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Exploring Knowledge Management Principles for Decision-making in Low-Energy Building for Sustainable Construction

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Abstract

Low energy building retrofit presents important opportunities for reducing of greenhouse gas emissions in the environment. It has been considered as one of the key approaches to achieving sustainable development in construction industry. Nevertheless, such retrofitting proves challenging due to the fact that the industry has ignored the need to manage project knowledge in retrofitting these buildings. This has arguably made decision-making difficult for key stakeholders because lesson learned are not captured in low energy retrofit projects. Managing project knowledge has been established as essential in delivering low energy building retrofit projects through decision-making hence an informed decision support framework (IDSF) has been developed. The methodology employed in development of IDSF is through literature review covering, among other things, knowledge management (KM) principles and procedures. The IDSF will help improve decision-making capabilities of key stakeholders involved in low-energy building retrofit projects to make informed and appropriate decisions. It will also help to avoid post-decision mistakes in low energy building retrofit projects. Furthermore, IDSF will help in the development of decision support system (DSS) that will be used for making informed and sound decisions in achieving low-energy retrofit projects and also help in full uptake of retrofit projects.

Keywords: Climate change, existing buildings, knowledge management, low-energy retrofits, decision support.

Introduction

Climate change has imposed significant problems and risks worldwide. With the rapid increases in urbanisation and industrialisation more greenhouse gases (GHG) are emitted directly to the atmosphere. The built environment, particularly existing buildings and their operation contribute to a large extent amount of greenhouse gas emissions in the atmosphere (Asadi et al., 2012). This has necessitated the efforts of many governments and international organisations in the last decade in putting significant efforts toward energy efficiency improvement in existing buildings (Ma *et al*., 2012). For example the US government provided $30 billion for General Service Administration and Department of Defense to invest in energy efficient upgrades to their existing buildings and facilities (ARRA, 2009). In

Australia, the government in its 2009-2010 budget invested $454 million to progressively retrofit existing government buildings to increase the energy efficiency and reduce GHG (OEH, 2009). The United Kingdom (UK) government in 2010 made a significant contribution to upgrade the energy efficiency of existing buildings of about 7million homes by 2020 aimed at reducing GHG by 29% (DECC, 2011). This paper focuses on delivering low-energy building retrofit projects through a decision-making framework developed using knowledge management (KM) principles and procedures. The next section will further discuss the significance for low energy building retrofit.

The Imperatives of Low-Energy Building Retrofit

Existing buildings are responsible for half of the total greenhouse gas emission (GHG) in the UK with adverse impact on the global, environmental, human health and economy. It is recognised that 80% of the energy consumed throughout a building lifecycle occurs when it is occupied and in use and where the service life of the building ranges from 30-70 years (Menassa and Baer, 2014). This fact compels the industry to produce buildings that will be energy efficient during their life-cycle through low-energy retrofitting of the existing buildings using modern sustainability principles (UNEP, 2009). It has been suggested that significant reduction of GHG emission can be achieved through low-energy retrofitting of existing structures (Menassa and Baer, 2014). The important role existing buildings play in achieving energy reduction or GHG through low-energy retrofit can be part of a complete plan for sustainable corporate development (Hwang and Ng, 2013). According to Kubba (2010), low-energy retrofits should be designed for optimal energy efficiency and constructed with a preference for natural, reclaimed, and recycled materials. These buildings provide healthier, more comfortable and productive indoor environments for occupants by maximizing the effective usage of resources like energy, water, and raw materials. However, low-energy retrofit has many challenges (such as finance, assumed high cost, lack of decision-making etc.) that come with it. Embarking on the retrofitting of buildings is quite difficult to undertake because a building and its environmental nature is complex (technical, technological, economic, social, ecological, social, comfort) and this has necessitated the need for informed decision-making through managing knowledge when undertaking the retrofit measures (Duah et al., 2014). The ensuing section will discuss further the relevance of managing project knowledge to delivering low-energy retrofit by first describing what knowledge and knowledge management means.

Knowledge Management

Different definitions of knowledge exist in the academic literature and these definitions are coined to each author's perspective. Knowledge has been referred to as information which has been used and integrated within a person's knowledge-based experience and behavioural patterns (DeTienne and Jensen, 2001). One of the most common classifications of knowledge are 'tacit knowledge' and 'explicit knowledge' (Nonaka and Takeuchi, 1995). Tacit knowledge deals with a personal knowledge about a specific context. It is part of personal experience and difficult to formulate, record or express clearly since it is stored in human brains and mind (Kanapeckiene *et al*., 2010). Explicit knowledge on the other hand is learned and acquired and it can be shared and transferred through a medium of systematic or formal language (Kanapeckiene *et al*., 2010). Explicit knowledge can be easily collected, documented, stored, and retrieved very independently of any single individual through technological means and systems (Hari *et al*., 2005). An organisation is bound to require elements of both approaches, and must integrate the two effectively to achieve maximum positive impact (Hari *et al*., 2005). In construction, knowledge cannot bring competitive advantage unless it is managed (Shellbourn et al., 2006). Egbu *et al*. (2004) define it as an important resource for construction organisations due to its capability to provide market leverage and contributions to organisational innovations and project success. Furthermore, Achieving success from KM depends on the effective and efficient deployment of different KM procedures within the context of specific organisation (Udeaja et al., 2008a, Maduka et al., 2015b).

Knowledge Management Procedures/Approaches:

Success from KM depends on the effective and efficient deployment of different KM strategies and tools within the context of specific organisation (Udeaja et al., 2008a). It has been revealed that KM procedures have great influence on organisations achieving optimal performance in construction projects (Zack et al., 2009). Different studies have used different terms for KM procedure (for example: (Davenport and Prusak, 2000, Rollet, 2003, Chin-Loy *et al*., 2007, Chen and Mohamed, 2008, Fong and Choi, 2009, Zack *et al*., 2009, Omerzel, 2010). What differentiates each of these is the difference in viewpoint, application and level of details. For the purpose of this paper three KM procedures will be discussed which include knowledge capture, knowledge sharing/transfer and knowledge reuse.

Knowledge Capture: knowledge capture deals with the process of retrieving either explicit or tacit knowledge that is embedded in people, artefact or organisational entities (Hsieh *et al*., 2009). Knowledge capture prevents the loss of critical knowledge due to retirement, job downsizing and subcontracting. Egbu and Robinson (2005) reveal that a lot of organisations are concerned more with telephones, faxes, emails and internet and intranet. This is because they disregard the recording of valuable experience in electronic form in the area of documentation, data bases, webpages, which can assist in preventing the repetition of mistakes in construction activities. Tan *et al*. (2010) stated that knowledge capture involves three processes which include knowledge identification and location, knowledge representation and storage and knowledge validation. Identifying knowledge and locating it involves identification of the kind or type of knowledge to be managed and the location of learning situation (Kamara *et al*., 2003).This includes the creation of new knowledge and individuals with the relevant knowledge (Tan *et al*., 2007). Knowledge representation and storing comprises indexing, organising and structuring knowledge (Robinson et al., 2002) into theme-specific knowledge areas and authoring knowledge (Markus, 2001) in the standard or format specified. Knowledge validation deals with giving credibility to the captured knowledge by ensuring that knowledge captured and stored is fit for purpose.

Knowledge Sharing/Transfer: this refers to the provision of the right knowledge to the right person at the needed time (Robinson et al., 2002). Effective knowledge sharing is supported by supportive organisational culture and trust between the people that are engaged (Newell *et al*., 2002). Markus (2001) argued that this procedure can be passive or active. The author further explained that it could be passive in the area of newsletter publication or population of knowledge repository for users or active in the area of publishing knowledge via electronic alert to those who needed it. Similarly, Egbu and Robinson (2005) stated that knowledge sharing/transfer has been argued to be achieved through mobile phones, pagers, telephones, faxes, storytelling, quality circles, mentoring and shadowing, coaching and job rotation are all considered to be effective in sharing and transferring knowledge.

Knowledge Reuse: reuse of knowledge is stated to involve both recall (that information has been stored, in what location, under what index or classification scheme) and recognition (that information that meets the users' needs (Lansdale, 1988). Szulanski *et al*. (2002) specified that knowledge reuse deals with the reapplication of knowledge such as best practice. Similarly, Majchrzak *et al*. (2004) argued that it is the reuse of knowledge for innovation with necessary integration or adaptation of best practice. The reuse of knowledge encompasses conceptualising the issue or problem and selecting the best reusable ideas (i.e. knowledge) and also by perusing and revaluating reusable ideas. Tan *et al.* (2007) stated the various kind of reusable knowledge to include: process knowledge; costing knowledge; legal and statutory needs; knowledge of the best practices and lesson learned; knowledge of who knows what etc.

Managing Knowledge in Attaining Low-energy Building Retrofit

Egan (1998) suggested that managing knowledge from people, culture, technology and training perspectives was important for the construction industry. The significance of knowledge management (KM) in construction projects has been documented by various researchers in academic literature (Carrillo *et al*., 2000, Kamara *et al*., 2000, Robinson *et al*., 2001, Egbu and Robinson, 2005, Anumba *et al*., 2005, Shellbourn *et al*., 2006, Tan *et al*., 2006, Udeaja *et al*., 2008a, Kanapeckiene *et al*., 2010) and this is necessary particularly in low-energy retrofit. KM has received a great deal of attention in recent years. The role and essence or relevance of KM as a key source of potential advantage for construction organisation has been addressed by numerous authors (see for example,(Egbu et al., 2004, Anumba et al., 2005, Shellbourn et al., 2006, Udeaja et al., 2008b, Kanapeckiene et al., 2010, Maduka et al., 2015a). In Miller *et al.* (2008) study identified that whilst there is a genuine need for stakeholders to drive the uptake of low-energy retrofit, the level of managing knowledge in delivering low-energy retrofit projects and specific sustainability features remain disappointingly low. This is because professionals in the construction industry find it difficult to access core knowledge for highly knowledge-intensive activities, such as problem-solving, decision-making, etc. (Anumba *et al*., 2005, Egbu and Robinson, 2005). Construction organisations have been managing knowledge informally for years, but the challenges facing today's industry particularly in low-energy retrofit means that most organisations now need a more structured, coherent approach to KM to deliver projects (Kamara *et al.*, 2002, Khalfan *et al*., 2002, Anumba *et al*., 2006, Udeaja *et al*., 2008a). Kamara *et al*. (2002) and Petri (2014) stated managing project knowledge in low-energy building retrofit projects will help in reducing of project timeline, including quality and customer satisfaction. Therefore there is a need to explore KM principles to develop a decision support framework which will assist in addressing lack of informed decision-making in attaining low-energy retrofit (Maduka et al., 2015a).

Decision Support Models and Frameworks for Low-energy Building Retrofit

Decision support tools are useful for identifying and determining optimal retrofit measures (Ma *et al*., 2012). The complexity that emanates from retrofitted building projects can be tackled through decision support framework that is knowledge driven. Brozova *et al*. (2008) stated that decision-making is a mental process leading to the selection of the best strategy among several alternatives, and as such every decision-making process produces knowledge for the successful solution to a given problem. However, many decision-making models and methods have been developed to help deliver solutions to low-energy retrofit projects. Juan *et al*. (2009) developed an integrated decision support system to recommend a set of sustainable refurbishment actions for existing office buildings. This was developed based on the consideration of trade-offs among refurbishment cost, improved building performance and environmental impacts. Doukas *et al*. (2009) developed a decision support model for evaluating energy saving measures in a typical office building. The model was developed in consideration of an experience data base through systematic incorporation of energy data collected from building energy management system to calculate building performance indicators. Brozova *et al*. (2008) in their research developed a knowledge mapping model for decision-making process for theoretical analysis and application.Goodacre *et al*. (2002) developed a cost-benefit analysis framework to use to access the potential scale of some benefit from the comprehensive upgrading of heating and hot water energy's efficiency in English building sector. These studies have indeed demonstrated the need for decision-making in delivering low-energy retrofit building projects and have been able to address some low-energy retrofit challenges. However, there is a gap in developing a decision support framework or system through KM to inform key stakeholders on making informed and appropriate decisions in delivering these projects. However, a theoretical decision support framework has been articulated and developed through relevant literature reviews and this is shown in Figure 1.This theoretical decision support framework will be essential for collection of empirical data that will result to development of a decision support system.

Informed Decision Support Framework (IDSF):

A theoretical decision support framework has been developed and illustrated in figure 1. The framework is directed at the key stakeholders involved in low-energy retrofit building projects to enable them to make sound and informed decision in delivering these projects. The decision support comprises of Key stakeholders; Knowledge management database, retrofit criteria/measures; critical system thinking and decision unit.

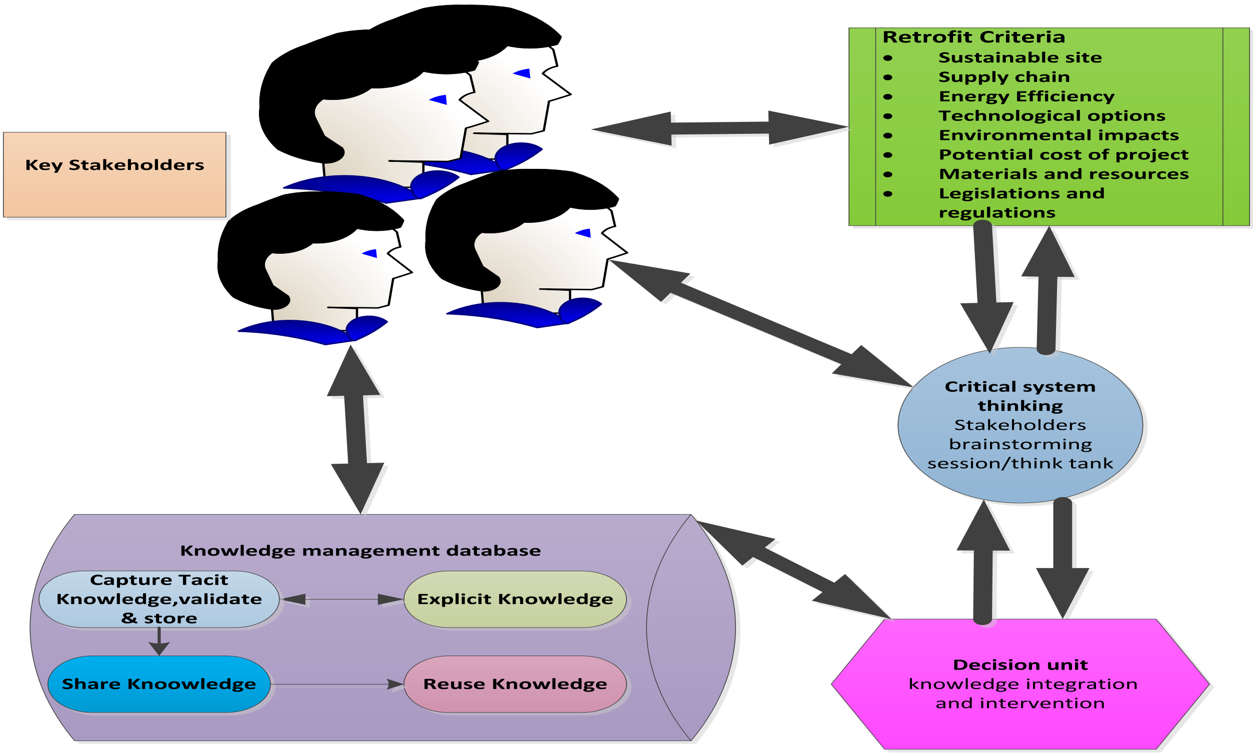

Figure 1. Informed decision support framework (IDSF)

The ***Key stakeholders*** are the decision makers with vested interests in low-energy building retrofit projects. These are considered to be clients, owners, tenants, and investors, building operators, designers (architectural, mechanical, civil and electrical) and project managers (Menassa and Baer, 2014). The ***knowledge management database (KMD)***, provides the central repository where the information of retrofit projects is captured, including the explicit knowledge which together is shared for reapplication or reuse. The KM database enables the key stakeholders in collecting information, diagnosing and analysing the existing circumstances. The information in KMD applies to relevant experience of stakeholders in a previous retrofit projects which can be reused in a current retrofit project decisions. KMD is established to help key stakeholders improve the utilisation rate of knowledge in terms of capture and share and increase the rate of knowledge reuse (Zhang and Lu, 2007, Udeaja et al., 2008b). At this stage, decision makers' wisdom and insight play a role by considering captured knowledge, shared knowledge and knowledge reuse or reapplication in decision-making and the need for these have been expanded in Section 4 of this paper. KMD will also assist in sharpening the intuition of the stakeholders and improve their mental capabilities in decision-making. This will help the stakeholders to avoid overconfident about their judgement, but rather set decision goals in order to make an informed decision. It will also enable them consider retrofit criteria and measures through critical thinking which involves brainstorming /think tank sessions. ***Retrofit criteria and measures (RCM)***, key stakeholders at this point will enable key stakeholders in considering sustainability criteria information, diagnosing and analysing the existing circumstances as regards to low-energy retrofit issues. RCM remains a key indicator that would help to inform and manage knowledge before appropriate decisions are made. ***Critical thinking system (CTS)***, the brainstorm/think tank session will assist the stakeholders to see through ostensible facts. This will help to reach a fundamental understanding of the apparent decision difficulties by integrating the knowledge in the database with the outcomes from brainstorming/think tank to enable an informed decision. ***Decision unit (DU)*** incorporates knowledge intervention and integration. Knowledge intervention *(KI)* is a mechanism which assists the stakeholders to surface hidden retrofit assumptions and reflects on them for a reflective thinking in making right decision about low-energy retrofit building projects. DU makes reference to KMD and integrates the outcome of the brainstorm/think tank session which will support them to make a sound and informed decision. At this point, knowledge reuse through KMD will be essential. Through knowledge reuse, proven solutions are integrated by learning from the use and failures of previous projects; avoid pitfalls and increase the chances to make right decision (Liu *et al*., 2015).

Conclusion and Future work:

KM is likely to become more pervasive in various industries particularly in construction industry as delivering of low-energy retrofit continues to pose a challenge due to its complex nature and stakeholders' varied options. Managing project knowledge is needed to be adopted in low-energy building retrofit projects in order to surmount the existing decision challenges through the development of an informed decision-making framework. Decision-making is a complex process as established through the literature and most decision support frameworks ignore KM contribution in decision-making process. This paper has demonstrated the need and essence of a decision support through KM principles and strategies by developing IDSF. The framework incorporates knowledge management database, retrofit measures, critical system thinking and decision unit. These were introduced through theoretical formulations to enable an informed decision-making for key stakeholders in delivering low-energy building retrofit. The use of the framework will minimise retrofit decision mistakes and maximise informed decision-making capabilities of the key stakeholders in retrofit projects. IDSF will also enable the full up-take of low-energy building retrofit projects in the built environment due to knowledge strategies demonstrated in the framework. In achieving low-energy building retrofit projects for sustainable development KM remains a crucial element as have been revealed in numerous literatures. The developed a theoretical IDSF precedes the next stage of the research which will be the collection of empirical data from intended case organisations with the help of literature reviews and other published sources. The data collected and analysis will, in turn, precede the development of a decision support system (DSS) through data analyses.

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