore, various IT tools and relevant technologies (such as data and text mining, case-based reasoning and project extranet) were investigated to ensure that the most appropriate solution could be found would be selected for the development of the methodology.

Among the KM technologies available, a Web-based knowledge base is the current practice closest to meeting the requirements identified. The reasons are as follows:

- *Allowing knowledge to be entered and accessed 'live' through the Web-based knowledge base*: Users can submit and view the knowledge captured by the system whenever and wherever with internet connection. This has met the foremost requirement identified for the design of the methodology. It can also provide huge knowledge storage space as required;

- *No significant additional cost*: The pervasive use of intranets by companies to connect their offices together nowadays has laid the necessary foundation for implementing a Web-based knowledge base. A Web-based knowledge base can run on the existing intranet/internet 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. The knowledge base can be designed to be as user-friendly as possible. Some information can be captured by the knowledge base automatically (e.g. author's details and the date of entering a knowledge) to reduce the amount of information to be entered and the additional workload created for the users;

- *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;

- *Allows a standard format for representing project knowledge to be specified*: A templates can be created to ensure that project knowledge is entered in accordance with the format developed;

- It can provide the necessary platform for the access and sharing of knowledge which is captured in the form of video clips and other formats of multimedia files. It may be used in conjunction with other Web-based applications (e.g. Groupware and video conferencing tools) to enhance the sharing of knowledge, particularly the tacit knowledge.

The Web-based knowledge base was developed using Microsoft's ASP.NET technology. The decision was made due to the availability of a ASP.NET development tool which allows a developer to develop the knowledge base "visually" and the associated shorter learning curve. These features helped to hasten the progress for developing the Web-based knowledge base.

KNOWLEDGE CAPTURE APPROACH

The Web-based knowledge base has provided a tool for the storage and sharing of knowledge. To build up the content of the knowledge base, reusable project knowledge will be captured from:

- *Individual users.* Allowing individual user to submit and access knowledge at any time and place through the Web-based knowledge base is an important feature that realizes the concept of 'live' capture and reuse of project knowledge; and

- *Project team in a group setting*. This refers to the capture of reusable project knowledge from Post Project Reviews (PPRs), and project meetings/reviews. Capturing knowledge in a group setting helps to ensure a more holistic and complete set of knowledge is captured than through individuals alone. This is done by making knowledge capture as an agenda item of the PPR or project meetings/reviews. The project team then spends about 10-15 minutes for discussing the knowledge learned since the previous meeting/review. A person who is in charge of taking the minutes of the meeting will also be responsible for recording the knowledge captured, and entering it into the Web-based knowledge base.

PPRs and other project meetings/reviews conducted at routine intervals were chosen for capturing knowledge in a group setting since this option creates less additional workloads. This is because conducting PPRs have already become part of the quality system

requirements of many construction companies, whereas conducting routine project meetings is a must-do task for all construction projects. Trials at weekly site meetings also found that the project team members did not see this workload as significant and unacceptable.

A STANDARD APPROACH FOR REPRESENTING KNOWLEDGE

The case studies revealed that reusable project knowledge often exist as a mix of tacit and explicit knowledge. Therefore, concentrating on either capturing explicit knowledge through codification of the knowledge or building a network of people for sharing tacit knowledge will fall short for managing reusable project knowledge effectively. To address this problem, the methodology was designed to explicate project knowledge into the tacit form as far as possible since it is easier to be shared and transferred for reuse. For the remaining tacit knowledge which is really difficult to be explicated, links (e.g. contact details) are provided to connect the author of a knowledge with those who need it for the sharing of that knowledge.

Corresponding to the end-user requirement, a standard format for representing the reusable project knowledge captured (i.e. one of the requirements identified) was proposed. This introduces the concept of a Project Knowledge File (PKF) which contains relevant project information and project knowledge that can be reused both during the execution (e.g. in subsequent phases) and after the completion of the project. The PKF covers:

a) *Background information on the project* – These include project title, project location; project sector; type of project; type of contract, start and completion dates, duration, companies involved, and 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. Video clips, images and photographs can also be used to help explain the details about the knowledge.

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, where further details may be obtained. Hyperlink to webpage showing the contact details of the author (e.g. phone number, email and photo) to aid the transfer of tacit knowledge is also provided here.

In addition, a knowledge map and an index should be provided to give users an overview of the knowledge available.

THE METHODOLOGY - CAPRI.NET

The methodology for 'live' capture and reuse of project knowledge was encapsulated into a Web-based tool, i.e. CAPRI.NET. CAPRI.NET comprises:

- A Web-based knowledge base – This is where all the knowledge captured from a project (i.e. a Project Knowledge File or PKF) is stored. It also contains the template designed for capturing reusable project knowledge. 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) 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.

First, knowledge is to be entered in the stipulated format of the knowledge base. This is followed by a validation process, which is essentially the review of the knowledge by a group of designated people, before the knowledge can be shared and reuse. However, the knowledge captured from project meetings/reviews and PPR is deemed to have been validated and will be shared through the knowledge base instantly. This is because the capture of the knowledge in project reviews/meetings should have involved some discussion and review, which can be regarded as a validation process of the knowledge. 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). All project team members can retain a copy of the PKF at the end of a project.

CONCLUSIONS

This paper reviewed the importance of the 'live' capture and reuse of project knowledge approach in construction. A methodology for 'live' capture and reuse of project knowledge was proposed, which was then developed based on the requirements identified from the case studies conducted. The development of the methodology involved: (1) the exploration of various techniques and technologies that could facilitate the 'live' capture and reuse of project knowledge; (2) the selection of the most appropriate enabling technology for the purpose; (3) the development of an approach to capture knowledge from the project team members; (4) the development of the Web-based knowledge base and the format for representing knowledge captured. The Collaborative Learning and "learning histories" which revealed how knowledge can be captured in a group setting and represented explicitly had impacted on the design of the methodology. The case studies showed that a Web-based knowledge base is most appropriate in facilitating the 'live' capture and reuse of project knowledge. However, in addition to capturing knowledge from individuals, the knowledge base should be complemented by project meetings and reviews conducted at various project

stages where the collective knowledge of the organisations involved in the project can be captured in a collaborative environment.

The methodology developed was encapsulated into a Web-based tool called CAPRI.NET. It comprises mainly a Web-based knowledge base, a Project Knowledge Manager (PKM) responsible for administrating the Web-based tool, and an Integrated Workflow System (IWS) depicting how reusable project knowledge is captured from project meetings/reviews and individuals, and how knowledge is validated and shared subsequently. Further work will involve the testing and evaluation of the software prototype for refining purpose.

ACKNOWLEDGMENTS

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