A project knowledge management tool for the construction industry

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ABSTRACT | Knowledge Management has attracted a lot of attention in the last decade and it has widely been cited as a major competitive tool for many businesses. In the UK construction industry, it has been identified that one third of major clients are dissatisfied with contractor and consultant performance. Similarly, the Egan Report [1], 'Rethinking Construction', stated that the industry suffers from low and unreliable profitability, insufficient research & development, and a lack of customer focus. These problems in addition to the project based business environment of the sector, typically relate to the industry's adversarial nature, and to move forward the industry needs to capture the knowledge that is generated by the project team, share it, and more importantly, determine how it can be reviewed and used by other project teams for future projects. This paper introduces an IT approach, the Process Protocol Toolkit to satisfy the needs in managing knowledge in construction projects based on the Process Protocol framework. The paper also suggests that significant realisation of IT benefits can only be achieved by knowledge based systems, which are underpinned by a consistent design and construction knowledge framework.

KEYWORDS | knowledge management, information technology, knowledge based system, construction process, project management

1 Introduction

Knowledge management has been the subject of much debate in the last few years. Goodman and Chinowsky [2] claimed that knowledge management is necessary and an important component for organisations in order to survive and maintain their competitiveness. Drucker [3] has described knowledge, rather than capital and labour, as the only meaningful economic resource in the knowledge society. To remain at the forefront and to maintain competitiveness, organisations must have a good capacity to retain, develop, organise, and utilise their employee competencies [4]. There is an agreement among scholars and industrialists that a transformation has occurred in the society, and knowledge is at the centre stage [5]. Those organisations that will succeed in the global information society are those that can identify, value, create and develop their knowledge assets. The UK construction industry is no exception to the need for change to maintain its competitiveness as it has been continuously criticised for its less than optimal performance by many government and institutional reports. Most of the reports such as Latham [6] and Egan [1] conclude that the fragmented

nature of the industry, lack of co-ordination and communication between the parties, the informal and unstructured learning process, lack of research and development, adversarial contractual relationships and lack of customer focus is what inhibits the industry's performance and cross-project learning. The business of construction firms is largely project based, information and knowledge created during the project are often owned by the individual team, and the lack of information and knowledge sharing become an important factor to affect their company business performance. This paper is an attempt to improve the prevailing situation by implementing a knowledge-based system, the Process Protocol Toolkit, which is able to assist the construction project team to structure the knowledge created throughout the project, and capture and manage it effectively using the system based on a robust framework.

2 Background

2.1 Information and Knowledge

There are often confusions between information and knowledge and the terms tend to be used as interchangeable concepts. According to Encarta World English Dictionary, information is

1. Definite knowledge acquired or supplied about something or somebody.
2. The collected facts and data about a particular subject.
3. The communication of facts and knowledge.
4. Computer data that has been organized and presented in a systematic fashion to clarify the underlying meaning.

Knowledge is

1. General awareness or possession of information, facts, ideas, truths, or principles.
2. Clear awareness or explicit information, for example, of a situation or fact.
3. All the information, facts, truths, and principles learned throughout time.

4. Familiarity or understanding gained through experience or study.

From these definitions, it is in fact quite confusing, there is no clear distinction between these two concepts. Various people have thought carefully about varying definitions of these terms and produced their own analysis of the terms.[7][8][9] Among them, the author believes that the following one is most suitable to distinguish between the two terms.

"Information becomes individual knowledge when it is accepted and retained by an individual as being a proper understanding of what is true and a valid interpretation of the reality. Conversely, organizational or social knowledge exists when it is accepted by a consensus of a group of people. Common knowledge does not necessarily to be shared by all members to exist, the fact that it is accepted amongst a group of informed persons can be considered a sufficient condition." [10]

2.2 Knowledge Management and Knowledge Management System

There are many ways to define Knowledge Management (KM), Davenport [11] argued that "Knowledge Management is concerned with the exploitation and development of the knowledge assets of an organisation with a view to furthering the organisation's objectives…" some authors have put emphasis on different aspects of KM, Holsapple and Joshi [12][13] have presented several KM frameworks, they have developed descriptive framework that provides a number of building block which can be used to form prescriptive approaches. Other authors have taken a process view and even an 'entire KM process' has been mentioned, which includes consideration of strategy, organizational culture, learning and distinction between tacit and explicit knowledge and knowledge tasks. Wiig [14] lists all major building blocks of KM, which are:

1. Obtain management buy-in.
2. Map the knowledge landscape.

3. Plan the knowledge strategy.
4. Create and defined knowledge-related alternatives and potential initiatives.
5. Portray benefit expectations for knowledge-management priorities.
6. Set knowledge – management priorities.
7. Determine key knowledge requirements.
8. Acquire key knowledge.
9. Create integrated knowledge transfer programme.
10. Transform, distribute and apply knowledge assets.
11. Establish and update knowledge management infrastructure.
12. Manage knowledge assets.
13. Construct incentive programs.
14. Coordinate knowledge management activities and functions enterprise-wide.
15. Facilitate knowledge-focused management.
16. Monitor knowledge management.

Monsanto also built its approach to KM [15], which includes five processes:
1. Connecting people with other knowledgeable people.
2. Connecting people with information.
3. Enabling the conversion of information to knowledge.
4. Encapsulating knowledge, to make it easier to transfer.
5. Disseminating knowledge around the firm.

Galagan [16] proposed the following knowledge management process.
1. Creating new knowledge
2. Accessing knowledge
3. Representing the knowledge in a digital form
4. Embedding the knowledge in processes
5. Transferring the knowledge around the organisation
6. Using the knowledge in decision making
7. Facilitating the knowledge growth through culture and incentives
8. Measuring the value of the knowledge

Technological development has raised the interest of knowledge management, the emerging technological developments enable global sharing of information across platforms and continents [17]. Systems have been developed to cater for each part of the knowledge management framework. Davenport et al.[18] studied a number of knowledge management projects that are currently being implemented and showed that many organizations have demonstrated that knowledge management can affect the bottom line of business by implementing quick fix solutions, rather than attempting to develop a knowledge management solution throughout the organisation. Davenport et al. [18] categorized these projects on the basis of the project objectives.

• To create knowledge repositories
• To improve knowledge access
• To enhance knowledge environment
• To manage knowledge as an asset and to recognize the value the knowledge to an organisation.

According to Lee and Hong [19], no single information system could support the whole lifecycle of knowledge management. Typically, several individual information systems support each step in the knowledge management process.

Knowledge is often regarded as an information management problem. It deals with the creation, management and exploitation of knowledge. Broadly, it can be divided into four separate but related stages, which include:
1. collecting information
2. storing information
3. making information available
4. using information.

The first two stages are invariably linked, both on abstract theoretical grounds and in practice. At the first step in the process, there is acquisition of information. At the second stage, the information is entered into a storage system and organised logically. Almost every

definition of knowledge management includes the storage of knowledge [20][21][22][23][24][25][26]. KM is about acquisition and storage of knowledge and making information accessible to other employees within the organisation. This is often achieved by using various technologies such as Intranet and databases, and it is claimed that it can facilitate the conversion of tacit knowledge to explicit knowledge [27]. Once the information is stored in the various databases, the third stage is initiated. At this stage, the stored information is made accessible to as many employees as possible within the organisation [28] and across different projects. It is about distributing it into the hands of the appropriate end users at the right time [29] and where it can be of best use [30]. The final stage is about utilisation. This process begins with people sharing knowledge by talking and socializing with one another or by exchanging information in digital or analogue form [31]. Lee and Hong [19] categorised four typesof knowledge IT applications for each stage respectively:

• Applications for knowledge capture – they are commonly based on database systems, data warehouses or digital library, they aim to capture and store the information in a digital form.

• Applications for knowledge development – they are mainly techniques for performing specific analysis on the information stored in the database. For example, data mining techniques, OLAP (On-Line Analytical Processing)

• Applications for knowledge sharing – knowledge sharing is often achieved by communication systems, such as groupware, and Internet/Intranet which have an increasingly important role.

• Applications for knowledge utilization – It is the front-end of the knowledge system, it requires user-friendly GUI (Graphic User Interface) to present information to enable easy access to information for the users.

Having reviewed the literature, it is not difficult to find out that most of the research work to date have identified the process /stages of the knowledge management and many studies have been carried out

for each part of the process. It is acknowledged that knowledge management requires proper knowledge framework for effective knowledge capture, development and utilization. The Process Protocol research has shown that a proper knowledge framework is very important for construction project information management. This paper presents an IT approach to knowledge management for the design and construction process.

2.3 The Design and Construction Process

The UK construction industry has been seeking to improve the construction cycle and several government and institutional reports have been produced to support it, including Simon [32], Banwell [33], British Property Federation [34], Latham [6] and most recently Egan [1]. It was recommended that the construction should be viewed as a manufacturing process by adopting the techniques developed by the manufacturing industry. The Generic Design and Construction Process Protocol project, funded by the Engineering and Physical Sciences Research Council (EPSRC) under the Innovative Manufacturing Initiative (IMI), was initiated following such recommendations.

2.4 The Generic Design and Construction Process Protocol

The Generic Design and Construction Process Protocol is a project framework for the transfer of knowledge in the development of a generic process protocol for the construction industry, using experience from the manufacturing sector.

The Process Protocol is based on a number of key principles that have been proven to work in the manufacturing industry. It is believed that these principles are fundamental to the successful operation of construction projects. These principles [35] are:

• Whole Project View
The process has to cover the whole life of the project from the recognition of needs to operation and maintenance of the finished facility.

- Progressive Design Fixity
  Learning from the 'stage-gate' approach in the manufacturing new product development process, a phase review process that applies a consistent planning and review procedure throughout the project has been adopted.
- A Consistent Process
  The generic properties of the Process Protocol allow a consistent application of the Phase Review Process irrespective of the project in hand.
- Stakeholder Involvement / Teamwork
  The stakeholder view will ensure that appropriate participants (from each of the key functions) are consulted earlier in the Process than is traditionally the case.
- Co-ordination
  Appointed by Client, Process Management will be the delegated authority to co-ordinate the participants and activities of each phase, throughout the process.
- Feedback
  The Phase Review Process will record and update the project experiences throughout the Process and thereby informing later phases and future projects.
- Flexibility/adaptability: Adaptive systems that recognise and accommodate project particulars without affecting the integrity of the project system

The Generic Design and Construction Process Protocol (GDCPP) was led by Alfred McAlpine Special Project and was developed by the University of Salford in 1998 in collaboration with a number of companies representing the whole construction project supply chain. It is a high-level process map that aims to provide a framework to help companies achieve an improved implementation of the design and construction process [36]. The map draws from principles developed within the manufacturing industry (as described above) that include stakeholder involvement, teamwork and feedback, and suggests a reconstruction of the design and construction team in terms of Activity Zones rather than in disciplines to create a cross-functional team. These Activity Zones are multi-functional and may consist of a network of disciplines to enact specific task of the project, allowing the 'product' and the client requirements to drive the process rather than the function as is the case in traditional sequential approaches. Luck and Newcombe [37] argue that traditional roles and responsibilities change from project to project, often resulting in ambiguity and confusion; the use of zones potentially reduces this confusion and enhances communication and co-ordination [38]. The Activity Zones (see figure 1) contain high-level processes spanning the duration of a project from inception, through design and construction, and including operation and maintenance. The responsibility for completing the processes may lie with one Activity Zone or be shared.

The aim of the project was for construction firms to take the process map and to use it as a framework to help them improve their business and through industry interest and acceptance, further funding has been committed to continue the research in collaboration with Loughborough University and further construction companies. This brings the generic protocol down to a secondary-level (Level II) which itself can be broken down further to more detailed levels to create sub process maps of the eight Activity Zones within the Generic Design and Construction Process Protocol Model (Figure 1 illustrates a small part of the model).

The Process Protocol Level II project subsequently aimed to identify such sub processes, by considering a number of issues, as follows:

- Due to the complexity of construction projects, the process model will become very complicated. It is almost impossible to manage all the processes manually.
- Companies might only adopt part of the Process Protocol model, depending on the nature of the project.
- Some companies have their own working process and may not be willing or able to accommodate a new approach.
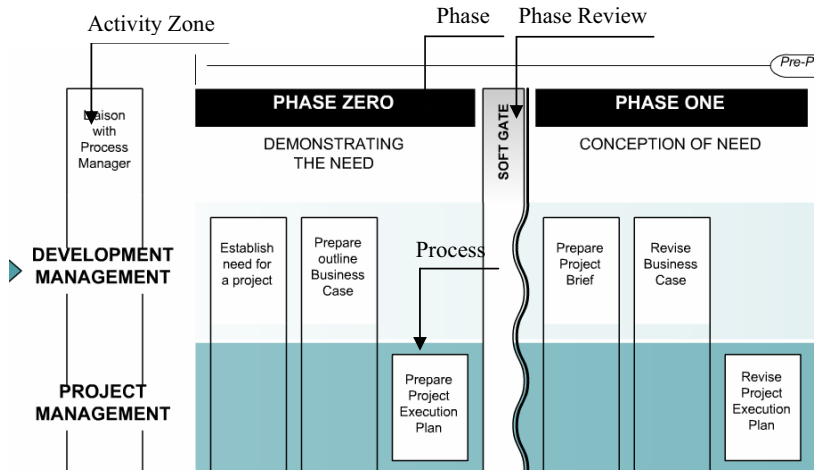
Figure 1. Process Protocol Model

- The individuals who are responsible for the process modelling and management of a project need detailed knowledge of the Process Protocol.
- Process and Project information needs to be shared by whole project team
- Project activities and information need to be recorded for future reference. Lessons can be learned and best practises applied.

These issues can be resolved by a knowledge based IT solution, however, the majority of the current knowledge management systems often focus on processing and sharing information, and they are not designed to accommodate a specific framework. To achieve effective project information management, project information has to be managed in a well-accepted information framework. The Generic Design and Construction Process Protocol provided such framework and the Process Protocol toolkit is developed to assist the implementation and customisation of the framework in order to manage project information without loosing the integrity of the system.

3 Research methodology

The aim of the Process Protocol Toolkit is to assist the implementation of the Process Protocol framework

in construction industry. A prototyping approach is adopted in the development. The structure of the approach includes preparation, implementation and evaluation where the implementation and evaluation is an iterative process.

Preparation is mainly concerned with the identification and evaluation of the current process mapping packages. It was found that most of the tools provide quite powerful functions, but all these tools only support standard modelling methodologies, like IDEF–0. The Process Protocol framework has its own process modelling methodology developed with the industry to meet their simple requirements, Therefore, it was decided that the Process Protocol Toolkit need to be developed separately.

Development includes conceptual data model development, prototypes development. A conceptual data model is developed to understand the relationship of each element of the Process Protocol framework by using entity relationship diagram (Figure 2), and an initial prototype is developed for expert review. The review process is also part of the evaluation process and more revised prototypes are developed during the whole evaluation process.

The evaluation was conducted in the form of workshops and the individual workshop panel included industry experts, academics and the project team. Six workshops were carried out and most of the feedbacks were incorporated into the revised prototype. The prototypes have also been introduced in various academic networks, conferences [39]. Also postgraduate courses have used the Toolkit as teaching material for introducing the Process Protocol Framework.

4 The Process Protocol Toolkit

The Process Protocol Toolkit is a software tool to help the construction industry to adopt the Process Protocol and to enable effective project information management and knowledge sharing between projects based on a consistent framework. This is achieved by demonstrating and communicating the underlying principles and philosophies of the Process Protocol Framework. The toolkit is composed of two major components: the 'process map creation tool' and the 'process management tool'.

4.1 Process Map Creation Tool

The process map creation tool is a process-mapping knowledge tool specially designed for the creation of the project process map based on the Process Protocol framework. It automates the map creation process and guides the user who might lack knowledge of the Process Protocol to create a project process map at the early stage of a project. Users will be able to tailor and customise the process map to suit their own project and company requirements, whilst having access to the template and default features that demonstrate the knowledge derived from previous projects and the Process Protocol framework.

To some extent, the process map creation tool is similar to many process modelling tools availableon the software market for years. Many companies have adopted a process-oriented view of their business operation, replacing the traditional functional viewpoint to achieve a better integration of operation [40]. However, the aim of the process map creation tool is not only to create a process model, but the basic
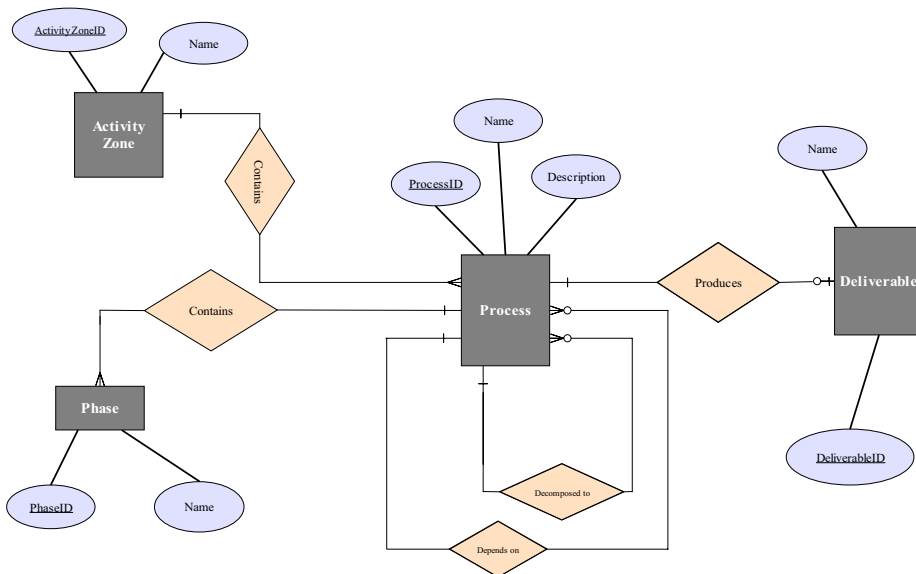

Figure 2. Entity Relationship Diagram of Process Protocol Framework

information structure based on the Process Protocol framework. The prototype of the process map creation tool has been developed under the Process Protocol II project (see figure 3). It enables the production of a project process map based on the generic Process Protocol framework, and it can be used across different projects. There are three major components in the tool, which are the main creation tool, generic processes data store and project process data store.

The main creation tool provides the functions for data retrieval, map creation and map customisation for different projects. Users will be able to define their processes, and create the project process map by referring to the generic processes provided by the Process Protocol. All the generic processes developed in are stored in the generic process data store built according to the Process Protocol data model. The project process map created by users is stored in the project process data store, which provides the basis of the process management tool.

Figure 3 is a screen shot of the prototype of the process map creation tool. It is a standalone MS Windows application developed using Microsoft Visual Basic programming tool. Its interface consists of three main parts:

Process Tree

On the left side of the window, the process tree is used in a similar windows file explorer style to show the decomposition structure of the process map. Processes in three different levels are represented in a process tree hierarchy respectively. Processes in the process tree are selectable, they can be selected by mouse click and the corresponding process in process map will be highlighted. In figure 3, the process "Update Financial Factors" is selected and the same process in process map is highlighted.

Process Map

Process map is a visual representation of the Process Protocol Map, it interacts with the process tree on the left. Processes in different levels are represented in different colours on the screen. (Figure 4)

Process Details
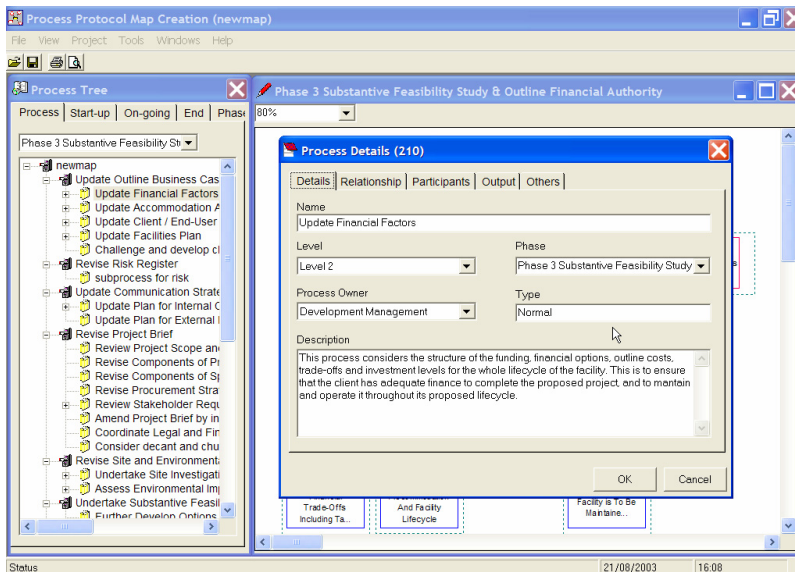
All the information associated with each process is

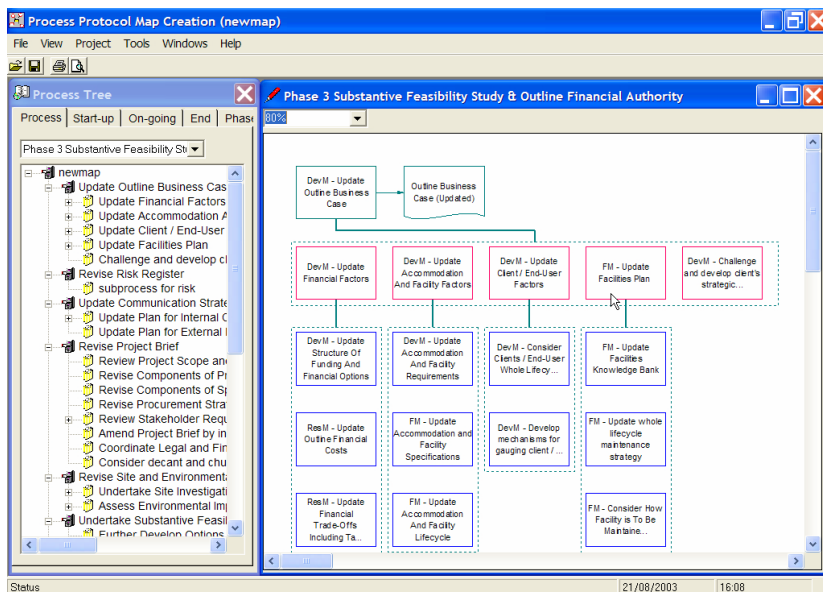**Figure 3.** Process Map Creation Tool (1)

Figure 4. Process Map Creation Tool (2)

shown in process details dialogue box. It includes name, process level, process owner, description, type etc. Figure 3 shows the detailed information of process "Update Financial Factors".

4.2 Process Management Tool

The process management tool is a knowledge based project information management system which integrates the process model as its core information framework. Due to constraints of resources, the research only identified the requirement of the process management tool, which should provide:

- Knowledge capture functionalities, such as document/drawing publishing to record project activities and archive project documentation based on the process frame created by the 'Process Creation Tool'
- Knowledge development functionalities, using data mining or OLAP techniques to analyse the project information to identify the information pattern, potential conflict, such as potential resource issues on

site, optimised construction programme, construction process simulation for possible crash detection.
- Knowledge sharing functionalities, such as messaging service, email notification, document sharing.
- Knowledge utilisation functionalities, web based interface, personalised project information page for each user, fast search tool for document or information retrieval.

In such knowledge based environment, teams can reduce costs and save time as they gather and disseminate information throughout the project lifecycle. Furthermore, the integrated project process map will become the route map to help and guide the project management team to monitor and track project progress, documents, etc. The centralised project information can be reused in a future project where the knowledge captured and stored can be used to inform decision-making and Value Engineering.

The proposed process management tool has some attributes currently found in some web based project

management systems, also called Project Extranet, which has grown rapidly in the UK since 2001. Over 1500 projects with a total capital value of more than £20bn are now managed by web based project management systems. [40]

The main function of a Project Extranet is to share project documents, and the current systems are now not only allowing sharing documents through the network, but also enabling users to view most formats of computer files without installing any extra software. Moreover, users are able to mark-up (redline, comment), make revisions, which become a part of the original document. A Project Extranet is also a restricted network for the project team, every user is identified by the user ID and password. It is therefore possible to automatically track and log the activities of individual users, such as who made what comment, who viewed a particular file or modified it, etc. It is also possible to introduce the project hierarchy and assign different access level to ensure the information to be seen by the right group of users. Another important advantage of Project Extranet is that all the project participants have access to most up-to-date versions of project information. It will, in theory, significantly reduce the expensive mistakes caused by working with out-of-date information, which is quite common in the construction industry. Furthermore, the cost of sending and printing project documentation will be reduced, since most of the documents are exchanged electronically. However, current systems are mainly concentrated on storing and indexing project documents, and sharing the documents via the Internet. It only achieves knowledge sharing and part of the utilization. The major benefit of the proposed Process Management Tool is using the construction process as a knowledge /information framework to capture project information, which makes it possible for reusing or analysing such information for future projects.

Since the Process Management Tool has some similar features as web based project information systems, it makes sense to further develop the existing systems rather than developing a complete new tool. Some industrial partners have approached the research team to discuss possible collaboration. It is believed that it will be the next generation of construction project management tools.

5 Conclusions and Recommendations

IT has become one of the crucial factors to the success of business and the construction industry is no exception. The Process Protocol Toolkit aims to provide an IT approach to manage project information and knowledge throughout the project lifecycle based on the Process Protocol framework. The toolkit in its current state focuses on project documents rather than the information within the documents. The authors believe that the full benefits of integrated IT systems can be realised when they are focused on the exchange of information, which is contained within project documents, to facilitate effective knowledge sharing and learning. This poses great challenges in the way that project information is communicated in a project environment and the way in which people interact to add value and recycle information and knowledge. It is not only the IT systems that need to address the integration issues but the culture within construction projects needs to be addressed.

Furthermore, IT systems like CAD, 3D modelling, cost estimating, and project planning systems which are widely used by the industry, have not been incorporated into the Toolkit presented in this paper. The ultimate objective is to bring all types of IT systems together working within the Process Protocol framework, or indeed other process frameworks, sharing information and allowing greater integration of knowledge across functions and project deliverables. For example, it should be possible to enter resource and time information in the process framework once, and be able to extract complete project plans without the need to enter the information in a project planning tool. Technologies,

such as XML, can achieve such an objective. Further research is required to develop a truly integrated system to improve the performance of the construction industry.

The Toolkit, however, achieves its objective in enabling the effective understanding and use of the Process Protocol framework, in that it focuses the people involved in a construction project to understand the interdependencies between project deliverables, to provide a clear illustration of the projects' status and to enable clients and supply chain members to make informed decisions at the appropriate stages in the process, and across different projects.

Acknowledgement

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