Knowledge-based Building Information Modeling (K-BIM) for Facilities Management

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Abstract -

Knowledge Management (KM) is a business management technique that promises improved competitive advantage among other benefits for an organization. The application of KM in construction is fairly researched and reported. Although Building Information Modeling (BIM) is gaining wide acceptance among Architects and Project Managers for efficient and effective design and construction management, the adoption of BIM in operations during post-construction phase such as Facilities Management (FM) is in its normative stage. As FM is knowledge and information intensive and relies heavily on historical information, a Knowledge-based BIM (K-BIM) that is developed on the basis of as-constructed information of the facility has the capability for effective and efficient FM and thereby enhance the competitive advantage of a FM organisation. Ontologies have the potential to represent the body of knowledge of the various domains involved such as KM, FM and BIM. Integration of KM, FM and BIM can also be achieved through ontologies. The proposed conceptual framework, K-BIM is an attempt to advance BIM by way of integrating KM, FM and BIM using ontologies, rather than building a system on a model built using BIM.

Keywords -

IT Applications; Knowledge Management; Building Information Modeling; Facilities Management; Knowledge-based BIM; Ontology

1 Introduction

Of late, in the quest of sustainable competitive advantage, organisations have come to realise that their competitiveness edge is mostly the brainpower or intellectual capital of their employees and management. To be more specific, an organisation's competitive advantage depends on *what it knows – how it uses* what it knows – and *how fast* it can know something new. In order to stay ahead of the pack, organisations must leverage their knowledge internally and externally to survive. Specific KM activities help focus the organisation on acquiring, storing and utilising knowledge for problem solving, dynamic learning, strategic planning and decision making. It also protects intellectual assets from decay, adds to organisation intelligence and provides increased flexibility. The emergence of KM may be explained by the confluence and natural evolution of several factors. KM is a necessity, driven by the market forces of competition, market place demands, new operating and management practices, and the availability of KM approaches and Information & Communication Technologies (ICT).

The application of KM in construction is fairly researched and reported. Although Building Information Modeling (BIM) is gaining wide acceptance among Architects and Project Managers for efficient and effective design and construction management, the adoption of BIM in operations during post-construction phase is in its normative stage. Facilities Management (FM) is one of the major tasks involved in the post-construction phase. As FM is knowledge and information intensive and relies heavily on historical information, a Knowledge-based BIM (K-BIM) that is developed on the basis of as-constructed information of the facility has the potential for effective and efficient FM and thereby enhance the competitive advantage of a FM organisation. An integrated ontology-based KM framework for FM facilitated by BIM has the potential to promote the efficiency and effectiveness of a FM system. K-BIM is such a framework that attempts to advance BIM by way of integrating KM, FM and BIM using ontologies.

2 Literature Review

2.1 Knowledge Management (KM)

KM can be defined as the *systematic and explicit management of knowledge-related activities involving knowledge-workers in an organisation to improve organisational knowledge-related efficiency and effectiveness, thereby to achieve specified organisational goals and objectives.*

There has been a quite extensive research reported on the role/application of KM in construction [1,2]. The applicability and usefulness of KM in construction has been researched in strategic management of construction [3], general construction project management [4,5,6], knowledge discovery from construction databases [7], design management [8] and corporate memory for construction [9]. Carrillo and Chinowsky investigated the implementation of KM initiatives in major engineering design and construction organisations in United States of America [10]. Chen and Mohamed studied the impact of the internal business environment on KM within construction organizations in Hong Kong [11] and also the strategic importance of tacit knowledge management activities in construction [12]. It has been reported that the changes in organizational culture are critical to successful KM [13].

2.1.1 Ontologies in KM

Ontology is an explicit specification of a conceptualisation [14]. Ontologies can be effectively used in solutions for many KM processes, especially for knowledge representation [15]. Maedche et al. proposed an integrated enterprise-KM architecture for implementing an Ontology-based KM System (OKMS) [16]. Saito et al. described the KM technologies according to their support for strategy through an ontology development method and categorised the KM technologies based on their relationship with KM strategy [17]. Ontology-based KM frameworks have been reported for engineering design management, risk management in construction projects and competency development of construction project managers [18,19,20].

2.2 Building Information Modeling (BIM)

Essentially, BIM combines technology with new working practices to improve the quality of the delivered product and also improve the reliability, timeliness and consistency of the process. It is equally applicable to asset and facilities management as it is to construction. *BIM provides a common single and coordinated source of structured information to support all parties involved in the delivery process, whether that be to design, construct, and/or operate.* Because all parties involved with a BIM project have access to the same data, the information loss associated with handing a project over from design team to construction team and to building owner/operator is kept to a minimum. It has been reported that BIM is a suitable facilitator for KM in construction for various applications such as knowledge sharing [21], construction supply chain management [22], sustainability & asset management [23] building maintenance [24] construction defect management [25] and lean architectural practice [26].

2.3 Facilities Management (FM)

Facility management is a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology. [27]

It has been reported that the potential benefits of using BIM in FM seem to be such as valuable 'as-built' (heritage) documentation, maintenance of warranty and service information, quality control, assessment and monitoring, energy and space management, emergency management or retrofit planning [23,28,29,30]. Decontamination or deconstruction processes could also benefit from structured up-to-date building information to reduce errors and financial risk, e.g. through deconstruction scheduling and sequencing, cost calculation, rubble management, optimization of deconstruction progress tracking or data management [28].

2.4 Summary of Literature Review

It has been observed that the application/role of KM in construction is well researched and in the other phases of the built environment projects is limited. Ontology is a potential technique for the solutions involving KM systems. Research efforts on the role of BIM in KM as well as in FM are in their normative stage. It would be interesting to investigate how KM and BIM contribute together for better FM.

3 K-BIM for FM Framework

The objective of this framework is to effectively facilitate the FM through the strengths of KM & BIM. K-BIM attempts to incorporate the best practices of the three domains viz. Knowledge Management, Building Information Modeling and Facilities Management as shown in Figure 1.

In 2009, a global job task analysis (GJTA) of International Facility Management Association (IFMA) defined 11 core competencies of facility managers. The GJTA included responses from facility managers in 62 countries. It is the most comprehensive to date and the first truly global survey and analysis [27]. Those core competencies are:

- **Communication** - Communication plans and processes for both internal and external stakeholders
- **Emergency Preparedness and Business Continuity** - Emergency and risk management plans and procedures
- **Environmental Stewardship and Sustainability** - Sustainable management of built and natural environments

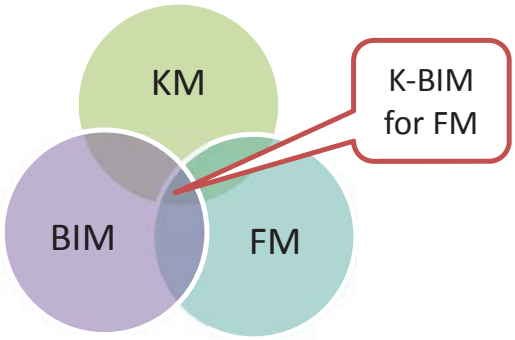

Figure 1. K-BIM for Facilities Management

- **Finance & Business** - Strategic plans, budgets, financial analyses, procurement
- **Human Factors** - Healthful and save environment, security, FM employee development
- **Leadership and Strategy** - Strategic planning, organize, staff and lead organization
- **Operations and Maintenance** - Building operations and maintenance, occupant services
- **Project Management** - Oversight and management of all projects and related contracts
- **Quality** - Best practices, process improvements, audits and measurements
- **Real Estate and Property Management** - Real estate planning, acquisition and disposition
- **Technology** - Facility management technology, workplace management systems

At the very outset, development of all the above mentioned core competencies of facility management can be facilitated by adopting the best practices of KM, BIM and FM. The concept map of the proposed K-BIM framework (as shown in Figure 2) is based on the premise that BIM models of the constructed facilities would facilitate the FM processes. Hence, it is expected that BIM would play an important role in the development of the core competencies of FM as BIM is the interface between the facility managers and the knowledgebase.

There are three major components in the proposed K-BIM framework. They are (i) Knowledgebase, (ii) K-BIM Layer, and (iii) Stakeholder Interface.

3.1 Knowledgebase

The knowledgebase of the K-BIM framework is primarily consists of two components. They are: Ontology of KM and Ontology of FM.

3.1.1 Ontology of KM

The entire body of knowledge of the KM domain is represented in this ontology. This include the KM processes, knowledge domains, KM tools (techniques & technology) and knowledge mapping [20].

3.1.2 Ontology of FM

The domain knowledge of the FM is represented ontology of FM. This include the FM processes, historical information, and best practices in FM. It would also have the definition, assessment guidelines, and performance criteria of the various core competencies of FM as well as the competency mapping.

These ontologies can also interact between them based on the context.

3.2 K-BIM Layer

The BIM layer consists of the BIM models of the constructed facilities and the associated standards such as National BIM Standard - United States (NBIMS-US) [31]. These are managed by the BIM managers. The data/information present in the models are depends heavily on the knowledgebase as they are context-specific. Whenever there is a request for information (RFI) from any stakeholder, the knowledgebase is referred before returning a result. Also, any updates shall be applied to the BIM models/standards. In this way, the capability of the BIM is enriched. The data/information present in the BIM models are primarily knowledge-driven rather than information-dependent. Hence, this becomes the crucial layer of the proposed K-BIM.

3.3 Stakeholder Interface

Various stakeholders involved in the project/facility, especially facility managers, shall use this interface to interact with the K-BIM for problem-solving or decision making.

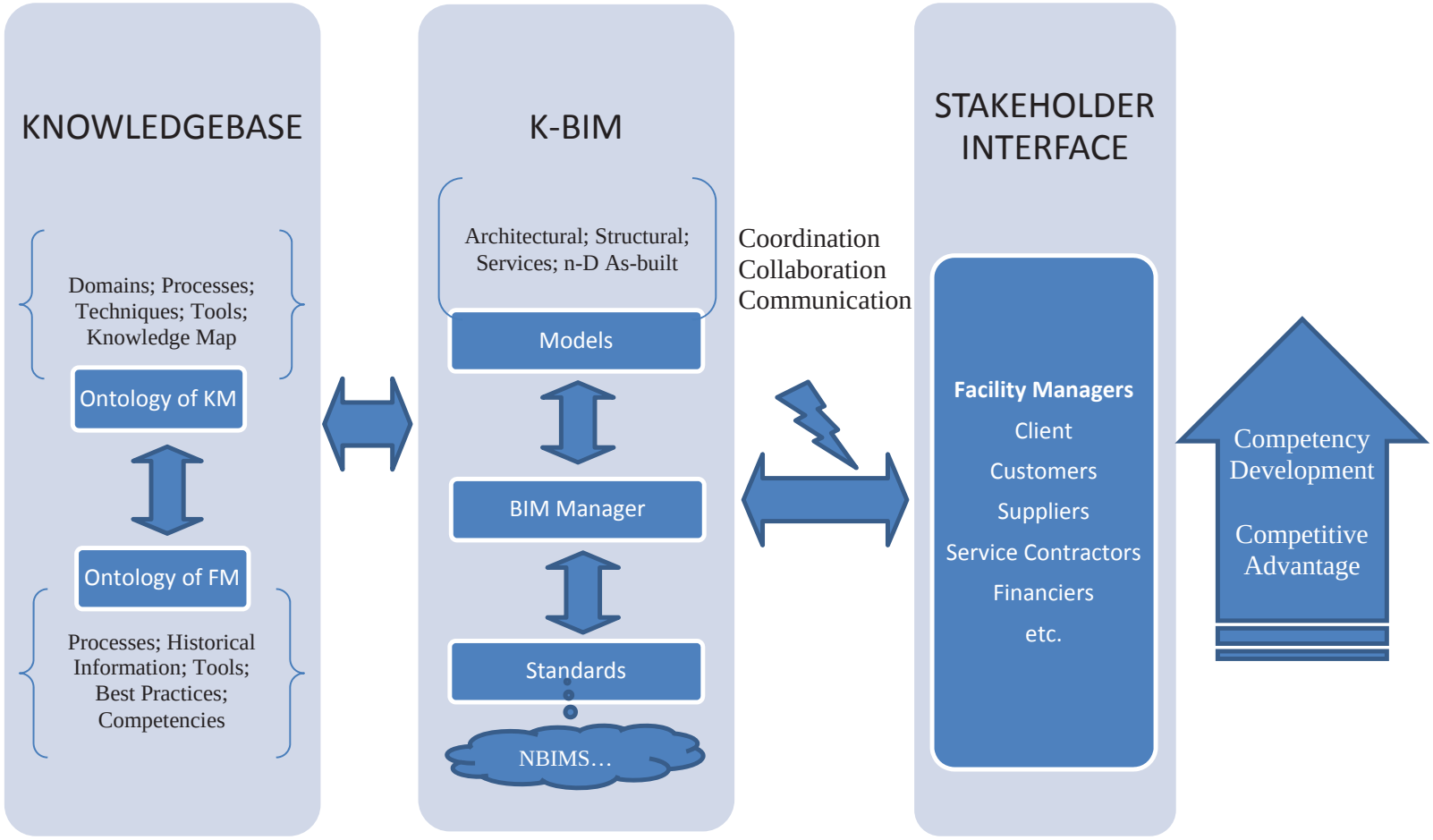

Figure 2. Concept Map of K-BIM Framework for Facilities Management

Based on the context of the query (may be related to the core competencies of FM) the I-BIM returns appropriate information derived from the knowledgebase that would facilitate the competency development of the manager as well as better facility management. This in turn, would enhance the competitive advantage of the FM organisation.

3.4 Suggested Methodology for Implementation

The proposed framework can be implemented by first building the knowledgebase. Ontologies of KM & FM shall be developed using Knowledge-Engineering methodology [32] or use some existing ontologies. BIM models shall be integrated with the existing standards & protocols to achieve the intended goals such as coordination, collaboration & communication across various stakeholders and this needs to be moderated by the BIM managers. The stakeholder interface shall be integrated with the workflow management systems to maximise the operational efficiency.

4 Summary

The proposed K-BIM framework for FM is an attempt to harness the power of KM and BIM to facilitate the FM processes. As discussed, the framework consists of three major components viz. knowledgebase, K-BIM layer and stakeholder interface. The entire body of knowledge of the KM & FM domain are modelled in the knowledgebase. Ontologies are the potential technique for design, development and update of the knowledgebase. The middle layer, K-BIM is an enhanced BIM (models/standards) that is driven by the knowledgebase. The stakeholder interface is the platform through which all the stakeholders of the project/facility would interact. This framework would also be helpful in the competency development of the facilities managers.

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