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BIM IMPLEMENTATION: FROM CAPABILITY MATURITY MODELS TO IMPLEMENTATION STRATEGY

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Abstract. *There have been very few empirical studies that attempt to delineate the critical issues that drive successful implementation of BIM in construction organisations. The purpose of this paper is to develop a systematic approach to BIM implementation via a series of steps designed to synchronise BIM solutions and organisational change processes. The paper reviews a number of BIM capability maturity protocols and methods and draws the attention on a number of reasons why these protocols cannot enter the mainstream organisational practices without devising implementation strategies. Based on the findings of an exploratory study using semi-structured interviews with 10 BIM-enabled construction organisations, a four-stage implementation strategy is proposed; comprising brain storming, concept building, realisation and manifestation stages. Each of the stages represent a distinct milestone in the implementation process, thus a condition for achieving overall success is to pay full attention at each stage of the process. The proposed implementation strategy can be used as a basis for integrating the existing and emerging list of construction IT solutions (e.g., BIM, Artificial Intelligence, Virtual Construction, Computer Information Construction, and Sharepoint Project System) and organisational change process.*

Keywords: *Building Information Modelling, capability model, implementation process, construction industry*

1 INTRODUCTION

The face of design and production of facilities in the architecture, engineering and construction (AEC) sector is changing according to the trend of the 21st century. As the world's population continues to grow at the rate of about 1.4 million people per week, the challenge for building more sustainably and using a better means of construction has become apparent (Hardin 2009). In essence, the sector needs to use the right tools to create less waste, better utilise materials and build more sustainable facilities to meet the increasing demands. Some of the main solutions to the challenges faced by the construction sector may lie in the rapidly evolving technologies, such as BIM, green-tech, integrated databases, e`lectronic data interchange (EDI), artificial intelligence, laser scanning, rendering and visualisation, and innovative solutions to building processes and products. It has been reported that, construction related technologies have recently been gaining momentum (e.g., NBS 2012). Pike Research (2012), a consulting team that provides in-depth analysis of global clean technology markets has also characterised the global BIM market as 'nascent' but 'evolving rapidly'. They have predicted that by 2020, annual worldwide revenue for BIM products and services solutions will grow from $1.8billion in 2012 to almost $6.5 billion 2020.

As such the real challenge for the AEC sector is to develop innovative strategies on how to manage and use the available technological tools and knowledge of BIM to create more efficient and sustainable facilities in ways that might not have been possible in the past. Nevertheless, technological implementation has proven to be a difficult challenge for organisations in the past. For example, in 2010, NBS (2011) research indicated that 62% of people aware of BIM anticipated to use it in 2011, but only 41% ended up using it in 2011 (NBS 2012). Weston (2001) has previously emphasised that organisations that realise full benefits of a technology are those that make necessary changes in their organisational structures, strategies and processes. A survey conducted by Austin et al (2003) revealed that notwithstanding the high investments in enterprise systems, implementation of these systems are still mired by cost and schedule overruns, resistance to business process change, absence of adequate skills, and overall underachievement comparative to the expectation of benefits accruing from the technology. The critical challenge in BIM implementation is to first identify the gaps between the generic functionality of the chosen BIM system and the specific organisational requirements (Soh, et al., 2003). Too often, implementing organisations fail to understand business requirements which the BIM processes are expected to address (Azhar, 2011). Ehie & Madsen (2005) have suggested that the fundamental business practices embedded in the technology has to replace the existing practices in the implementing organisation if the functional benefits of the system are to be realised.

Ultimately, mobilising technological solutions for the delivery of sustainable construction projects call for companies to gain better understanding of the concomitant innovative processes that are associated with the technology. It is thus important for organisations to be aware of critical issues affecting the implementation of such integrated IT systems and give careful considerations to these issues. To improve the odds of BIM success, construction organisations perhaps need a shift in paradigm from viewing BIM implementation as a large-scale IT infrastructure upgrade to a holistic business resurgence. Thus, through an empirical study, this research proposes a framework for BIM implementation.

2 THEORETICAL CONTEXT

2.1 Construction Technology Transformation Timeline

When the construction sector moved from the drawing board (manual delivery) to “electronic delivery” CAD systems, the products were initially the same, it took about a decade to develop the CAD system from 2D to PC driven basic 3D drafting (Bevan 2012). Just as the drawing board was once the accepted technology prior to CAD, the era of BIM has begun – but this time, the change is revolutionary (table 1 elaborates on construction technology timeline). The reality with the CAD system is that, too often, fragmented, unreferenced, and inaccurate data is distributed between the construction team and then handed over to the owner to be used as information for maintenance of the facility (Hardin, 2009). Unlike CAD, a BIM project is not drawn in a traditional sense with lines, dots, and texts in multiple documents. Instead it is built digitally as a database in a BIM-based platform. BIM has been referred to as ‘a revolutionary building design and construction technology’ (Osan et al., 2012), because it is purported to bring wholesale changes to every phase of the project delivery lifecycle.

Numerous suggestions have been put forward on how BIM could be integrated into the construction processes. These include the AEC (UK) BIM protocol (AEC (UK) CAD, Standard Initiative, 2010), Mervin Richards' BIM standard framework and guide (Richards, 2010), BIM implementation planning guide - proposed by Pennsylvania State University (The CIC Research, 2012), and BIM overlay to the RIBA outline plan of work (RIBA, 2012).

Others have also defined different BIM maturity stages, with each stage exhibiting disparate competences (e.g. Succar 2010; NBS 2012). In general the progressions from low to higher levels of maturity indicates 1) better predictability and forecasting by lowering variability in competence, performance and costs; and 2) greater effectiveness in reaching defined goals and setting new more ambitious ones (Succar, 2010).

2.2 BIM Maturity Capability Models

In 2008, Mark Bew of BuildingSmart and Mervyn Richards of Construction Product Information Committee (CPIC) developed the BIM Maturity Diagram model, (Richards, 2010), which is now a well-known diagram. It acknowledges the impact of both data and process management of BIM and defines three different levels of maturity for BIM. In essence, level 0 provides 2D unmanaged CAD with electronic paper as the likely data exchange format. Level 1 provides 2D or 3D managed CAD with standalone standard data packages with no integration. Level 2 BIM provides information in a 3D format, with the various members of the project team creating and maintaining their own individual models. These federated models are interoperable in a Common Data Environment (CDE) or with the use of proprietary interfaces. The level 3 on the other hand, utilises a single project model, accessible by all the participating project team members. It is an open process and data integration is enabled by web services compliant with existing and emerging IFC standards, managed by a collaborative model server. Level 3 has also been regarded as "iBIM" or integrated BIM, potentially employing concurrent engineering processes.

There is also a BIM capability stages developed by Succar (2009). It defines the minimum BIM requirements or the major milestone that need to be reached by organisations as they implement BIM technologies and concepts. There are 5 BIM stages as shown in figure-1. The starting point represents the pre-BIM stage, and it identifies with the status of the industry prior to the emergent of the BIM concept (as captured in table-1). According to Succar (2010) BIM stages 1 to 3 are defined by their minimum requirements for BIM uptake. As an example, for organisation to be at stage-1 (object-based modelling), it need to have BIM authoring software similar to Vectorworks, Bentley, ArchiCAD, or Revit. At this stage however, data exchange between project stakeholders is unidirectional and communications are asynchronous and disjointed. At stage-2 (model-based collaboration), an organisation needs to operate BIM effectively on a multidisciplinary collaborative BIM project. At BIM capability stage-3, an organisation needs to be using a network-based repository platform to share object-based models. At this stage, interoperable data interchange across discipline is possible. The final stage (post-BIM) encompasses a variable ending point with ever evolving connotations, which deploys virtual-integrated Design, Construction and Operation (viDCO) tools and concepts (Succar 2010). At this stage, model deliverables extend beyond semantic object properties, incorporating all the design information required at each stage of the lifecycle of a facility to include business intelligence, green policies, whole lifecycle costing etc. each stage has different prerequisite for technological, process and policy structures.

Time	Pre 1980s	1980s	1990s	2000s	2010s	Future Anticipation
Practice	Drawing board	Computer Aided Drafting (CAD)	Basic Computer Aided Design (CADD)	Increased Computer Aided Design (CADD)	BIM Stages	Post BIM
Features	• Manual scheduling • Manual collaboration • Constant duplication • Zero transparency • Limited efficiency	• Primarily 2D • Mainframe driven • Limited compatibility • Limited collaboration • Relatively reduced duplication	• Basic 3D visualisation • PC driven • Consultant centric • Relatively better consistency • Limited collaboration	• Increased 3D modelling • LANs – Networked PCs • Project centric • Increased collaboration • Improved coordination	• Single disciplinary use of object-based 3D modelling • WAN network and federated repositories • Limited multidisciplinary sharing of BIM-models • 4D &5D benefits – time/cost • Full coordination • Increased efficiency	• Integrated practice • Multidimensional federated model • Synchronous communications • Virtual integrated Design, Construction and Operation (viDCO)

Table 1: Construction technology transformation timeline (From drawing board to BIM) Adapted from Bevan (2012) and Succar (2010)

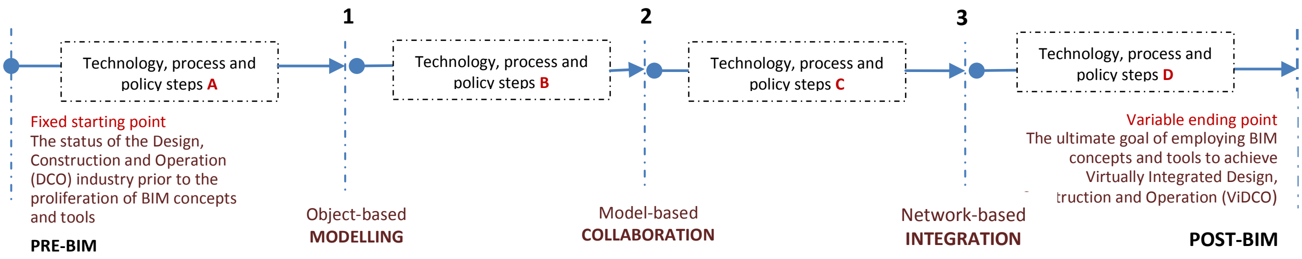

Figure 1: BIM Capability stages (Adopted from Succar 2010)

The maturity model and Succar's (2009) 5-BIM capability stages as discussed are examples of how BIM is anticipated to drive construction improvement in quality and efficiency and also, bringing about wholesale process changes for the different phases of a project lifecycle. Without BIM standards and benchmarks, organisations are not able to assess their BIM competences, and also to measure their successes or failures, these capability levels are therefore a prerequisite for BIM performance improvement. These frameworks are rather more descriptive than the sort of coherent implementation approaches needed to deal with the organisational challenges as a result of introducing BIM. Unfortunately, there are several publications pointing out the inexpediencies relating to the use of technologies in organisations (e.g., Azhar, 2011; Ehie & Madsen 2005; Weston 2001).

In general, implementation of information systems is challenging and suffers from high failure rates, failure to either deliver design objectives, intended benefits, failure to deliver on time or budget (e.g.,Markus & Benjamin, 2012). While it is important to develop maturity diagrams and stages of BIM capabilities, it is equally important to establish implementation processes consistent with maturity stages and adaptable by different organisational sizes. This is vital to laying the foundation for organisations to develop their BIM competency. An implementation strategy, such as the one proposed here, is a timely contribution to the debate on how the sector can move forward with BIM.

3 METHOD

This paper attempts to develop an approach to BIM implementation that synchronises BIM solutions and organisational change processes. The process is developed based on evidence gathered from construction organisations that have developed their organisational BIM capabilities and are involved in BIM projects. Given the exploratory and interpretive focus of this research, i.e., how construction organisations manage the implementation of BIM as a core process for project delivery, a qualitative enquiry is deemed appropriate. A qualitative research approach is considered an effective method to obtain meaning via involvement in the practice and as such is appropriate for answering questions relating to "why" and "how" (e.g., Fellows & Lui 2008). Given the nascent but rapid evolution of BIM utilisation within some construction practices, it was deemed necessary to target organisations that have implemented BIM within their organisations and have demonstrable BIM projects. The participating organisations were selected based on the evidence they displayed at a recent BIM event. In November, 2011, Construction Mobile IT (COMIT) in collaboration with University College London, (UCL), organised the "delivering the value of BIM" seminar at UCL. 10 different organisations presented various ways BIM tools were being applied in their respective organisations. Invitations were sent to the 10 organisations and seven were willing to participate in this research. Access to three additional BIM-enabled organisations was also secured bringing the total number of participant organisations to 10, 4 represented contractor organisations, 5 were design and engineering firms, and 1 was a project management firm. The data collection effort took place over 8 month span. The respondents from the participating organisations held various professional roles in their respective organisations. They included group level directors, middle managers (e.g., BIM coordinators), operational site-based managerial staff (e.g., site engineers), and other professionals such as architects, quantity surveyors, MEP and structural engineers.

The data collection involves semi structured interviews, and BIM documentations. Interviews lasted 30 minutes to 2 hours, with the average interview lasting 1 hour. Interviews were audiotaped and transcribed. To enable triangulation and reveal contradictions, the interview transcripts and the BIM documents were integrated into a research database and analysed. The overarching aim was to gather information on how the participating organisations tackle their BIM implementation procedures. The participants were asked to discuss the extent to which BIM has been implemented within their organisations and on their respective projects. Informants were also able to spontaneously discuss topics that they felt were important regarding their implementation process. From the interviews, an understanding of how a typical construction organisation successfully implements BIM was gathered. A framework was then developed; it represents a common strand of the implementation processes from the various viewpoints. Interview quotes that specifically respond to interview questions on implementation issues were included in the qualitative content analysis. As suggested by Ryan & Bernard (2003) the key word in context (KWIC) technique was used for the data analysis. With the KWIC technique, all instances of key phrases and in their immediate context, relating to successful BIM implementation were coded into a spreadsheet. The KWIC technique has been used to generate a more concise understanding of various viewpoints, it helps to encapsulate a complete thought that could be compared and contrasted with other quotations to formulate constructs. The quotes were then systematically analysed using constant comparative method (CCM) to identify patterns in an axial coding process (Corbin & Strauss, 1990), thereby developing and refining the KWIC spreasheet. CCM ensured that the KWIC spreadsheet was constantly revisited until it was clear that no new theme was emerging. This enabled the attainment of a profound understanding of the participating organisations' viewpoints and hence the extractions of issues relating to BIM implementation.

4 FINDINGS AND DISCUSSION

Implementing BIM successfully is considered important to competitive strategy for construction organisations. Bringing organisation's BIM standard into an acceptable capability status (Succar 2010) is a comprehensive task that requires paying attention to some critical processes. The participating organisations discussed a number of peculiar construction related issues capable of posing a challenge to BIM implementation. These are competence issues, problems relating to information sharing, especially across different disciplines, choice of BIM authoring tools, and difficulties in crossing boundaries from familiar to uncertain and ambiguous work practices. The extent of change (as quoted below) perhaps contributes a great deal in making the implementation more challenging.

"…but, when we moved to BIM, it was a wholesale change in all respects. New hardware, new software, new processes, new training required, new mind-set required, new possibilities,

different ways to communicate, different ways to collaborate, different outcome, everything is different. It is a game changer" (Technical advisor).

Barger (1995) has cautioned that changing from old to new work processes come with ambiguity and uncertainty which has to be managed. As a means of addressing these challenges, the organisations inculcated measures as part of their overall BIM-enabled organisational practices. From the interviews, the implementation strategy employed by participant organisations focuses on measures such as: establishing BIM implementation plan; consulting the workforce to include their interests in the plan; conducting training for all affected stakeholders and selection of appropriate BIM authoring tools specific to a particular organisational niche. While the implementation approach considerably differed from one organisation to another, there were also common strands across the participating organisations. The following four key stages exemplify the implementation processes of BIM in the participant organisation as inferred from the from the empirical data:

1. Brainstorming stage
   A managing director expressed the need to "*...get heads together at day one to deliberate the huge nature of the change*".
2. Concept building stage
   "*a strategic team was put together … a 60page paper was prepared, based on the report, targets on how BIM should be embraced have been set by the board all the way down and agreed by all managing directors*" (Head of BIM)
3. Realisation stage
   "*…everybody in this office went on a 3-day training course, it gave us the basics of the skills we need. But you need to work on at least two or three projects, I have been working on it for like four years, but anytime I go back, it just gets better, and I am still getting better at it*" (BIM coordinator).
4. Manifestation stage
   "*from logical and common sense point of view, adopting BIM is completely the right thing to do, but it is about continuous cycle of change, we've got to be flexible to change anytime until the BIM benefits fully manifests in this organisation" (Director).*

One prior condition to the viability of the organisational BIM implementation process is the existence of a valid and clear mission or business strategy for the organisation. As one BIM manager simply puts it: "*…. So you need a vision. If you try to implement BIM without a vision you are actually not going to get there really. It is more of if we are going to do it, this is the reason and an appropriate implementation plan with a realistic milestone and budget lay out to the company, to say, this is what we need to do"(BIM manager)*. This perspective resonated across the views of the other participants. The process coordinates measures from the organisations' own practices and those which stem from academic literature, in particular, the AEC (UK) CAD standard. This standard is in accordance with BS1192, and is intended to support all BIM work undertaken within a practice to, "realise a unified, usable, coordinated approach to Building Information Modelling in a design environment" (AEC (UK) CAD Standard Initiative 2010).

Each implementation stage represents a distinct milestone in the BIM process. It is important that at the end of each stage, there is a review to make sure that there is consensus on the outcome before proceeding to the next stage. This ensures that there is unanimity and mutual understanding for the way forward. The implementation process therefore begins with an assessment and discussions of a company's current status and strategic enterprise and surrounded by change management and business development components. This brainstorming stage examines the driven motive for implementing BIM, and the extent of anticipated changes. The established implementation motives coupled with the extent of change seek to integrate the resource dimension and coordinate daily operations. The concept building stage involves people handling leadership roles. It requires both top-down level of support and bottom-up involvement, establishing implementation feasibility, budget targets, and defining timeline and implementation plan to be followed. Assessing the organisational situation in terms of available resources, and a better appreciation of '*what is in it for key stakeholders*' (senior quantity surveyor) determines the scope, timing, and viability of the BIM implementation initiative.

In the realisation stage, the analysis of the existing organisational functions provides the background for vendor selection and choice of specific BIM software to support the business operations. The realisation stage ensures that the appropriate BIM station is configured into the organisation systems, and the supporting computer systems have to be viable with efficiency. A BIM coordinator described that, "*… prior to this, my old laptop had 32bits OS and 3gig RAM which is ok for a laptop, but with Revit civil 3D, which is a big package, you've got to have 64bits OS and 8gig RAM, so the machine you see here is viable with efficiency*". Simultaneously, the people intended to use the system and those influenced by it have to go through education and training needed to understand how to operate the new work station and how information flow at each point of the supply chain has been affected by the new process. A Manager emphasised: "*….from my experience, i can say, some people embrace it quickly, and yet, others need a bit of coaching to take it through. Because what a coach does is not only train how to play football but he coaches them to play better football. The same applies to BIM*" (head of BIM).

The extensive education and training on functionality and configuration give people the needed insight to map the new process, designed to suit their work routine. This occurs at the manifestation stage. At this stage, it is also very critical to apply the knowledge on a pilot project. This marks the beginning of an ongoing BIM-learning cycle. A sound strategic-level support acts as a significant condition for achieving overall success with BIM uptake. The final phase emphasises knowledge flow optimisation and continuous expansion of the system to ensure new competitive advantage. Knowledge gained from each stage of the process is stored, and is easily accessible and retrievable by other employees. It serves to improve and reshape the implementation cycle. As summarised by a BIMM Manager, "*we will not spend that fortune and throw half of the learning out. We are taking it in stage by stage and keeps on feedback(ing) what's gone wrong so we can learn from them*'. The knowledge bank is thus an integral part of implementing other BIM maturity models and subsequent improvement.

The process actions required at each of the 4 stages of the BIM implementation as evident from the interviews and documentation analysis and discussed above can be synthesised into a process map as shown in Figure 2 which represents a BIM Implementation Framework. The process actions within the framework ranges from establishing the driving motives of the implementation, vision statement, to the enforcement of change management and business process development in the implementing organisation.

5 SIGNIFICANCE OF FINDINGS

The framework as shown in figure-2 synthesises preconditions and process actions for an effective BIM utilisation as practiced by the BIM-enabled organisations that participated in the study. The actual use or adaption of the BIM process starts with a particular professional context: architecture design, mechanical and electrical design, or structural design. In this way, the organisation can acquire the relevant BIM authoring tools and develop the necessary knowledge, and internally use the acquired knowledge on the first few BIM projects. For example, an architect will develop an internally consistence BIM model for a new project, but will also have to issue 'non-BIM' project documents which is in compliance with ongoing project specifications and contractual arrangements. Practitioners often call this stage, 'lonely BIM stage. This is usually the beginning of the learning process; it provides opportunity for those who have been trained on the use of new BIM software solutions to practice the process on a real project. At this stage, BIM is used for internal coordination purposes and the mode of communication is asynchronous. That is, background information from the model, which do not exist previously, such as 3D graphical images and textual data are generated and reviewed for internal coordination purposes, and can also be used to support internal capacity for subsequent improvement/development. Applying the BIM knowledge on some pilot projects and few early BIM projects could assist organisations to develop competency in BIM level-1 which typifies 2D or 3D managed BIM authoring software with standalone standard data packages but no integration (e.g., Richards 2010; Succar 2010). BIM however, consist of the use of 3D, real-time intelligent model to facilitating successful coordination and collaboration among the heterogeneous project stakeholders (e.g., Holness 2008). The real benefit of BIM cannot therefore be realised at maturity level one or at the 'lonely BIM' stage, because of the lack of coordination and collaboration with other BIM users.

In order to move beyond lonely-BIM, communication mode has to be synchronous and BIM coordination has to occur beyond one professional organisation domain. At this stage, 'real-time' interaction between BIM-enabled heterogeneous project members is possible, where project information is shared and used on a common project repository for the benefits of both the project and all the project stakeholders. The coordination can however, only occur between organisations that have developed internal BIM implementation process. Nevertheless, each capability maturity level requires the need to upgrade the implementation process with additional knowledge and additional technical artifacts. For example, at the moment, no two different BIM authoring tools can be coordinated without reliant on an open standard specification such as the IFC (Industry Foundation Classes), which in itself, is going through an improvement cycle. Also, if the model is expected to be handed over to the client to help manage the post-construction operation and maintenance, then there is a need to comply with the Cobie (Construction, Operations and Building Information Exchange) standard, which provides a framework for a robust information organisation for facilities management (NBS 2012). The Cobie standard is one of the key requirements contained in the UK BIM task group report (2011). This suggests that, every level of the BIM maturity hierarchy requires the need to accordingly upgrade the internal BIM process with new technological artifacts and new competency or trainings that suits the particular maturity level. The reconfiguration of the process should be designed to reflect the heterogeneity of the knowledge boundaries – multiple actors with different functions and different artefacts involved. However, achieving a competency at one level of BIM maturity hierarchy and retaining all the necessary knowledge within the implementation process could act as a springboard to the next maturity level.

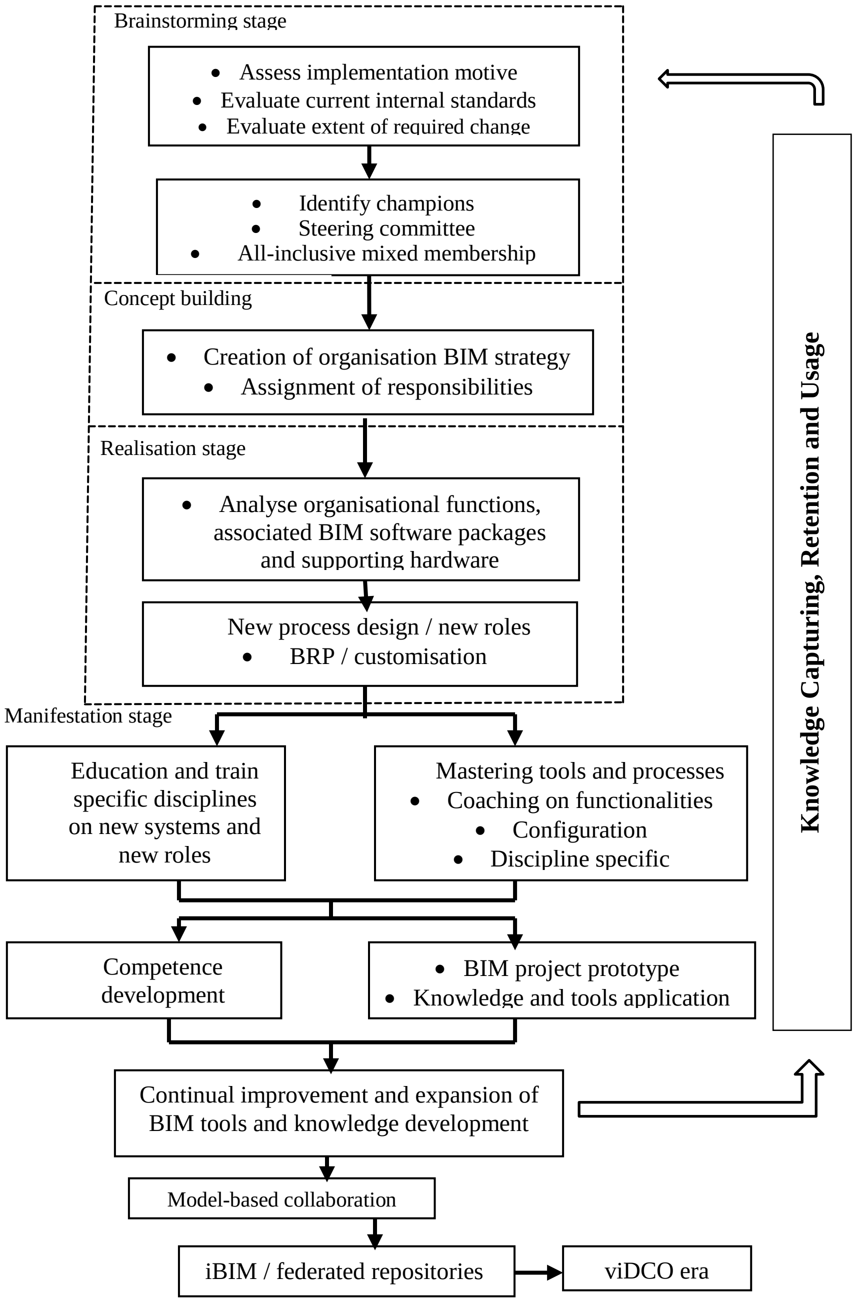

Figure 2: BIM implementation framework

6 CONCLUSIONS AND FURTHER RESEARCH

The paper has reviewed some recently developed BIM capability models from literature. There rarely exists any strategy or approach that can steer or guide organisations to successfully implement these BIM capability models. BIM Implementation process model is presented, and it is based on the recommendations for a good implementation process as evident in the exemplar BIM utilisation strategies of construction organisations who participated in this study. The success of BIM implementation depends on many factors. Both top-management commitment and operational (shop-floor) level BIM champions driving the implementation effort is found to be very essential. People at both strategic and operational levels, who have different roles, but may be affected by the process, have to be represented in the design process. End users are to have adequate amount of training to ensure that they perceive themselves to be competent when performing their roles under the new organisational protocol. It is beneficial to pilot-test the strategy on a typical project. It is also important to aim for gradual and continuous change process not just an episodic change. Evaluation, development and sustenance of the implementation process via knowledge retention could guide the path towards higher maturity levels. This paper provides a useful framework and baseline for construction organisations trying to identify a niche or a starting point for BIM uptake. It is however believed that the framework developed through this exploratory study requires further interrogation in BIM-enabled construction contexts to enhance its validity and reliability.

Nonetheless, BIM implementation is not only about 'logically laid-down' processes that should be followed. It also involves several sociological or people issues and technical challenges. These could affect the implementation outcome in fundamental ways (e.g., Markus & Benjamin 2012). Future research should examine in tandem, the complex nature of the sociotechnical interplay among the people attributes, the technical interface and the new processes involved. This could expand our understanding of the mutual adjustments required among the sociotechnical antecedents through which the BIM concept and other emerging construction technologies can successfully be implemented.

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