LIVE CAPTURE AND REUSE OF CONSTRUCTION PROJECT KNOWLEDGE: CAPRI.NET APPROACH

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ABSTRACT

The role and importance of knowledge as a key source of potential advantage for construction organisation has been addressed by several authors. As such, managing this knowledge is not new for the construction industry. In the course of construction project, people face problems that they cannot solve alone; their natural response is to study past experiences and re-use previously acquired knowledge, either from their own experiences or from resources within their organisation. However, there are indications that current practice does not provide an effective strategy for the capture and reuse of project knowledge. In this paper, the authors describe a web-based development (CAPRI.NET) that facilitates the live capture and reuse of project knowledge. The distinguishing feature of this research is that it emphasizes “live” capture of construction project knowledge, which is still an elusive solution in Knowledge Management (KM) undertaken. Hence knowledge live capture and reuse are key elements in project development. Following a problem definition and related work discussion, the research underpinning CAPRI.NET is discussed. This is followed by a description of the development and further works. CAPRI.NET allows project participants to document their learning during the course of a project in a Project Knowledge File (PKF) which is collectively owned by all participating firms. The knowledge captured in the PKF can be reused during or after the project. A preliminary evaluation of CAPRI.NET by AEC practitioners suggest that it proffers unique possibilities for knowledge capture and reuse in AEC projects.

Keywords: Construction, Project Management, Knowledge Management, System, Live Capture and Reuse

1. INTRODUCTION

The role and importance of knowledge as a key source of potential advantage for construction organizations has been addressed by several authors (Rezgui, 2001; Kamara et al., 2002 and Lima et al., 2003). Managing knowledge is not new for the construction industry. The project nature of the industry is abound with a frequently reconfigured set of participants, non-repetitive nature of work, pressure to complete, and lack of incentive to appraise performance or improve overall project delivery (Patel et al., 2000). This means that information is not often captured for re-use in future projects (Kamara et al., 2003). Furthermore, it does not allow the current project to be improved by incorporating the knowledge being captured as the project
Because of these disparate repositories of knowledge, a key aspect of project Knowledge Management (KM) in construction is therefore the capture and reuse of knowledge for the ‘common good’ of the project at different levels and subsequent projects. In tackling some of these problems, different techniques & technologies have been proposed and developed. However, the field has been slow in formulating a generally accepted, comprehensive solution for live capture and reuse of project knowledge. At the same time, the web is now an established medium for capturing the knowledge in organisations across the globe. This important development has been driven by the increasing use of ‘Internet’ at both project and individual levels. A recent survey by Andersen Consulting has shown that one of the areas in which there is increasing use of Internet is in capturing & sharing of knowledge/information among organisational personnel, and that this trend is set to grow in the near future (CIRIA, 2002).

As part of the effort to improve knowledge management in construction project, CAPRIKON (CAPRIKON Report, 2004) has been developed to capture ‘live’ project knowledge and reuse this knowledge in subsequent tasks. However, this paper reports on the study undertaken at University of Newcastle as part of the CAPRIKON project. The work reported here focused on the development of a prototype web-based application for capturing and reusing ‘live’ project knowledge, known as CAPRI.NET. The paper first outlines the problem/requirements of projects. Next, the paper reviews previous related works in the application of project knowledge management. The framework adopted in the research is then presented, and is followed by a description of the prototype system. This includes the way the system should be navigated. Finally, the paper outlines further work that is required to enhance the functionality of the prototype, and gives some recommendations that could facilitate the adaptation of the CAPRI.NET application in the construction projects.

2. PROBLEM DEFINITION

Many practitioners and researchers in the industry have acknowledged the limitations of current approaches to managing information and knowledge related to and arising from a construction project (Fruchter et al., 2000; Rezgui, 2001 and Lima et al., 2002). These limitations are due to several technical, human, and business related factors. However, these outline the requirements and problems of live capture of knowledge in construction projects. A detailed outline of these problems is documented in an initial report (CAPRIKON Report, 2004). The key issues can be summarized as follows:

- Each team member develops multiple alternatives. Evolution of discipline solutions and interactions among professionals are hard to document and track;
- Most of the concepts generated in the early phases of the project as well as the rationale behind these concepts are not captured. These concepts are hard to communicate to the stakeholders of the project and re-used in future projects. Consequently, a large rework time and effort are involved in recreating these concepts and linking them to the later stages of the project, such as design, design development, and construction;
- Unsatisfactory changes prompt team members to backtrack to earlier solutions, which at many times have to be recreated;
Different discipline solutions interact with each other. The process of identifying shared interests is ad-hoc and based on participant’s imperfect memories. This error-prone and time consuming process rapidly leads to inconsistencies and conflicts;
- Memos are generated by computers but handled as paper documents, distributed to selective team members, and filed. Paper memos cannot be easily updated and are hard to retrieve;
- Project documents that are captured in heterogeneous media preclude team members and clients to have a global project memory that they can access, visualize and navigate through;
- Project documents are not linked with the information on the construction site. This precludes the design-build team to quickly assess the status of the project, identify current delays, and act in an informed fashion and;
- Much of construction knowledge still resides in the heads of individuals, or at best, exists in an informal and unstructured form that makes it difficult to comprehend and exploit.

These factors have not merely inhibited effective knowledge management; but they have inhibited the industry’s ability to capture, learn and re-use project knowledge for improved performance. Improvements in project procurement using Knowledge Management (KM) can reduce the construction period and help clients save cost. Some of these improvements can be accomplished through better capture and reuse of knowledge during the project life cycle. From the above problem definition, the requirement is to use appropriate knowledge infrastructure, and improve collaborative working between members of project team. The construction industry still has a significant gap to bridge to reach best practice in KM strategies. What are required are fundamental changes to address the issues stated above. However, the research work presented in this paper, addresses how web-based application can be deployed to capture live project knowledge and reuse them in subsequent activities within the project.

3. RELATED WORK

There have been several research projects on the potential applications of knowledge management in projects. Academic and industry have led these projects. CLEVER (Kamara, et al., 2002) focused on the development of a framework for the transfer of knowledge in a multi-project environment in construction. The framework developed assists construction firms in selecting an appropriate strategy for the transfer of knowledge that is appropriate to their organisational and cultural contexts. e-COGNOS (e-COGNOS, 2002) focused on specifying and developing an open model-based infrastructure and a set of tools that promote consistent knowledge management within collaborative construction environments. KLICON (Patel et al., 2000) focused on the role of information technology (IT) in capturing and managing knowledge for organisational learning on construction projects. Other initiatives in the US (Stanford University) focused on the development of a project memory capture system for design evolution capture, visualisation and reuse in support of multi-disciplinary collaborative teamwork (Reiner & Fruchter, 2000); work at Dresden University of Technology in Germany on the retrieval of explicit project knowledge from heterogeneous documents (Scherer & Reul, 2000). The list of related works is not
exhaustive but it demonstrates growing interest in knowledge capture and sharing in construction projects.

4. FRAMEWORK DEVELOPMENT

The work presented in this paper emphasizes modeling of the overall knowledge/learning event in a project as shown in Figure 1. The approach will enable the project knowledge to be captured ‘live’ (i.e. in real-time, or as soon as possible after the knowledge is created or identified) and then reused ‘live’ either in the subsequent stages of the same project. The development consists of seven blocks, which are designed to capture the knowledge from the various learning situations of a project.

![Figure 1: Project Learning Event Framework.](image)

The Figure show that to capture knowledge/learning event in a project, three main approaches can be used: knowledge from meeting, knowledge from individual and knowledge from project documents. However, only the individual knowledge and document knowledge needs to be validated, before being stored in the database (as Project Knowledge Files). The reason for this is that these kinds of knowledge capture require verification before they can be reused. However, the work reported in this paper will present the prototype development, but details on the work undertaken to identify methodological issues of this framework are discussed in (CAPRIKON Report, 2004).

5. PROTOTYPE DEVELOPMENT

5.1 System Architecture

For the solution advocated to work properly, their implementation needs to be carried out on a system architecture that enables good coordination and collaboration between different entities that exist in a project environment. Given the nature of the methodology discussed in the CAPRIKON Report (2004), web-based project management system (PMS) was adopted. The system architecture is built as a platform for an electronic PMS conducted via a private network called “CAPRI.NET” using Internet protocols to transmit project knowledge. Only team members of the project can gain access to the system of which the team members can be located in different organisations. The system generally provides a centralised,
commonly accessible, reliable means of transmitting and storing project knowledge files (PKF) (Kamara et al., 2003). Project knowledge is stored on a server and a standard web browser is used as a gateway for project team members (PTM) to exchange project knowledge. Hence, the system can help the PTM transfer the knowledge captured faster and more effectively. Figure 2 depicts the system architecture and delineates the various functional activities that are carried out within the project Extranet.

The CAPRI.NET has been implemented using multi-tier architecture; in this case the three-tier architecture composed of three logical layers (Figure 3): client side, middle layer and the server side. The Server side (that encompasses the product side implementation) scripting language PHP (Meyer, 2003) is used to generate dynamic content from the database for producing the standard web pages in the system (see Figure 3). PHP provides a simple scripting language that can be embedded in specialised tags in HTML documents. When a user request such a document, the document is parsed by the PHP interpreter prior sending it back to the web Client, and the embedded scripts can generate the dynamic portions of the document at this point. The main reasons this language was chosen will not be discussed here, but it will documented CAPRIKON report (CAPRIKON, 2004) and other relevant script language materials (Meyers, 2003).

In the development of the system architecture in this research, the implementation was divided into two parts. The first part dealt with the development of the product issues (encompassed within the Server side); while the second part concentrated on the process issues dealing with the workflow management decision issues (Client side and middle layer). The remainder of this section will discuss and describe the development in detail.
5.2 Product - Side Development

The product-side of this development as shown in Figure 4 deals with Project Knowledge Files (PKF) and other relevant information needed for capturing knowledge. The PKF will contain information relating to the ‘project knowledge’, but will focus on knowledge that can be reused both during the execution (e.g. in subsequent phases), and after the completion of the project. The kind of knowledge to be captured and the format and contents of the PKF has been determined through detailed research into Reusable Project Knowledge (RPK) (CAPRIKON Report 2004), but the goal is to develop an ongoing ‘learning history’ for the project within a collaborative environment. The PKF will be agreed on at the onset of a project and all parties are required to contribute to its compilation. Other project information will also be present within the development (such as project detail, members’ information, other relevant documents etc.). Hence in implementing such a development require an understanding of knowledge/information flows within an organization or project undertaken for different construction project participants. A key decision in the set-up of this research is that all product data will reside on a central repository. Thus, this will facilitate the sharing of project Knowledge/information across CAPRI.NET. The vision of the research in this regard, is for system architecture to draw from a common pool of project knowledge/information, which is stored in a database. Thus enables specific knowledge/information to be retrieved and disseminated in a variety of views and levels of abstraction. The use of the shared pool of project knowledge/information in this way improves knowledge management; however, this would hinder the system/user access to a much wider range of knowledge/information that would otherwise be practical in a world wide web.

The work presented in this research on product development, looks at the construction project knowledge/information from a clear perspective of product model that needs to be abstracted, modelled and mapped into a database (see Figure 5.3). The Figure shows that knowledge/information presented in product side development has inter-relationships that are necessary for the knowledge/information to be abstracted and translated in the form of a model that will transcend into a database. In the system, all project knowledge/information is centralised in a database residing in the project server, instead of being distributed to many different locations. By utilising the latest web technology, the system works as a knowledge/information platform for all participants of project throughout the life cycle of the project. On the issue of database design, the system was designed to represent all the product details in Figure 5.3. Hence the database consists of the following: Project Information, Reusable Project Knowledge (RPK), Contact and Authentication details etc.

![Figure 4: Knowledge manager’s View of Knowledge Capture and Reuse.](image)
5.3 Process - Side Development
Process-side of this development deals with the Client side applications. This has been implemented as a set of common client modules for communication (prompt and email), knowledge capture Templates, and workflow management engines, as shown in Figure 2. The modules are made up of the following: Knowledge, Workflow services and dissemination modules. Thus, in final implementation these modules will appear as static and dynamic web pages that the Project Team Members (PTM) can interact with using a web browser to access the server side (PKF and other project information). Figure 3 above shows the interaction within the CAPRI.NET system. The figure depicts how PTM in a project can capture, store, reuse knowledge/information within the CAPRI.NET environment. Through the middle layer, the client will send a request to the server, and then the server processes the request and sends back the result through middle layer in a language the client will understand. A detailed discussion of how this will work is presented below.

6. KNOWLEDGE CAPTURE AND REUSE ENVIRONMENT
The CAPRI.NET is operated through a user interface, to which access is via the internet domain address (see Figure 3). During knowledge capture in the system, the sequences of interactions are initiated by the PTM through the web browser and this is numbered 1-6 in Figure 5. These sequences are described below:

1. When PTM first accesses the address, the first page that he/she sees is the ‘login page’ with the registration link page (see Figure 6).
2. Before the PTM can use the site, the PTM has to register his/her details first. Once the system receives the details of the PTM, he will send out a confirmation through email and this will activate the PTM authentication. There are two levels of authentication, the user and administration level. The reason for this is to allow only PTM to register and also the administration level gives the PKM a high level authorisation to add and update project details. The other process the system does is to upload the details of the member in the PKF (2c).
3. Equipped with the log-in details, the PTM can now log into the CAPRI.NET system. The first and main page after the ‘login page’ is the ‘index page’. The index page is used to show and link all the knowledge that has been captured. However, at the initialisation stage the knowledge section is blank, only the add knowledge and logout links are visible. Once the PTM captures knowledge using the template, it will then appear in the table (see Figure 6).
4. The add knowledge page is a template used to capture the different types of categories and the approach used in capturing the knowledge (see Figure 4.1). Once the template has been filled in and submitted, the system stores the captured knowledge in the PKF and immediately generate a fresh index page that contains the captured knowledge. The other process at this stage is for the system to send out email to every member, informing them that knowledge has been captured (4c).
5. The view knowledge page is used by members to view various knowledge added. The distinguishing fact of the view page is that members can open various captured knowledge, but the system will not allow them to edit the capture knowledge unless it was captured by that particular member. To view knowledge the system interacts with the server to generate stored knowledge.
6. The update knowledge page is used by members to update knowledge they have added. This can only be done through the index page as shown in Figure 6. The system also prevents members from updating knowledge they have not added. Once knowledge has been updated, the system stores updated knowledge in the PKF (6b).

The other sequence of interactions that were not illustrated within the flow chart is the search and project detail section. The search section can be used by the PTM to search for RPK that has been captured and stored in the PKF. The project detail section is the PKM only section. It is a private protected section that can only be accessed by the PKM to update or configure project details or even remove members from the system (see Figure 6).
7. FURTHER WORKS

The research project is bound to uncover issues that need to be investigated further. This work is no exception, as a number of issues have been identified to improve the development. This section outlines the further works that could enhance the deployment of the prototype. These recommendations are based on the emerging trends and the issues raised from the test and validation exercise carried out with representatives of the industrial partners. These further works are as follows:

- Searching tools – Although the search tool implemented in this work might be appealing to many, difficulties with search are expected to worsen as the amount of RPK increases. This is mainly due to the problems of information overload and vocabulary differences. This problem can be harnessed by developing data mining approaches that support knowledge retrieval from the PKF.
- Improving web automation – The of the web automation will employ agent concepts, the approach here is that the project development is viewed as a virtual environment that employs concepts from multi-agent system field to organise and coordinate the activities of knowledge capture and reuse. This will help prevent knowledge loss due to time lapse in capturing the knowledge and also help relieve PTM of their mundane tasks (such as responding to their email request and sending confirmation to other participating agents).

Beside searching and improvement issues described, there are other issues such as the textual mining, the transfer of domain knowledge into agents, the empowerment of agents, agent-based search paradigm, agent’s ability to learn from each other, the legal issues of agent roaming the web, and agent-based engineering services that deserve further investigation.

8. CONCLUSION

This paper has proposed ways in which CAPRI.NET, promote, enhance, and support live capture and reuse of knowledge. In the current dynamic environments, the potential of CAPRI.NET for enhancing a live capture and reuse can be even more important. For example, when project team member are faced with making quick decisions, the system can provide efficient and effective capabilities for capturing live knowledge. Using this knowledge, team members can easily rectify the mistakes they made in a previous task with project development. The approach corresponds to the development of high and low – level functionalities – that help a supply chain to deal with many activities within a project. However, in the early part of the paper, the general concept of project knowledge was emphasized. Comparative descriptions of existing limitations were presented and the related works were also highlighted. This chartered a course for development of a new system adopting ‘live’ capture approach. The CAPRI.NET has demonstrated how a web-based application can be used to partial automate the ‘live’ capture and reuse of project knowledge in construction. This is an important step towards the deployment of full commercial approach in the industry. It is evident that the industry stands to reap many benefits from this approach of ‘live’ capture and reuse of knowledge in this way, once a number of existing problems are resolved. Some of these benefits are as follows:

- Construction supply chains will benefit through the shared experiences that are captured as part of the learning on key events (e.g. problems, breakthroughs,
change orders, etc.). The benefits to this group are both short- and long-term. Short-term in the sense that project teams would be enabled to manage better the subsequent phases of a project (through the capture and transfer of learning from a previous phase). Long-term because it will increase their capacities to better plan future projects and their ability to collaborate better with other organisations. Furthermore, learning from past projects can be used to train new employees and project managers.

- Other project teams can use the learning captured from previous/similar projects to deal with problems; reflection on previous learning can also trigger innovative thinking (to think about issues that might be relevant to their project).
- Client organisations will benefit from enriched knowledge about the development and construction of their assets. This will contribute to the effective management of facilities and the commissioning of other projects. In the longer term, clients will benefit from the increased certainty with which construction firms can predict project outcomes.
- Improved supply chain management, as team members would work more collaboratively and share the lessons learnt on construction projects.
- The construction industry will benefit from an enhanced knowledge base as much learning that is presently not documented can be captured and reused.
- Facilitate the reuse of the collective learning on a project by individual firms and teams involved in its delivery.
- Provide knowledge that can be utilized at the operational and maintenance stages of the asset’s lifecycle.
- Involve 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 for both ongoing and post-project evaluation.
- Maximise the value of reusing the knowledge captured through ‘live’ capture and reuse. The true benefit of capturing knowledge comes only when the knowledge is being used, particularly if the knowledge is being reused ‘live’ after it has been captured.
- Enable the knowledge to be disseminated for reuse as soon as possible before the opportunities for reusing the knowledge diminishes. This helps prevent knowledge loss due to time lapse in capturing knowledge.

To conclude, this paper has described and discussed some ways to think about project procurement of today and the future, which can enhance the project team’s activities. Ultimately, improvements in the project procurement as a result of ‘live’ capture and reuse approach can reduce the construction period and decrease the cost of projects.

9. REFERENCES

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