DEVELOPMENT OF AN INNOVATIVE FRAMEWORK FOR CLIENTS' REQUIREMENTS INFORMATIONMANAGEMENT IN CONSTRUCTION PROJECTS

A.K. Jallow[1].; P. Demian[2].; A.N. Baldwin[3].; C.J. Anumba[4].

[1, 2, 3]Department of Civil and Building Engineering, Loughborough University, LE11 3TU, UK

[4]Department of Architectural Engineering, The Pennsylvania State University, University Park, PA16802, USA

ABSTRACT

Properly managing client requirements information can contribute to high construction productivity and improve the quality of built facilities. This paper presents an innovative framework which defines a life-cycle approach to managing client requirements information. The Enterprise Requirements Information Management Framework (eRIM) introduces an approach to managing client requirements throughout a project lifecycle. It defines an information-centric and process-oriented approach to requirements management and describes how Information Technology (IT) / Information Systems (IS) can serve as support tool. It supports life-cycle requirements information availability, facilitates coordination, enables visibility, traceability and dependency checking which is crucial for analysing the impact of proposed changes in requirements. The paper includes findings from three case studies of construction projects through observations of meetings and interviews with selected construction practitioners. The results indicate that implementation and incorporation of the framework in construction projects could contribute towards improved performance and more efficient and effective client requirements management.

Keywords: projects, lifecycle, information, requirements, requirements management

INTRODUCTION

Documenting and managing client requirements are a catalyst to successful completion of projects and provide resources for project evaluation and post-project reviews. Construction client requirements information is a vital value chain resource needed at each project phase during construction and through-life of a facility. Client requirements information is initially produced as a *program document* (or in UK, the client '*brief*') which is generated following programming, a process to gather and determine client needs, wishes and expectations for a building leading to statements of architectural problem and the requirements to be met (Duerk, 1993; Pena and Parshall, 2001). Programming is often regarded as a continuous process thus the program document needs to be flexible and dynamic to incorporate emerging

requirements and changes.
This research has identified that consideration of requirements information is commonly concentrated at the early phases of construction projects and becomes disjoint in later phases. Once the design begins and progresses, these requirements are left aside and the design is used subsequently to interpret client wishes. Similar observations have been made by Kiviniemi et al. (2004). Managing client requirements including their communication to all parties to the construction process is not easy because of the large volume of information that comprises the requirements as well as inputs from the many stakeholders involved in the process (Charoenngam et al., 2003).

The research reported in this paper adopted case study observations to enable an in-depth analysis of the process of client requirements management as currently applied to construction projects. Three case studies were conducted through observations of different construction projects during which the researcher served as a semi-participant observer. These observations helped to provide an understanding as to how requirements are gathered, stored, distributed and communicated between stakeholders and interpreted into later stages of project phases. They also demonstrated how changes to client requirements are requested and handled through the authorisation mechanism and how the information generated from it is managed.

The findings reported in this paper are part of an on-going project to develop a client requirements information management framework and prototype system for construction projects taking a lifecycle approach (Jallow et al., 2008). The aim of eRIM is to help construction organisations reduce the cost and time of construction projects and to improve on the provision of quality facilities through better management of requirements information. A framework is formulated for managing information relating to client requirements from when these requirements are first elicited in the program document through to the decommissioning and/or disposal of the facility. This framework provides storage for central access to all stakeholders and facilitates management of changes.

The central focus of this paper is specifically on the development of the innovative eRIM framework and its constituent components. Since this is part of an on-going research, implementation of the framework has been briefly introduced with a detail discussion aimed for subsequent publications.

RELATED WORK

Project teams require on-demand access to information (Aziz et al., 2006). This necessitates appropriate project information management systems. The information generated by such systems may be of different types (ranging from client requirements, design information, cost and budget information, tender and contract documents, to construction programme) and formats/media (text, images, CAD, Gantt charts, video, etc.). These are normally filed in hardcopies or in some cases, electronically (e.g. Word, spreadsheets, etc.).

The management of such information includes storage and retrieval mechanisms, distribution and communication amongst project teams and generally managing any changes. It is necessary to manage the information exchange and sharing between distributed project teams and heterogeneous computer systems. Making project information available to projects teams all through the lifecycle of construction projects is vital for successful completion of projects (Kong et al., 2005). Inadequate information management is what contributes to delays and construction waste (Smith and Tardif, 2009). Information collected during programming must be properly documented in order to enable effective communication among project team members (Pena and Parshall, 2001). Major efforts have been made to develop systems and standards to enable information sharing and exchange. These include Industry Foundation Classes (IFCs) (Smith and Tardif, 2009). Distributed systems have been developed using the internet as the backbone for the access and retrieval of project information (Bridges, 1997).

Jokinen (1996) recognised that the internet is an advancing technology, an infrastructure which makes an excellent platform for distributed applications where different types of information can be accessed from different locations. Project extranets (which are internet enabled systems make use of a central shared storage drive for project information management) are widely used within the construction industry (Moses at al., 2008; Wilkinson, 2005). They facilitate the access of project documents but are temporary repositories for the duration of projects and they do not also adequately provide process management i.e. coordination of information flow between humans and systems. They are document-centric rather than data/information-centric. Independent and heterogeneous software/systems used in construction projects have greatly enhanced information management efficiency but they have serious limitations in sharing information between systems and being interoperable (Anumba et al., 2008). Service Orientated Architecture (SOA) which according to the World Wide Web Consortium (W3C), is "A set of software components which can be invoked, and whose interface descriptions can be published and discovered" coupled with web services technology (which can support interactions between systems using Extensible Mark-up Language (XML) based messages via the Internet) can facilitate information sharing and interoperability of heterogeneous systems.

Requirements management as a discipline originated from the software industry where it has been applied intensively and later extended to other industries (Green et al., 2004). The discipline is concerned with gathering requirements from clients, organising and analysing this information, and managing the processes of reviewing and changing the information as well as the documents in which it is contained (Schmidt and Souza, 2007). In construction, these processes are spread across the entire lifecycle of a construction project and the resulting facility. Green et al. (2004) believe that requirements management has no equivalent in construction but similar practices are applied such as programming, value management and change control.

Several change management systems and models have been developed for the construction industry (Isaac and Navon, 2008; Charoenngam et al., 2003; Ozkaya and Akin, 2007; Sun et al., 2004) but none of these is known specifically to address client *requirements* changes but instead they focus on *design* changes. They lack a dedicated component for change management linked to a repository of requirements. In addition, they do not take a lifecycle

approach by managing the changes through the life-time of the facility. The eRIM framework proposed in this paper follows earlier efforts by Kamara et al. (2002) who developed the Client Requirements Processing Model (CRPM). That work served as an important point of departure for the current research but did not take a lifecycle view and change management. The Computational Hybrid Assistance for Requirements Management (CHARM) system was also developed defining a process where the designer/architect needs to be aware of requirements information (Ozkaya and Akin, 2007).

ANALYSIS AND DISCUSSION

Both literature and case studies show that the management of client requirements in the construction industry is currently manual, paper intensive and inefficient. Automation was rarely used for storage purposes, but then with many limitations. Client requirements are usually written or printed on paper documents which are then archived along with other project documents. Sometimes, this information is transferred into electronic form using word processors or spreadsheets and later converted to Portable Document Format (PDF). There is little attempt to co-ordinate requirements information across the project supply chain. Each of the parties involved in the project work on their own copy of the requirements. This proves to be ineffective when changes are made or considered. Despite email being a great tool for sending and receiving information, it is not effective for requirements management. Requirements management requires task process management, traceability, visibility and an audit trail of requirements changes and their impacts. Email does not provide such functionality. Collaborative systems such as project extranets were not utilised in any of the case studies observed. The reasons given for this included: many projects are too small to warrant implementation of such systems; collaborative systems are not user friendly and demand a high level of IT support; project extranets collate too much un-necessary information.

Analysis of the type of requirements information required at each project phase highlighted how the nature of the information varies for each phase. One key issue identified is that there is no mapping of requirements information between the phases. This makes it extremely difficult to manage dependencies and traceability between them. As the initial client requirements are documented in the program document, the information needs to be stored in a purpose built repository which facilitates shared and distributive access. Consequently, all subsequent types of requirements and project information should be mapped to their origins within the program document. This will indicate traceability of dependencies between requirements at all project phases through-life.

Program documents from all three projects were studied and analysed thoroughly. It was found that the '*rationale*' of client requirements and '*priority*' of requirements were not defined within the typical documents used. There were situations where a decision was needed with respect to a particular requirement but it was difficult to ascertain how important or relevant it was; a rationale and priority statement would have eased decision making. When there was a change to a particular requirement, it become virtually impossible to update all the instances of that requirement on all the copies. The most obvious way is to

make newer copies of the requirements and re-distribute them. It was frequently observed that different versions of requirements were in circulation with teams and ascertaining the most up-to-date could make version control difficult. Design and eventually construction errors were observed to occur as a result of working with out-dated sets of requirements information. The data collected highlighted the importance of: managing client requirements at each phase of the project and throughout the life of the facility; the need for a centralised storage system; easy access to details of the requirements for all the project stakeholders; and efficient and effective co-ordination and control of the requirements change process.

THE INNOVATIVE FRAMEWORK (ERIM)

eRIM provides a defined and controlled requirements management process that registers client requirements from program document stage, through design and construction and all through the life of the facility. It ensures that details of client requirements are available at all times; provides a history of previous changes to requirements and enables the project manager to manage change effectively through a defined and controlled change management process. eRIM has been developed from a data/information-centric perspective with the concept of providing an on-going view of clients' requirements. It places emphasis on collaborative working, interoperability, thus enabling information sharing and exchange between humans and systems (both homogeneous and heterogeneous), providing shared and distributed access to requirements information over a centralised repository with lifecycle approach. An overview of eRIM is shown in Figure 1. The basic system comprises (i) a requirements repository and (ii) a change management system which is business process management-oriented to manage the requirements change orders/requests and authorisation process. The supporting scheme defines requirements information to be identified for each of the project/facility lifecycle phases. (This research adopted the life cycle phases of the Royal Institute of British Architects (RIBA) "Plan of Work").

Requirements repository

Client Requirements, as defined at each project phase, should be stored in the repository within a separate requirements library module designed for that phase. Dependent requirements should be mapped between modules to provide traceability between requirements necessary for impact analysis of changes. New requirements can be added into the repository using any of the identified media (online form, telephone, email, paper form, verbal instructions through face-to-face or at meetings). Alternatively, information on requirements can be recorded in an external document which can then be directly imported into the repository. Such external documents need to be specifically *structured* and *formatted* according to the data schema of the individual modules of the repository. The database structure should support detail requirements information storage and should include attributes such as requirement type, description, rationale and priority. '*Rationale*', information on why a particular requirement is needed, is considered a key attribute. It is also essential and relevant to understanding changes and their impact and can mitigate from people making assumptions on requirements. The repository provides up-to-date and real-time requirements information, as a centralised storage, which can be accessed concurrently by distributed teams at different locations. Project team members, subject to roles and authorisation are able to log-in to the repository and create/view/edit requirements. Different systems are used at

various phases of a project to facilitate activities of those individual phases. E.g. a material procurement system is used to order construction materials. Such systems carry data and information associated with requirements yet they stand independently. eRIM framework's proposition is that they should be integrated with a requirements repository. This will enable the constant checking of compliance with requirements to validate any requirements information carried in those systems in accomplishing activities at the phases in which they are used. With our example, the material procurement system can be integrated with the requirements management system to check order information against the requirements for compliance (Jallow et al, 2008). This is vital toward efforts to reduce purchase of wrong materials that do not meet requirement specifications.

Requirements change management system

Change management is an integral and essential component of the framework. Requirement changes should be executed under a coordinated approach to streamline the change process and assist in real-time capture of the change information. Different construction organisations may have different change management procedures or protocols in terms of execution. eRIM accommodates for these differences. Change may be requested through different channels: Face-to-face (individually), meetings, telephone, email, paper-based Requests for Information (RFIs) and on-line forms. eRIM recognises all these types and are factored within the framework.

The system views requirement change management as a process-driven activity and adopts a business process management (BPM) approach to manage all changes ensuring the synchronisation of process activities and to integrate different processes, people and systems together with the information required to provide coordination, visibility and traceability. Process-orientation is vital to support collaborative working and information flow and facilitates integration of processes. In his work on a data-centric, process-oriented model for effective collaborative working, Bacon (2009 in Shen et al., 2009) echoes that "without putting process at the heart of collaborative working, the adoption of a technology solution, be it an extranet or a BIM, is unlikely to deliver value to the collaborating team or to the client". Change request will be routed accordingly during the change management process as defined by the workflow with activities and tasks performed by both people and systems. Because the BPM system is integrated with the repository, requirements information can be made available from the repository through the integration layer which can be used to analyse impact of change request. This is dependency checking. The '*requirements dependency checker*' searches the repository for all related requirements to the one proposed in the change request. This enables the user to be fully aware of the dependencies and impact that could be caused as a result of the proposed changes. Once approved, the system updates the changes that have been agreed using the '*requirements updater*' without any manual input. The change process system then communicates that information to all affected stakeholders through email notifications.

Project and facility lifecycle phases

The case studies highlighted changes in the detail of client requirements as the design is developed. Traditionally these requirements are held in a number of different documents. Client requirements must therefore be represented at each project phase in different levels of detail. At the earliest phase, requirements could be represented in simple business language

describing the business case and client needs of the project in a program document. The content and representation becomes more detail in the later phases, for example in design, producing the specifications and room datasheets. The eRIM system accommodates this need by recognising project and facility life-cycle phases and types of documents at each phase. The relationship between the requirements information of the different phases must be identified and represented. No matter what type of information is defined at a particular phase, there will be some element of client requirements which should reflect to the original program document. The project and facility lifecycle phases are shown in figure 1 as the 'standard document layer'. This figure includes examples of the standard documents and information generated at each phase of the life-cycle. (These are for the purpose of demonstration but this information is by no means exhaustive).

On the layer below, the '*requirements information layer*', client requirements information will be extracted from the standard documents from each phase and stored in the repository. This demands the following activities:

- Identification of client requirements information at each phase
- Structuring and formatting of the identified data fields and information in an appropriate format according to the database schema of the repository to enable storage and to facilitate the drive for compatibility between systems and teams.
- Identification of attributes to be used as a 'mapper' to the program document (The mapper is a requirement identifier that links related requirements which is essential for traceability across the lifecycle).
- Storage of the information within the repository which is essential for consistency, accuracy and completeness of requirements information.
- Integrate the repository with other systems used at various project phases using service oriented technology and web services.

Implementation of eRIM framework

A prototype of eRIM has been developed to validate its functionality using a MySQL database engine to develop the repository with PHP as the scripting language for the web interface. This web-based system runs on Apache web server and can be accessed using any web browser. The change management system is implemented using a business process management suite/system to design the process model and orchestrate that into an executable automated change management system. The integration between the repository and the change management system and applications used at different project phases takes a Service Oriented Architecture (SOA) philosophical approach with web services as the integration technology. When implementing the change management system in an organisation, the following activities need to be undertaken:

- Develop a process map of the requirements change process: This can be developed using Business Process Management Notation (BPMN) - recommended.
- Automate the process model into an executable process. E.g. transform the BPMN model into Business Process Execution Language for web services (BPEL4WS): a Business Process Management Suite/System can be employed for this.
- Deploy the executable process by publishing the BPEL into a process engine/process server for execution.
- Define and develop the integration between the change system and the repository using SOA and web services technology.

It is important to note that only the key steps of the change management process are shown on the architecture of the framework (Figure 1) for illustration purpose. During implementation, these would require expanded modelling using BPMN showing all sub activities, information flow and their interactions across functional units, roles and other systems (both internal and external).

REQUIREMENTS MANAGEMENT ROLE

Our research identified that personnel from several functional areas within a construction project are currently responsible for capturing and managing the client requirements. The client, architect, consultants, project manager (PM), quantity surveyors (QS) and cost consultants (CC) play key roles in managing the client's requirements. The designer and contractor play a major role because they focus on transforming customer needs, expectations and constraints into design solutions and supporting them throughout the construction process. With the several parties involved, it becomes cumbersome to identify who is responsible for the management of the requirements. In other areas of the construction process, specific role(s) are created to be responsible for specific management tasks and activities. Within other product development sectors such as manufacturing, aerospace and software, 'Requirements Managers' are hired specifically to be responsible for customer requirements (Schmidt and Souza, 2007). Within the construction industry, there is currently no known role responsible for specifically managing client requirements. Given the difficulty of managing client requirements, the research team recommends the introduction of 'Requirements Manager' into the project team.

CONCLUSION

Managing client requirements is challenging and requires a structured approach. The Enterprise Requirements Information Management Framework (eRIM), defines a lifecycle approach to managing client requirements. The framework is information-centric and comprises two main components: a requirements repository and a requirements change management system. Based on the combination of the advantages of web-database systems and business process management, the framework expands the scale of traditional client requirements management to include a lifecycle approach from a process management standpoint. This approach identifies requirements at each phase of the project. Requirements information derived from each phase is stored in the repository with related requirements mapped using a unique identifier. This ensures traceability between requirements which is crucial in enabling dependency checking and impact analysis during change request. The change management system provides clear control and coordination of the change process and contributes towards historical knowledge on all changes that occurred during a building lifecycle. The applicability of eRIM was evaluated through a charrette. The industry representatives present believed that, if properly adopted, such a system will improve on the current requirements management practice.

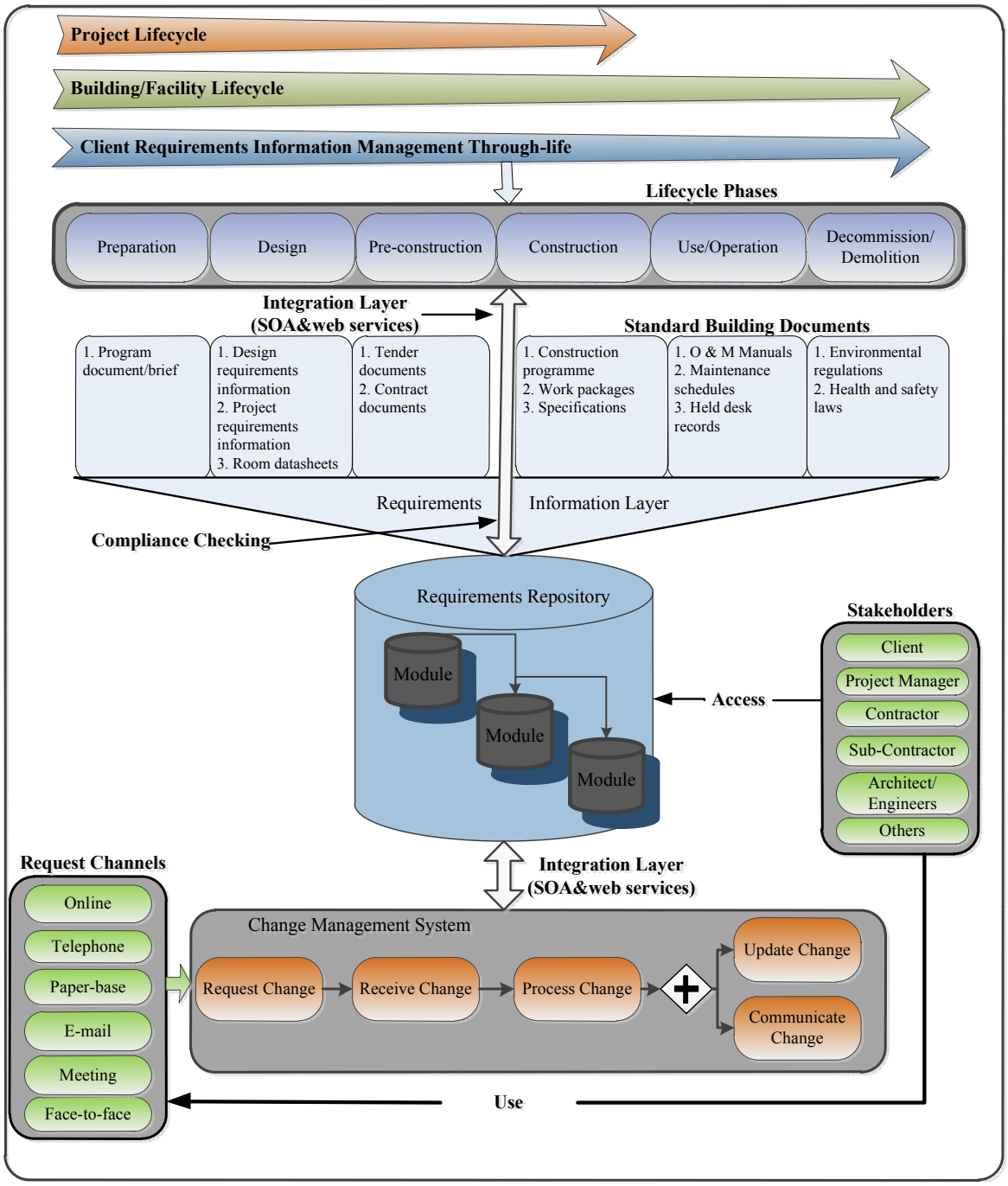

Figure 1: Architecture of enterprise Requirements Information Management Framework (eRIM)

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