Requirements Management in the Architecture, Engineering and Construction (AEC) Industry: The Way Forward

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Abstract

Requirements are the basis for every project, defining what the stakeholders need from it and also what the end product must meet in order to satisfy that need. Requirements, therefore, form the basis for project planning, risk management, acceptance testing, trade off and change control. They are the essential elements of the briefing, design and construction stages of any development projects. However, past research studies overlook the lack of identification, management and traceability of the requirements during the life cycle of construction projects in the AEC industry. In addition, research on Requirements Management (RsM) in the AEC industry is very limited in comparison with studies on Requirements Engineering (RsE) in the system and software world. The aim of this paper is to investigate the need for and focus of research on Requirements Management (RsM) in the AEC industry. A comprehensive literature review on RsE/RsM in the system and software engineering as well as in the AEC industry has been conducted. The findings, imperatives and challenges for Requirements Management are discussed in this paper. We propose a framework for future research directions on Requirements Management in the domain of construction project management. This research is of significant value to professionals and academics in the AEC industry for improvement of RsM processes to achieve successful delivery of construction projects.

Keywords: construction, project management, requirements engineering, requirements management, AEC industry

1. Introduction

Facing increased competition and greater project complexity, architectural, engineering and construction (AEC) firms are seeking ways to gain client satisfaction and improve project performance. Requirements are the basis for every project, defining what the stakeholders need from it and also what the end product must meet in order to satisfy that need. Requirements, therefore, form the basis for project planning, risk management, acceptance testing, trade off and change control (Hull et al., 2005). They are the essential elements of the briefing process as well as the whole development process. The briefing process in construction is the process through which a client informs others of its needs, aspirations and desires for a project (CIB, 1997). Previous research reveals that there is a lack of identification, management and traceability of the requirements during the project development process in construction projects (Kelly et al., 1992; Barrett and Stanley, 1999; Kamara and Anumba, 2001; Yu et al., 2005, Arayici et al, 2006, Chan & Liu, 2007). The management of requirements in the whole development process in the AEC industry require professionalism and good communications among stakeholders; innovative use of IT as a facilitating platform; and a collaborative mindset and objective supporting system for decision making, but many of these are inadequate (Kamara and Anumba, 2001, Chan et al., 2005, Chan & Yu, 2005, Hull et al., 2005, Arayici et al., 2006, Chan et al., 2007).

Research on Requirements Management (RsM) in the construction industry is very limited in comparison with its counterpart on Requirements Engineering (RsE) in the system and software world. There is already plenty of developed theory and practice in RsE from which construction researchers could learn. The aim of paper is to investigate the need for research on Requirements Management (RsM) in the AEC industry. This aim is achieved through, first, a comprehensive literature review on RsE/RsM in the domain of systems and software engineering as well as the AEC. Then follows analysis and discussion of the findings, imperatives and challenges for Requirements Management in the AEC industry. The paper concludes with a synthesis of a vision for future research on Requirements Management. This research is of significant value to professionals and academics in the construction industry for improvement of RsM processes to achieve successful delivery of construction projects.

2. What are requirements?

A requirement is a statement identifying capability, physical characteristics, or quality factor that bounds a product or process need for which solution will be pursued. ‘Requirements’ in the computer engineering world are defined during the early stages of a system development as a specification of what should be implemented (Sommerville and Sawyer, 1997). They are descriptions of how the system should behave, concerning application domain information, constraints on the system’s operation, or specifications of a system property or attribute (Kotonya and Sommerville, 1998). They may be a constraint on the development process of the system. For example:, (1) *the system must ensure that personal information is never made available without authorisation* or (2) *the word processor must include a spell check and correction command*. Good requirements are complete, unambiguous, consistent, feasible, solution neutral, traceable, and necessary. Requirements should not

be used for the wrong purpose, be concise, correct, and verifiable (Kamara and Anumba, 2000; Young, 2004; Zielczynski, 2008). The importance of good requirements and the underlying dynamic nature of the process mean that it is necessary to identify the different types of the requirements in a project.

In the architecture, engineering and construction (AEC) industry, there are different types of project requirements. They are (Kamara, et al., 2002):

1. Client requirements – Requirements of the client which describe the facility that satisfies its business need. These incorporate user requirements, those of other interest groups (stakeholders) and the lifecycle requirements for operating, maintaining and disposing of the facility.

2. Site requirements – These describe the characteristics of the site on which the facility is to be built (e.g. ground conditions, existing services, history, etc.)

3. Environmental requirements – These describe the immediate enviromental (e.g. climatic factors, neighbourhood, environmental conservation, etc.) surrounding the proposed site for the facility.

4. Regulatory requirements – Building, planning, health and safety regulations, and other legal requirements that influence the acquisition, existence, operation and demolition of the facility.

5. Design requirements – Requirements for design, which are a translation of the client needs, site and environmental requirements.

6. Construction requirements – Requirements for actual construction, which derive from the design activity.

The interrelationship between these project requirements is illustrated in Figure 1. Client requirements combine with site, environmental and regulatory requirements to produce design requirements, which, in turn, generate construction requirements. Other project requirements are generated from the business need of the client that is to be satisfied by the proposed facility. The end product of the building construction, the building, should fulfil the needs and requirements of all stakeholders in a comprehensive manner. This is the ultimate target of Requirement Engineering in AEC industry.

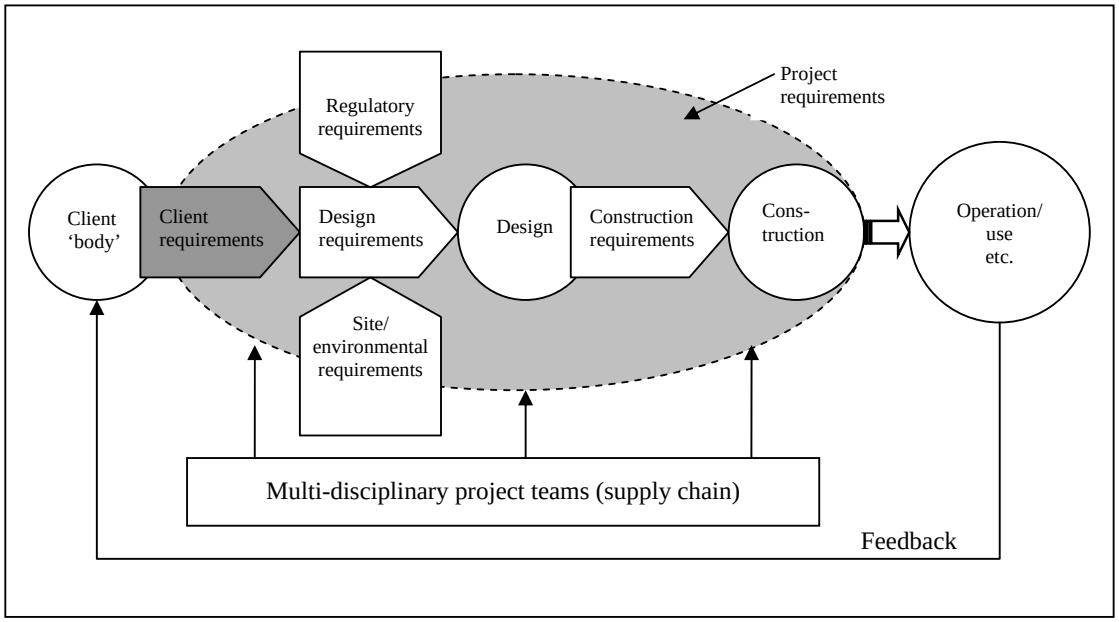

Figure 1 Interrelationship between project requirements (Source: Kamara et al., 2002)

A requirement is necessary attribute in a product or system, a statement that identifies a capability, characteristice, or quality factor of a product or system in order for it to have value and utility to a client or user (Young, 2004). Requirements are important because they provide the basis for all of the development work that follows. In the AEC industry, once the requirements are set, developers initiate the other technical work: design, tendering, construction, commissing and operation. The practice of Requirements Management is critical to the successful delivery of a construction project.

3. What is requirements Engineering/Management?

The requirements problems have been existed for a long time. In their 1976 empirical study, Bell and Thayer observed that in adequate, incomplete, inconsistent or ambiguous requirements are numerous and have a critical impact on the quality of the resulting software. Noting this for different kinds of projects, they concluded that 'the requirements for a system do not arise naturally; instead they need to be engineered and have continuing review and revision' (Lamsweerde, 2009). Some 20 year later, different surveys over a wide variety of organizations and projects in the United States and in Europe have confirmed the requirements problems on a much larger scale. Poor requirements have been consistently recognized to be the major cause of software problems such as cost overruns, delivery delays, and failure to meet expectations of degradations in the environment controlled by the software.

Numerous initiatives and actions have been taken to address the requirement problem. Process improvement models, standard and quality norms have put better requirements engineering practices in the foreground. An active research community has emerged with dedicated conferences, workshops, working groups, networks and journals. Requirements engineering courses have become integral parts of software engineering curricula. Today Requirements Engineering has become inescapable for System and Software Engineering. It has been invented to cover all of the activities involved in discovering, documenting, and maintaining a set of requirements for a computer-based system

(Sommerville and Sawyer, 1997). The use of the term 'engineering' implies that systematic and repeatable techniques should be used to ensure that system requirements are complete, consistent, relevant, etc. Requirements Engineering is also about management and hence issues in relation to requirements and management blend to show how requirements can be used to manage systems development. The main purpose of Requirements Engineering is to create better requirements and to manage these requirements.

Requirement management is the process of managing changes to the system requirements. Requirements for a system always change to reflect the changing needs of system stakeholders, changes in the environment in which the system is to be installed, changes in the business which plans to install the system, changes in laws and regulations, etc (Kotonya and Sommerville, 1998). These changes have to be managed to ensure that they make economic sense and contribute to the business needs of the client. The technical feasibility of change proposals must be assessed and it must be possible to make the changes within budget and schedule.

The requirements management process ensures that we know what the client wants and that the design solution and the end product efficiently meet these requirements. The end product should fulfill the needs of all stakeholders in a comprehensive and logical manner. In order to attain this, the client requirements need to be identified and captured. This is the first target of requirements engineering. Since it is impossible to satisfy all needs of all stakeholders for various reasons, the second target of requirements engineering is to put the different client requirements together. When requirements of the various stakeholders contradict, it is difficult to judge whose need is more important than others. Robertson and Robertson (2006) suggested that the ranking of stakeholders' opinion is based on the power, interest and proximity of the stakeholder. This may be the third target of requirements engineering. In addition, the compliance of design with the requirements should be verified constantly during the project. Finally, it is necessary to ensure the final product complies with the requirements of the client.

4. Imperatives for requirements management in the AEC

The dominant storyline in the literature of the construction industry exhorts the adoption of RsM with reference to a number of longstanding problems that are common in the AEC industry (Fernie, et al., 2003): failure to deliver projects within budget; late delivery of projects; failure to consider project decisions from a whole life cycle perspective; and poor customer satisfaction. As concluded in the Latham Report (Great Britain, Latham 1994), "more effort is required to understand client needs". The report by the Hong Kong Construction Industry Review Committee (2001) has also recommended clients to "set out the requirements of their project clearly, systematically and comprehensively."

Client requirements are the foundation for most all development projects. They are like an architect's plans for a building: If the plans are wrong, the builders will construct the wrong building. However, an architect's plans can only be correct if he has gone to the trouble of finding out exactly what the building owner needs, and the building's intended use (Robertson and Robertson, 2005).

The first job of client requirements is to show what results clients need, and these must be documented. Thereafter, they will almost certainly be changed during the development process of the project. Moreover, every stakeholder may have different views and interpretations of the project's original scope and objectives. All the stakeholders in a project, whether users or not, have requirements. The requirements allow the stakeholders a chance to say what they need and want and to represent these different viewpoints.

Writing down each requirement lets the project participants check that the building, as built, does what it should: they can check each part of the design and each function separately. From the developers' viewpoint, this translates to what the designed building has to do. In addition, from the development project manager's point of view, a clear requirement means that progress can be measured and areas needing attention can be identified. Everyone can be confident that the project is on track when it comes to meeting the client because they can see ***how much*** of the job is done already, and ***how well*** it has gone so far.

From the engineer's point of view, a requirement is both something to be tested, and a source of acceptance criteria. Meeting these criteria provides evidence that a product does what it should. Good, sharp acceptance criteria come naturally from precise and well-organized requirement statements.

The proper application of Requirements Management to the AEC industry will help to integrate the project requirements into the design process and ensure the final product meets these requirements. It will not only elicit the true needs of the client and create a good brief in the briefing process but also allow the requirements to be recorded and traced back systematically during the project cycle for change management and performance assessment of the final building. Traceability of requirements can contribute to the following benefits (Hull et al., 2005):

a) greater confidence in meeting objectives

b) ability to access the impact of change

c) improved accountability of subordinate organisations

d) ability to track progress

e) ability to balance cost against benefit

5. Challenges of requirements management in AEC

The challenge in writing requirements is mainly to communicate reliably and adequately between groups of project stakeholders who may never meet, and who have quite different viewpoints. For example, it may be difficult for the sub-contractors to meet end-users: their direct boss is the main

contractor of the construction projects. The problems of RsM may be as follows (Alexander and Stevens, 2002):

1. Gaps between people - There are various groups of stakeholders who need to communicate well to make a new project a success. In the construction industry, there are bound to be gaps between developers and marketing managers, users and developers, project participants and clients, designers and contractors, contractors and sub-contractors.

2. Time to work out a good structure – Getting the requirements structured correctly and precisely takes time because the structure depends on what kinds of user there are, on what each kind of user needs the project to fulfill, and on the nature of the constraints. Time must be allowed for gathering, organizing and checking out the requirements both formally and informally. This is not something that can be rushed.

3. Expected effort and time taken – To put some numbers to all this, Alexander and Stevens (2002) suggested to spend about 5 percent of project effort on the requirements and also allow a generous chunk of the schedule – up to 25 percent of calendar time – for requirements on shorter projects, but not more than three months on larger ones.

4. Requirements effort throughout the life cycle – Some effort on requirements is needed throughout the project because compromise and change are inevitable. An essential element in any acceptable compromise knows how important each requirement is to its owner. The issues concerning change of requirements are discussed in the next section.

5. Allow for change and feedback – The lack of well-documented updates make it difficult to trace the changes in Employer's Requirements (Oberg, et al., 1998). Changes from outside are also inevitable. Every project with a lifetime of more than a few months will experience pressures from competitors, market or operational changes, from new technologies, and from stakeholders to change the requirements and the design. The change of requirements should be able to be tracked back, updated and recorded properly for future use and feedback for subsequent projects.

6. Allow for users' participation and feeling – The lack of adequate end-user's involvement causes failure to manage end-user's expectations (Kujala et al, 2005; Arayici et al., 2006). The users are the real stakeholders that occupy and perform activities in the building. Their voice toward the requirements must be heard and should be paid attention to as early as possible during the project development process. Some users may be defensive about giving their opinions, especially if, for instance, they think their jobs may be affected by the project being developed. In that situation, it is essential to gain their trust before trying to start developing the project. It is necessary to consider who will really benefit from the use of the building and a win-win situation should be achieved if possible.

6. A vision for future research

After analysing and discussing the principles, imperatives and challenges of RsM, the next step is to carry out a comprehensive review and reflection of them and develop a practical framework for RsM in AEC industry. This is presented here and the authors of this paper propose this as a preliminary framework of RsM for construction projects (Figure 2). A more refined version will be developed on the basis of the results of further investigation. The proposed refined framework is likely to comprise some guidelines and critical success factors for managing project requirements in a holistic RsM process.

A further step will be to develop a practical "how-to" guide which explains the application of RsM principles in construction projects based on a literature review, followed by further data collection through interviews and questionnaire survey. The guide will provide practical solutions to critical issues frequently encountered by clients, consultants and contractors in the RsM process. The is intended to provide the necessary tools, techniques and examples of tasks such as: how to elicit project requirements, define the requirements, identify the needs and wants, prioritise requirements, verify requirements, record and trace the changes of requirements in construction projects.

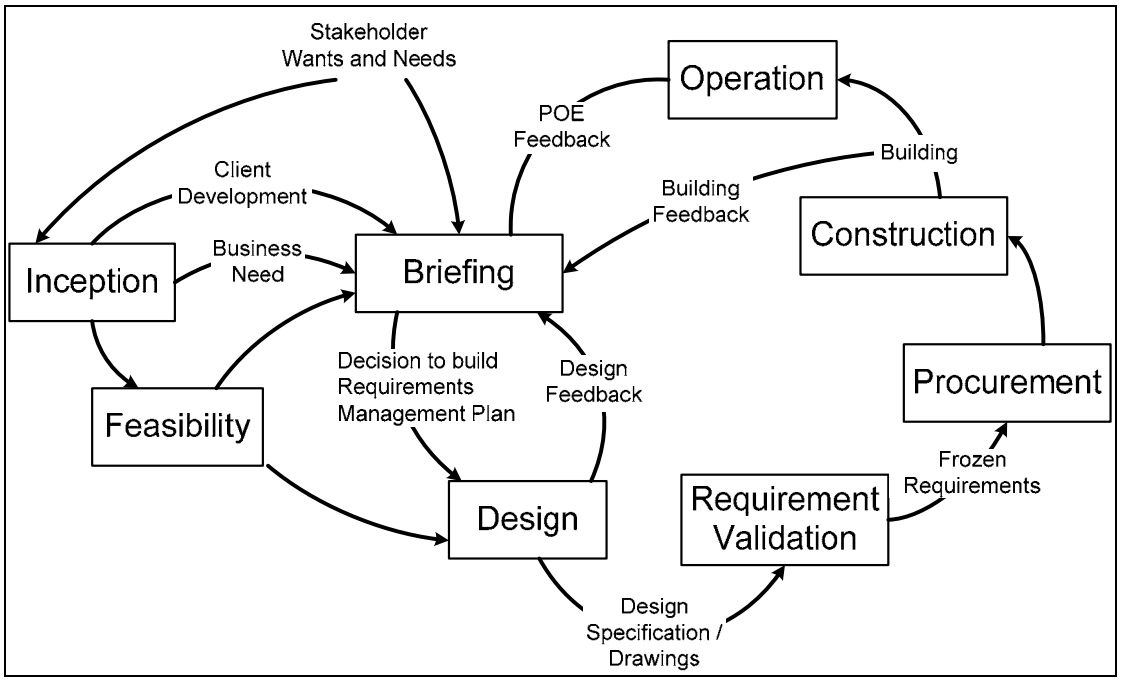

Figure 2 Preliminary framework of RsM in construction projects

7. Conclusions

Requirements Management is crucial to the successful delivery of construction projects. Good Requirements are complete, unambiguous, consistent, feasible, solution neutral, traceable, necessary, concise, correct, and verifiable. The proper application of Requirements Management to the AEC industry will help to integrate the project requirements into the design process and ensure the final product meet these requirements. It will not only elicit the true needs of the client and create a good brief in the briefing process but also allow the requirements to be recorded and traced back systematically during the project cycle for change management and performance assessment of the final building.

Research on Requirements Management in the construction industry is limited in comparison with Requirements Engineering in the system and software world. There is already a significant body of knowledge about developed theory and practice in Requirements Engineering which AEC professionals could learn from. There is a need to evaluate the existing practices of Requirements Management in the construction industry and to investigate best practices to improve the Requirements Managements process for construction projects.

This paper has put forward a preliminary framework as a basis for further investigation.

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