Building Information Modelling Processes: Benefits for Construction Industry

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Abstract

Many industry reports have enunciated on the nature of complications in some forms of construction problems. These include design errors, deficiencies in estimates, conflicts in design and implementations, and fragmented platforms that restrict information flow all through project life. The nucleuses of these phenomena have been expressed as major concerns on project performance and sustenance of innovation in the industry. A peculiar dimension to this challenge is the ability of conventional design, procurement and construction management protocols to generate, share and convey, without dissipation at any point, all necessary project data across all stages and discipline boundaries in construction development processes and project life. As some observations have been drawn in literatures on the implications of fragmented systems and spatio-temporal limitations of hand-drawn and entity-based 2D CAD design systems, there has been significant attention on the limitations of these conventional design tools. These include weak frameworks to facility design flexibility, automation, integration, visualization and robust capacity to drive data creation, storage, engineering and sharing between parties. Whilst these challenges are being addressed in Building Information Modelling (BIM) platforms, some potential opportunities have been identified in BIM as reliable alternatives in facilitating marked improvements in design, procurement, construction planning and facilities management processes. This study reviews literatures on evidenced benefits of BIM, especially on how it reduces confrontation and system inadequacies of entity-based 2D CAD through thorough integration, collaboration, communication and interoperation. Conclusions are drawn on the challenges of changes from conventional paradigms which are triggered by BIM in relation to construction project goals.
**Keywords:** building information modelling (BIM), construction processes, product development, project delivery
1. Background

Koskela (Koskela 2000) outlines the relationships between construction processes, formulation of design ideals and development of infrastructures in the industry. These processes, also known as Construction Product Development Processes (CPDPs), are often described as risky, uncertain, complex, dynamic and inter-dependent (Flanagan et al. 1987; Lyons and Skitmore 2004; Wang 2009). Components of CPDPs, in no particular order, include infrastructure architecture, landscape architecture, architectural engineering, civil structural engineering, estimating, mechanical and plumbing engineering, electrical services engineering, project management, construction management, procurement and facilities management. Apart from risks and uncertainties that filter into CPDPs’ systems in the directions of these disciplines, some recent studies on construction business models (e.g. (Shi et al. 2008)) have shown that most difficult complications are often triggered by stochastic frictions in commercial relationships between project stakeholders. Consequent upon these multiple dimensions of complexities, project stakeholders and teams often need to share information across trade boundaries to achieve project goals. These goals can be expressed in terms of the variables of feasibility and profitability, both in hard and soft measures (Barton 2000; Olatunji and Sher 2009a; Ustinovichius et al. 2007).

A wealth of evidence have shown that construction processes improve when stakeholders and project teams collaborate, cooperate, integrate and communicate effectively throughout all stages in the project life (Campbell and Harris 2005; Winch 2001). However, the frameworks to facilitate these have, up and until now, been deficient in both manual (hand-drawn) and conventional computer-aided drafting and design (CADD) tools. Different studies have enunciated the limitations of these tools and the subsequent implications on project lifecycle (Maher 2008; Slaughter 2001). Many authors (e.g. (Pektas and Pultar 2006) agree that hand-drawn design methods are time-consuming, bulky, prone to spatial limitations, conflicts and errors. Others (e.g. (Sommerville and Craig 2003; Succar 2009)) also posited that they support fragmented conventions and lack appropriate platforms to facilitate integration of non-graphic information into design components, as well as storage value and hygiene, compared to e-based systems. As panacea to these challenges, the construction industry has witnessed the deployment of two forms of CAD in CPDPs in the past decades; these are entity-based CAD (e-b CAD) and object-orientated CAD (o-o CAD). Whilst e-b CAD deploys only geometric data and “unintelligent” features like lines, arcs, splines and circles to create design products in 2D or 3D (two or three-dimensional) formats, o-o CAD uses intelligent objects that could store and engineer both graphic and non-graphic data in ways that spur integration and more sophisticated innovations.

As numerous potential opportunities avail for o-o CAD in CPDP systems, some empirical reports have argued that the industry has little to benefit from e-b CAD. (Aranda et al. 2008; Gu et al. 2008; Whyte and Bouchlaghem 2002) have averred strongly on the need to service project-based needs through strong and lasting balance between stored graphic and non-graphic data for convenient application in project life. Some of the specific constraints of e-b CAD being addressed and transformed into potential strengths of
CAD include improved spatiotemporal capabilities (nD), system integration, design flexibility, automation and simulation (Häkkinen et al. 2007). Although, some authors have triggered fears on the perceived reluctance of the industry to adopt innovations being derived from o-o CAD – especially building information modelling (BIM), (Barista 2009) allays this fear. According to a recent survey reported by this author, about 80 percent of largest AEC firms in the United States now use BIM. This implies BIM and allied integrated technologies are rather integral parts of contemporary research and training in the industry than mere theoretical propagandas. This study therefore reviews, by way of collation and comparison with previous technologies, strongly evidence of BIM’s potential benefits to the industry.

2. Building information modelling and construction processes

BIM represents a combination of fairly revolutionary ideals for design technology. Although some researchers (e.g. (Thorpe 2009)) aver that BIM related technologies were discovered in the early ’80s, several others (e.g. (Norbert et al. 2007) often refer to BIM as a nascent paradigm in the industry. Some studies have also argued that BIM adoption is still slow and some significant concerns about the reluctance of the industry to adopt or deploy potential change attributes in BIM have been evidenced (Succar 2009). As a panacea to this, (Gu et al. 2008) have suggested that this situation can be alleviated when industry stakeholders and disciplines understand their roles and opportunities in BIM. As BIM integrates multi-dimensional capabilities and facilitates major improvements in design and construction processes, there are strong indications that this could revolutionize project delivery in construction (Aranda et al. 2008). Some authors have conceptualized systemic benefits that associate with BIM deployment (e.g (Al-Humaidi and Hadipriono Tan 2009)), however it is not yet definitive from those studies who gets what and how, and how this could affect existing conventions in the industry. Moreover, while other studies focus on underpinning business drivers of BIM (Aranda-Mena et al. 2007), other authors (e.g. (Holzer 2007) have continued to resist popular opinions that BIM’s potential “wind of change” could significantly revamp the industry’s age-long challenges. The way forward therefore is to explore ways of comparing significant benefits (gains) with the demerits (pains) arising from BIM deployment.

2.1 An overview on BIM

Building information modelling (BIM) has been defined indexically by many authors (Aranda-Mena et al. 2007; Aranda et al. 2008; Gu et al. 2008 ; Holzer 2007; Succar 2009; Tse et al. 2005). These sources suggest BIM as a platform for integrated systems; although opinion varies on putting together a universal definition that will satisfy all discipline’s perspectives about BIM. However, a simple definition of BIM
may be surmised on this concept as a highly flexible object-oriented design process that provides viable platforms for multi-disciplinary integration. Unlike conventional CAD tools, BIM uses intelligent objects to represent distinctive features in designs. Some empirical reports have elicited how this reduces misconceptions, confusion and errors when interpreting designs (Dean and McClendon 2007). Other capabilities identified from literatures include its ability to generate photo-realistic graphics, multi-dimensional spatial configurations, system integration and robust embedment of graphic and non-graphic data into design components. Whilst rigid features like lines, arcs, splines circles etc used in conventional CAD applications are time consuming and redundant, BIM makes use of design objects such as walls, roofs, floors, windows, furniture, and services’ accessories etc which can ‘auto-update’ each time changes are made to the database. The use of design objects does not only improves productivity, its impact on the quality of professional services is overwhelming (Barista 2009). In addition, it also facilitates the simultaneous creation, access, management, storage, use, sorting, updating and sequencing of both geometric and embedment of non-geometric information into project databases to simplify in-line processes throughout facilities life-cycle management. The following section reviews these concepts as the benefit of BIM over conventional construction processes.

2.2 Benefits of BIM

Some evidence from technical reports from industry stakeholders, including software developers and vendors, CAD drafters, BIM modellers, construction administrators, researchers and contractors’ testimonials have continued to echo how discipline-specific professionals, clients, institutions and the industry are likely to benefit when BIM is correctly deployed. An outstanding part of this however, is the feasibility of these benefits when combined across disciplines. As more capabilities of BIM could become more explicit in the nearest future, it is expedient to explore them in relation to the enablers of unusual paradigm shifts in construction conventions, especially as per possible changes in professionals’ roles and responsibilities. However, while efforts are being made to document the directions of these changes, it is noteworthy that not many meaningful changes would come without a price. Some of the benefits of BIM are discussed as follow:

2.2.1 Simultaneous access

For many reasons, project stakeholders need to access project databases to input and move shared data across discipline boundaries speedily and repeatedly. This, in many occasions, needs to be simultaneous. Whilst this is impossible with manual systems, a possibility of multiple accesses to databases in conventional CAD systems is that of multi-user scenario. In Ohsuga’s (1989) argument on the limitations of CAD, the author pointed out that certain fundamental challenges are inherent in the underlying conventional information processing technology of CAD which deprive it from facilitating reactive intelligence and simultaneous access. This was also underlined by (Dean and McClendon 2007) on e-b
CAD-based 3D systems. However beyond this, according to Maher (2008), BIM provides platforms for project teams and stakeholders to have simultaneous access into project databases or servers. This phenomenon does not potentially shorten design and communication times, it allows early detection of design conflicts and errors as stakeholders are able to communicate and share ideas quickly. Moreover, simultaneous access allows the respective disciplines to create, update, sort, engineer and input their design opinions and information in a give-and-take manner at the same time. Therefore BIM users benefit from BIM as it permit timely integration, data sharing and creation of robust information on design components which are transferrable through the entire project life. Figure 1 show how stakeholders integrate in BIM environment.

![Figure 1: Integrated systems in BIM environment (Adapted from Olatunji and Sher, 2009a)](image)

**2.2.2 Robust information**

Several studies have pointed out that construction processes are responsive to intense and complex information on design, components’ applications and management. Construction processes are worse off when information flows inconsistently, subjectively and ambiguously (Pektas and Pultar 2006). Whilst manual and conventional CAD techniques are arguably deficient in this respect, BIM integrates both graphic and non-graphic data to create project specific information. (Chiu and Lan 2005; Ozkaya and Akin 2006) have outlined how BIM facilitates collaborations in digital medium through which project teams share detailed information about design intentions, material applications, manufacturer’s notes as well as guides to facilities operation and maintenance. As robust information reduces risks of conflicts and mismanagement, its effects are most evident in facilitating effective communication, interdisciplinary interactions, estimating, construction, facilities management and dispute management. This
phenomena breakthrough has been demonstrated by (Ballesty et al. 2007; Luciani 2008b). Embedded data in BIM are not limited to 3D models; they remain comprehensive even when designs are manipulated from 3D to 2D, and can be rendered fully functional in all parts of integrated systems. Figure 2 below shows model data in 3D and 2D drawings.

2.2.3 Auto-quantification

Interpretation of design information may be complex, and hence could be misleading when not definitive. Some studies have reported the implications of inconsistencies and variability in design quantification on project management (Aibinu and Jagboro 2002; Endut et al 2005). Sutrisna (2005) surmised that inefficient quantification methods might damage goals and genuine intentions in construction processes. There is yet no evidence that the shift from manual to e-b CAD applications in design have been able to eliminate this as they both tools are still delimited by constraints hampering consistent and accurate quantity measurement. According to (Gallello et al. 2009), BIM has potential to conceptualize automated measurement of quantities in useable scales and formats that allow stakeholders to sort and analyse information they require at anytime. However, this does not mean that comprehensive estimates can yet be automated from BIM for all conventional purposes. Although a process was outlined by (Bakis et al. 2009) on useability of international foundation classes) (2 x 3 ifcs) for comprehensive estimation of building and civil engineering projects, this study also noted that the industry still has many hurdles to cross to automate the generation of comprehensive estimates from BIM designs. As Ho and Ng (2004)
have observed how construction professionals resort to strenuous denial of faults when confronted with error dilemmas, auto-quantification is a potential saving grace as it entrenches accuracy, accountability and value integration in CPDPs.

2.2.4 Quality communication

Many research efforts have been focused on the importance of communication in construction processes (Koskela 1992; Gorse and Emmit 2005). Nevertheless, the limitations of manual and CAD design applications have evidently been proven. They have been linked to making construction processes more vulnerable to design errors and conflicts as well as other forms of inconsistencies in information flow (Acharya et al. 2006). Whilst manual and CAD applications do not have adequate frameworks for robust information and communication, BIM uses photo-realistic graphics, or convertible formats thereof, to transmit information. Moreover, some wealth of evidence from some industry reports (e.g. (Gorse and Emmitt 2004) have suggested that project stakeholders are more likely to integrate and collaborate effectively when project information and communication are simplified. Consequently, BIM provides enduring platforms for on screen training, simulation, and information sharing and value integration. Thus, this reduces risks associated with errors, inconsistencies and subjectivity.

2.2.5 Multi-dimensional integration

Manifestation of risks is multidimensional in construction processes which explain why construction is highly fragmented. However, evidence abounds in empirical reports indicating that fragmentation renders construction processes vulnerable to many significant limitations. Manual and conventional CAD applications support fragmented processes, as they may be manipulated through limited dimensions that mainly reflect geometric data only. BIM represents designs in multiple dimensions and forms that are usable through collaboration for architecture, engineering, procurement, estimating, construction planning and co-ordination, and facilities management (Tse et al. 2005). Whilst most CAD applications do not communicate with each other, (Gallello et al. 2009) have shown that the ability of BIM software to communicate with compatible applications facilitates collaboration and multi-dimensional applications. Figure 3 below shows how Vico Office®, a notable BIM software, relates with other modelling applications. This scenario, also known as also known as nD phenomenon, does not only optimise integration, it reduces process fragmentation and inconsistencies.
Project visualization enables project stakeholders to visualize and analyse design attributes through a phenomenon called *Second Life*. Second Life is a virtual life system where *avatars* are used to mimic human behaviours. This system is being used to teach, experiment and implement *gaming* and eConstruction (Gül et al. 2008). Benefits of this innovation include animation of real life concepts like the reactions of building components to thermal, illumination and ventilation factors, and other opportunities to review alternative options and ideals of value management. Barton (2000) outlines the impact of value management on clients’ satisfaction and project delivery. Some evidence also shows that BIM’s facilitation of project visualization and simulation of project components under different environments will be a significant competitive advantage for packaging CPDP business both now and in the future. This implies design and construction processes can better meet clients’ expectations on project feasibilities beyond project economics, legal and technical indices than manual and conventional CAD tools would do. Additionally, while these tools have not been used for this, design and construction processes can now be visualized and simulated in BIM to replicate real life challenges such as sustainability, buildability, energy-efficiency, flexibility and so on (Olatunji and Sher, 2009b). Figure 4 shows a project visualization using BIM.
2.2.7 Project documentation

As enunciated earlier, project packaging in manual and conventional CAD applications could both be time consuming and expensive. Apart from conflicts, inconsistencies and errors which are prone to fragmented processes, (Olatunji and Sher 2009b) have outlined other major disincentives to clients’ interests when project documentation is fragmented electronically or manually. Although, (Sommerville, and Craig 2003) have shown how electronic document management system (EDMS) trigger cost savings, however interoperability in conventional CAD has been a major limitation. With collaboration and effective communication, BIM provides platforms for thorough integration of project documentation right from conceptualization through to detailed design, procurement, construction and facilities management. With BIM, contractors can now received pre-quantified designs in electronic formats and still be able to modify fabrication and construction models, and store same for application in the project’s life cycle model. This improves productivity, communication and innovation in CPDPs, even though the cost savings of this method have not been reported.

2.2.8 Digital facilities management

Facilities management professionals still grapple with problems of data inconsistency, design errors and fragmentation of information management processes (Luciani 2008a; Olatunji and Sher 2009a). However, BIM provides interactive platforms for streamlined information management from design all through project life. This, according to Ballesty et al., (2007), has been tapped into in the management of Sydney Opera House, a global iconic masterpiece. Process gains triggered by BIM in facilities management include simulation, auto-alert and value intelligence. As it is becoming increasingly possible in BIM for
developers and facilities managers to test and validate design options in relation to post-construction modifications, the integration of certain information into project databases can also facilitate cost-in-use and automated responses from facilities components regarding use and application limits, maintenance and management.

3. The cost of change triggered by BIM in construction

Each past century has provided distinctive eras of change in construction technologies and processes from Stone Age of the third century to the industrial revolution of the 20th Century. Although, the role and scope of such changes have not been well documented as they vary from place to place, yet they are evident. Arguably, the construction industry might, sooner rather than later, re-appraise and reposition its process in the direction of digital technology like the rest of the world. This would result into knowledge gaps as appropriate competences will be needed to service these innovations. As this becomes more evident, many construction disciplines will be challenged to either improve their knowledge base or modify their services. Although, few of these skill needs have been documented by (Sher et al. 2009), (Hardie et al. 2005) have enunciated concerns how some existing disciplines still grapple with generation and adoption of knowledge-based innovations in the industry.

Moreover, (Tse et al. 2005) have reported some basic hardware requirements for BIM implementations, while (Aranda et al. 2008) have outlined its business drivers. Further evidence suggests how revolutionary BIM is than any other alternatives that are currently available. As it is therefore becoming increasingly evident that construction professionals might no longer be excused to not deploy with BIM when it is finally adopted, their commitment to knowledge acquisition through training and constant retraining will attract some costs. Even though this may not lead to extensive gain in the short run, all stakeholders – the public, clients, contractors and construction professionals will be better off.

According to (Succar 2009), it is difficult to effect, monitor and manage change in the construction industry. However, BIM is not just a necessity; it is gradually becoming a key indicator of competence and business effectiveness. Also, it is rapidly becoming the focus of construction education, training and research for institutions that would not want to be left behind. This wind of change implies BIM will potentially narrow the technological divide between manual and CAD systems. The present slow rate of adoption will only improve if institutions and disciplines take every possible fair step to be involved in driving the change towards fuller adoption of BIM across all disciplines and geographical boundaries.

4. Conclusion

The need for effective information management in construction is increasingly becoming important. While the industry still grapples with the limitations of manual and conventional CAD applications, BIM
provides more efficient alternatives that can overcome these challenges. This study has identified and presented gains inherent in BIM over manual and conventional CAD applications. The pain however is that, for the industry to survive the change being propelled by BIM, all institutions, professional disciplines, and government policy makers must be involved to facilitate the changes necessary. BIM promises unprecedented changes in construction education, training and research. Therefore, for organizations to be relevant in the future, achieving corporate goals in implementing BIM should be a priority.

References


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