KNOWLEDGE MANAGEMENT THROUGH BIM IN CONSTRUCTION SUPPLY CHAINS

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ABSTRACT

Collaborative working is the key driver for delivering projects in construction industry. In construction supply chains where there is huge knowledge and information flow between the contractors, subcontractors, suppliers and distributors, it is essential to create a collaborative environment during the projects from the bidding phase to the delivery to client. There are some key virtual collaborative tools which have been started to be utilized in major civil engineering projects. The recent concept Building Information modeling (BIM) has been utilized in some major and prestigious construction projects where architects, structural engineers, suppliers, contractors and sub-contractors can work within a three dimensional platform to achieve certain tasks as design, planning, resource allocation, logistics planning, clash detection, coordination and production of design drawings. This paper first explains the recent trends in construction supply chain management, knowledge management and Building Information Modeling. Then, it discusses the integration of Building Information Modeling into construction supply chains for improving information and knowledge management practices throughout the lifecycle of the project which is called as Building Knowledge Model (BKM).

Keywords: Construction supply chains, Building Information Modeling (BIM), Information Management, Knowledge Management (KM), Building Knowledge Model (BKM)

1. INTRODUCTION

Knowledge Management (KM) deals with the organizational optimization of knowledge to achieve improved performance, increased value, competitive advantage, and return on investment by integrating various tools, processes, and methods in the organizational workflow (Skyrme and Amidon 1997; Siemieniuch and Sinclair 1999). The integration of knowledge, information and materials flow between the client, and supply chain (SC) actors defines the concept of supply chain management (SCM) (Samaranyake 2005). Today, knowledge is regarded as the most important resource in the SC. Failure to transfer knowledge within organizations or along the complexities of SCs leads to wasting time and money reinventing the wheel for each project and impairs project performance (Koh and Gunasekaran 2006). Moreover, transfer of knowledge does not always mean the diffusion and internalization of knowledge in the SCs. The diffusion of knowledge through SCs depends on the KM abilities of the organizations in the SC.

Construction Supply Chain Management (SCM) deals with managing the process of knowledge flow, financial flows, materials, activities, tasks and processes involved within various networks and linkages (upstream and downstream) of organizations in order to develop high quality construction products and services to clients in an efficient manner (Akintoye et. al. 2000; Tucker et. al. 2001). In construction supply chains where there is huge knowledge and information flow between the contractors, subcontractors, suppliers and distributors, it is essential to create a collaborative environment during the projects from the bidding phase to the delivery to customer. Construction projects are generally unique and may need different supply chain configurations for each project. There are also important issues regarding the creation, and storage of the knowledge. Creating a collaborative working environment within this variable and complex supply chain context can be problematic. Thus, cross-discipline co-ordination and knowledge exchange are crucial for these multidisciplinary collaborative processes in the construction supply chain management (Aouad et. al. 2002). For effective supply chains, all elements of the supply chain must be connected to enable the flow of knowledge (Desauza et. al. 2003). This creates heavy reliance on information and knowledge management to co-ordinate the whole supply chain (Tucker et. al. 2001). As a result, the flow of knowledge within both the downstream and upstream of supply chains is considered a critical issue in construction supply chains.

Building information Modeling (BIM) is one of the most important tools in the development of the AEC industry. It has all the functions of 3D CAD as well as quantitative and qualitative data. It helps key stakeholders to visualize what is to be built in a computer-generated environment and to identify any design, construction or operation issues. BIM encourages the integration of the roles of all stakeholders on a project considering implementation of BIM on their project. BIM can be viewed as a single model that encompass all aspects, disciplines and structure of facility in a relative scale allowing all project team to collaborate more accurately and efficiently than using the traditional process. The full integration of BIM model depends on the accuracy of the input data, information and knowledge by each project team members. The need to ensure that BIM is available and integrated with the whole AEC (Architecture, Engineering and Construction) process from design inception to project completion, ongoing operation and eventual demolition, is fundamental to the success of BIM and to the future of AEC sector.

This paper first explains the recent trends in construction supply chain management, knowledge management and Building Information Modeling. Then, it discusses the integration of Building Information Modeling into construction supply chains for improving information and knowledge management practices throughout the lifecycle of the project which is called as Building Knowledge Model (BKM).

2. KEY ISSUES IN CONSTRUCTION SUPPLY CHAIN MANAGEMENT

SCM in construction includes principal contractors, sub-contractors, suppliers, and distributors. The network of suppliers in the construction sector can be extremely complex, generally on larger projects the number of supplier organizations can be many hundreds (Dainty et al. 2001). As a consequence of such a complex environment with thousands of actors, Supply Chain Management becomes an emerging concept in the construction industry.

The main roles of SCM are directing operations to link successive operating stages through product flow; and transforming these operating stages into a single cohesive unit by coordinating and controlling internal actions within these stages (Tucker et al. 2001). The upstream of construction SCM is in relation to the position of a main contractor consisting of the activities and tasks leading to preparation of the production on site involving construction clients and design team. The design team includes the architects, M&E Designers, structural engineers and specialist consultants. The downstream consists of activities and tasks in the delivery of construction product involving construction suppliers, subcontractors, and specialist contractors in relation to the main contractor. Downstream is believed to be the weaker link and needs to be improved if the full potential of SCM is to be realized (Akintoye et al. 2000). A case study in SMEs in the construction industry, carried out by Dainty et al. (2001) revealed that although there is a growing interest in supply chain integration in the upstream of construction, the downstream has important supply chain problems. Moreover, the flow of knowledge within both the downstream and upstream of supply chains is a critical issue in the construction supply chain. There is a heavy reliance on information and knowledge management to co-ordinate the supply chain (Tucker et al. 2001). As a result, information management becomes the heart of construction SCM.

A construction project includes various processes through the project lifecycle as procurement, planning, design, manufacture, construction, and facility management of buildings and other structures (Ireland 2004). Therefore, cross-discipline co-ordination and information exchange are crucial for these multidisciplinary collaborative processes (Aouad et al. 2002). However, in reality, the construction industry has many short-comings such as: being fragmented; lacking co-ordination and communication between organisations; poor collaboration, adversarial contractual relationships, lacking client focus; poor information flows within construction supply chains; disjointed supply relationships; fragmented supply chain structure; and lack of trust between clients, main contractors and sub-contractors perceived low productivity; cost and time overruns; conflicts and disputes; and resulting claims and time-consuming litigation (Latham 1994; Egan 1998; Tucker et. al. 2001; Chan et al. 2003; Love et al. 2005; Fearne and Fowler 2006). Evbuomwan and Anumba (1998) defined some of the consequences of the fragmentation problem as follows:

- inadequate capture, evaluation and implementation of client needs;
- the fragmentation of design, fabrication and construction data, with data generated at one specific location not being readily re-used within various business units and projects;
- development of sub-optimal design solutions;
- lack of integration, co-ordination and collaboration within the supply chain throughout the life-cycle of the project; and
- poor communication of design information, which results in design changes, inadequate design specifications, unnecessary liability claims, and increases in project time and cost.

Besides the fragmentation problems, the culture in construction supply chains is a serious issue. The culture is mainly based on price competition and organizational contractual arrangements depending on the complexity of projects (Saad et al. 2002). Clients and construction organizations are generally project-focused, with a short-term perspective, emphasizing competitive bidding as the main tool in contractors, sub-contractors and supplier evaluation. Consequently, customer-supplier relationships in construction are generally of the arms-length type rather than being strategic partnerships due to use of competitive tendering to procure projects. This assures that sub-contracting is provided by the lowest-price supplier with limited guarantee to future work. (Tucker et al. 2001) Therefore, the industry is characterized by project-based contracts and fails to develop long-term constructive relationships between main contractors and key suppliers (Briscoe et al. 2001). However, in the UK, there are some improvements with the Partnerships Framework Agreements in these characteristics over the last few years. Partnering initiatives and multi-year construction contractor's framework agreements are indicators of strategies that aim to reduce the short-term strategies. Having a strategy that covers continuous FM service delivery, associated with better learning should increase the potential for having more loyal and long term clients for construction projects (Brochner 2008). But these improvements are still in its developing stage and not enough to change these characteristics of the industry.

Apart from these, the construction supply chain is characterized by its generally unique product in every project, and repeated reconfiguration of project organizations for each project. This creates the instability, fragmentation and separation between the design and construction of the end product (Vrijhoef and Koskela 2000). As a result of these, construction projects are treated as a series of sequential and fragmented operations where project members put very little effort for the long-term collaborative success of the resulting end-product (Briscoe and Dainty, 2005). Therefore, an application for this industry has to be flexible enough to accommodate project based supply chains efficiently (Titus and Brochner 2005).

Construction supply chain is bombarded with initiatives trying to improve collaboration, integration, communication and coordination between customers and suppliers throughout the project supply chain (Akintoye et al. 2000; Vrijhoef and Koskela 2000). To create awareness of these issues, the UK Government reports were generated. Egan (1998) and Latham (1994) reports identified the main bottlenecks of the construction industry and highlight the main barriers that are needed to be overcome for better integrated construction supply chains. These reports both suggest that the industry could achieve expected improvement through teamwork at the organizational level between the parties including clients, suppliers, designers. Recommendations within these reports facilitated the use of long-term/strategic arrangements, partnering, joint venture, public private partnerships, prime contracting and supply chain management in order to improve the construction project lifecycle (Akintoye and Main 2007). However, the main barriers are still valid and there is an existing need for change in construction supply chains in order to be more efficient and effective (Fearne and Fowler 2006). Construction does not have a systematic and strategic approach to change the effects of the cumulative and evolutionary aspect of SCM relationships (Saad et al. 2002). The culture in construction impedes innovation and increases complexity making the construction industry a slow adopter of supply chain information strategies (Titus and Brochner 2005).

Based on a detailed literature review, recent trends in procurement strategy, SCM integration, collaboration and communication, partnering, trust, skill deficiencies, innovative thinking and KM are considered as the main issues that needs detailed investigation.

3. KNOWLEDGE MANAGEMENT AND BIM

A critical issue in SCM is the effective management of knowledge through the project lifecycle. This involves the flow of knowledge within and between different sectors of construction supply chain as well as the accumulation, coding, and storage of knowledge in the organizations. There is a heavy reliance on KM to manage the supply chain (Tucker et. al. 2001). As a result, KM becomes the heart of construction SCM.

A typical construction project involves various tasks which are divided between professional and trade disciplines (Love et al. 2005; Turner and Muller 2003). There are numerous distinct organizations working in a collaborative environment over long periods. The documents shared between these organizations vary from technical drawings and legal contracts to purchase orders, project reports, and schedules (Titus and Brochner 2005). Within such a complex environment, information and knowledge flow and sharing is the backbone of effective communication of supply chain actors.

The large number of organizations in construction and their complexity make it difficult to facilitate fluent knowledge flow and sharing (Titus and Brochner 2005). Construction organizations have an unwillingness to rationalize their supplier and client bases and share knowledge and information within their supply chains (Saad et al. 2002). Besides the tendency to keep knowledge, the nature of the construction projects is also a disadvantage for the knowledge sharing. Construction projects usually consist of temporarily designed teams from different organizations to produce a unique product. These team members are generally new to each other and have not necessarily worked together before. Thus, it is difficult to set up channels to exchange information and knowledge. In addition, lack of common goals make project participants focus only in their part and ignore the knowledge needs of their partners (Titus and Brochner 2005). The commitment of participants to contribute to both individual and common benefits is the first step of knowledge sharing (Simatupang and Sridharan 2004). Moreover, because the organizations in construction industry come from different disciplines, the shared information and knowledge may not have the same meaning for the supply chain partners (Love et al. 2005).

Because there are numerous documents in different formats that need to be shared between the organizations of different disciplines, the use of Information & Communication Technology (ICT), the tools for data and information creation and the collaboration technologies are important elements in knowledge management and supply chain integration. ICT and collaboration technologies create a platform to share information in order to improve supply chain performance among all of the players. However, in construction the effectiveness of these technologies in a construction project is hindered by inability to share data in an electronic form between partners (Mohamed, 2003). According to FIATECH, Fully Integrated and Automated Technology (2011), in construction industry:

- It is difficult to access accurate data, information, and knowledge in a timely manner in every phase of the construction project lifecycle.
- There is a lack of interoperability between systems, with several standards competing for managing data. A common methodology for managing construction projects' information assets does not exist.
- Program plans and designs are optimized for a limited set of parameters in a limited domain. The capability to support ‘‘total best value” decisions do not exist.
- Tools for project planning and enterprise management are maturing, but an integrated and scalable solution that delivers all needed functionalities for any kind of projects is not available.
- Lifecycle issues are not well understood and therefore modeling and planning do not effectively take all lifecycle aspects into account. Operation, maintenance, environmental impact, and end-of-life disposal issues are given limited consideration in the project planning equation.
- The ability to assess uncertainties, risks, and the impact of failures is not mature, partly due to the lack of knowledge to support these evaluations, and partly due to the limitations of available tools.
- The business foundation for addressing increased security concerns does not exist, and the ability to address these issues is limited by the lack of understanding of the risks and alternatives.

Despite these challenges Building Information Modelling (BIM) is increasingly used as an ICT support in complex building projects. Because BIM seeks to integrate processes throughout the entire lifecycle (Aouad and Arayici 2010), it is a potential source for construction supply chain integration. An effective multidisciplinary collaboration supported by an optimal use of BIM requires changing roles of the clients, architects, and contractors; new contractual relationships; and re-organized collaborative processes. Unfortunately, there are still gaps in the practical knowledge on how to manage the building actors to collaborate effectively in their changing roles, and to develop and utilize BIM as an optimal ICT support of the collaboration (Sebastian, 2010). Although BIM has existed for many years, it is only over the last few years that building owners are becoming aware that BIM promises to make the design, construction and operation of buildings much more streamlined and efficient (Coates et al., 2010). The main challenges for BIM in construction industry are defined as (Arayici et al. 2009 a,b; Eastman et al. 2008):

- overcoming the resistance to change, and getting people to understand the potential and the value of BIM over 2D drafting;
- adapting existing workflows to lean oriented processes;
- training people in BIM, or finding employees who understand BIM;
- the understanding of the required high-end hardware resources and networking facilities to run BIM applications and tools efficiently;
- the required collaboration, integration and interoperability between the structural and the MEP designers/ engineers; and clear understanding of the responsibilities of different stakeholders in the new process by construction lawyers and insurers

Despite these challenges, Building Information Model (BIM) is gaining wider acceptance in the construction industry around the world, future research in the field of knowledge management in construction industry should focus on how the knowledge management system can integrate with the BIM under a collaborative work environment and improve the management of construction supply chains in order to eliminate duplication of effort and wastage of time and resource for knowledge management as a standalone system. Therefore, this research first investigates the transformation of construction supply chains into knowledge chains and furthermore, explores the implementation of BIM throughout the project lifecycle to manage knowledge chains within construction supply chains.

4. BUILDING KNOWLEDGE MODEL (BKM)

Building Knowledge Model (BKM) describes the framework developed to enable construction bid managers/project managers plan and manage the project knowledge flow in the supply chain through Building Information Models (BIMs). BKM has been developed as a part of research project where there have been extensive literature review and case studies with major construction companies' supply chain of particular projects. The main purpose of the BKM is to enable construction bid managers/project managers plan and manage the project knowledge flow in the supply chain and organize activities, meetings and tasks to improve SCM and KM via Building Information Models throughout the project life cycle. The BKM is also intended to depict the knowledge flow in the construction supply chain specifically, and to offer guidance for specific business processes to transform the supply chains into knowledge chains. The BKM will be used by the bid managers and project managers in particular because they plan and manage the whole integrated project delivery from the early beginning to the end.

The BKM can be used as a practical guide for the systematic and standard implementation of a contractor's supply chain activities to improve the project knowledge flow in the supply chain. It can also assist the contractors in two ways; to inform and encourage the SC actors about the collaborative interactions which have to exist between the SC actors; and the content, type and format of the information and knowledge that needs to flow between these actors through the use of Building Information Models.

Figure 1 presents the project phases of integrated procurement type project, the SC actors who worked for each phase and the RIBA (Royal Institute of British Architects) Design stages achieved in each phase of the project. The BKM presents the key business activities to transform the construction supply chains to knowledge chains in four main phases of a project life cycle. The details specific to the project life cycle are identified through the case studies held in two large scale contractor's projects. There are four important phases for these type of projects. These are feasibility and bidding phase, contract close phase, construction phase and operation phase.

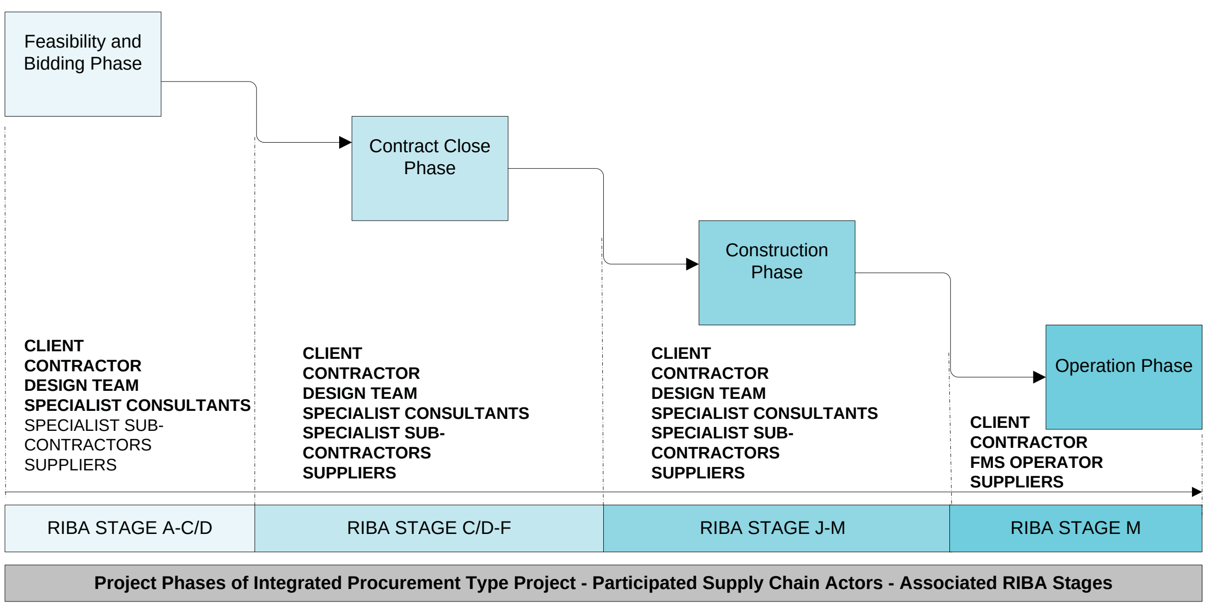

Figure 1: Project Phases of an Integrated Procurement Type Project

In BKM framework the tasks which needs to be delivered in each phase is shown using IDEF0 structure. The IDEF0 model shows the input (project documentation received from the client, standard BIM protocols and any lessons learned knowledge coming from previous projects) with arrows at the left side of the figure. The constraints (client requirements, laws and regulations, supplier BIM capability and human factors as cultural differences, lack of knowledge sharing mechanisms, etc. The main mechanisms which will lead this process are identified as project team, supply chain actors, BIM platform and project extranet where the whole project information and knowledge will be shared. Finally the output is presented as the BKM model.

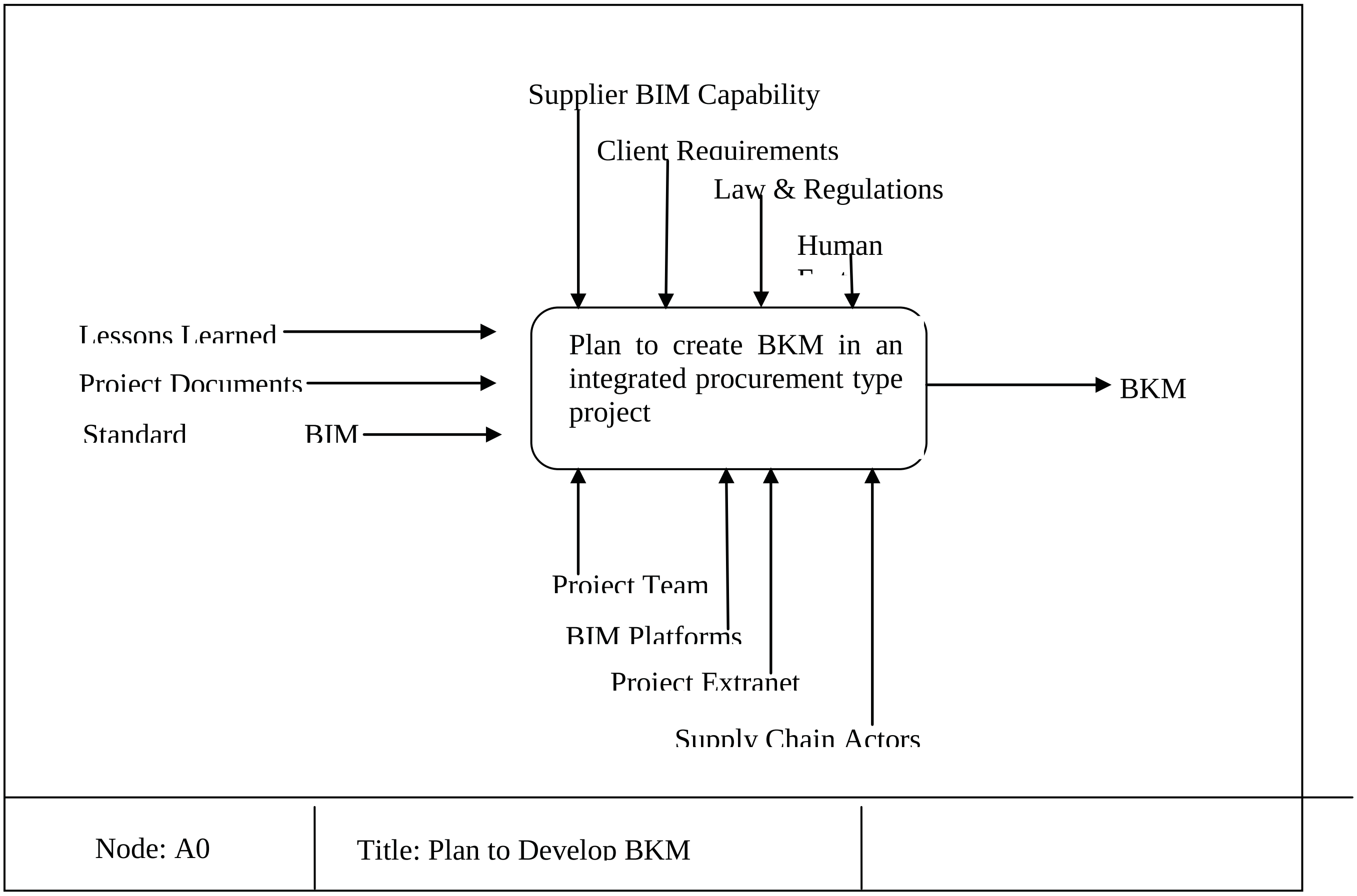

Figure 2: Plan to Develop BKM_A0 Level

This structure is then detailed with the activities that needs to take place in each phase to develop the BKM model. These activities are identified as a result of structured interviews with the contractors and the supply chain actors. The Node index showing the first break down of the A0 are presented as follows:

A0 Plan to create BKM in an integrated procurement type Project
- A1 Plan for Feasibility and Bidding Phase
- A2 Plan for Contract Close Phase
- A3 Plan for Construction Phase
- A4 Plan for Operational Phase

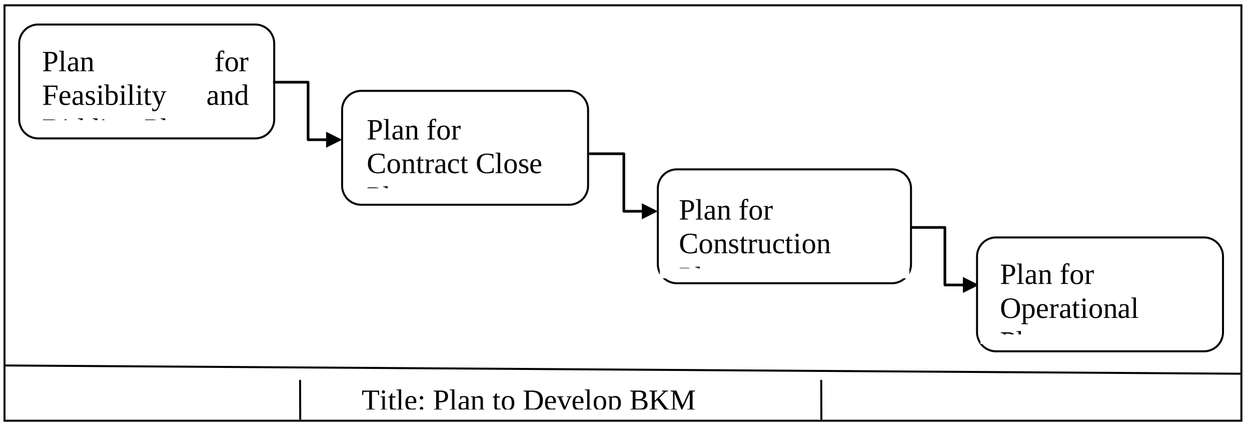

Figure 3: Plan to Develop BKM_Project Phases

This high level break down of BKM model was broken into series of activities considering the human and technology interactions to develop a fully integrated model for the use of the project actors. BKM model will be evaluated by major construction organizations throughout their strategic projects for identifying the issues around implementation to real construction projects. It will be presented following the implementation of the evaluation study results into the model in future stages of this research.

5. CONCLUSION AND FUTURE WORK

This paper presented the recent trends in construction supply chain management, knowledge management and Building Information Modeling. Then, it discussed the integration of Building Information Modeling into construction supply chains for improving information and knowledge management practices throughout the lifecycle of the project which is called as Building Knowledge Model (BKM). Building Knowledge Model has been fully developed as a framework within the research and it is going to be evaluated by major construction organizations throughout their strategic projects for identifying the issues around implementation to real construction projects as a toolkit starting from the early phases.

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