BUILDING INFORMATION MODELLING (BIM) SYSTEM IN CONSTRUCTION IN 2020: OPPORTUNITIES AND IMPLICATIONS

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Abstract:
Information Technology (IT) is an essential catalyst for effecting improvements in the construction industry. Despite the growth and acceptance of IT in the industry, construction remains slow to adapt the capacity of change proffered by Building Information Modelling (BIM) System as well as exploit the diverse range of opportunities this IT innovation promises. This study explores the trends, applications and opportunities of BIM in construction in the 21st century with projections to 2020. The implications of these opportunities are also reviewed and possible constraints and challenges are identified. Finally areas for further research are explored.

Keywords:
Building Information Modelling (BIM), construction, construction product, Information Technology, virtual enterprise

1 Introduction

An effective design process is very critical to the success of the construction process (Aish 1999). Moreover, the adoption of applications of information technology (IT) has been a significant part of major developments in several components of the global economy. The benefits are evident in monetary and assorted terms in Aerospace, Manufacturing, Architecture, Engineering and Construction (AEC), Health, Education, Agriculture and service industries. Although, the rate of adoption of IT innovations differs within these industries, there is overwhelming evidence regarding how the applications of IT could foster process improvements. These benefits are not limited to time and costs savings, they also limit risks and uncertainties in construction processes (Sarshar et al., 2000). Apparently, the construction industry is being challenged by some barriers regarding the adoption of few recent developments in the industry. These barriers are related to extrinsic and intrinsic constraints that closely associate with the nature and peculiarity of construction products, culture, and level of risk, uncertainties and systemic complexity of the construction industry. In addition, some other constraints can be relative to the different perceptions on the implications of the adoption of BIM on the future of some professional roles in construction processes.

Several efforts have been made by some authors to provide comprehensive definitions of BIM (French and Fischer 2000; Schwegler, Fischer et al. 2001; Tse, Wong et al. 2005; Lee, Wu et al. 2006; Kazi, Hannus et al. 2007; Norbert W. Young (Jnr), Stephen A. Jones et al. 2007; Tarja Häkkinen, Sirje Vares et al. 2007; Robert P. D. and Susan
Evidently, BIM means different things to different people. Thus, BIM could have different definitions due to its flexibility and multiple applications. Schwegler et al. (2001) define BIM as the process of creating an information database for a project. This is not limited to the presentation of designs in at least three dimensions (3D), it also represents the use of lifecycle information in an interoperable manner to create, engineer, estimate, illustrate and construct projects. Furthermore, relating this definition to other attempts, BIM could be referred to as computer-aided drafting and design (CADD) techniques and allied technologies, which extend beyond rendering designs in 2D or 3D with lines, arcs, splines and other rigid “unintelligent” features. It includes the procedures and frameworks for enhancing object-oriented productivity and creativity in design processes through simultaneous creation, access, management, storage, use, update and sequencing of both geometric and non-geometric data on building components to simplify project life-cycle information management. The baseline, however, is that BIM facilitates interoperability within the project team such that conflicts and insufficient information could be eliminated in design processes and construction communication.

Interestingly, there is significant evidence indicating BIM as having unprecedented capacity to drive efficient changes in construction history. (RiverGuide 2006) argue that BIM as a nascent idea in construction, the realization of which is many years out. Guillermo Aranda-Mena, John Crawford et al. (2008) and (Succar 2008) provide holistic description of the trend of BIM adoption and implementation in different parts of the world. Probably, due to reluctant features of the industry regarding the adoption of BIM, there are several misconceptions concerning the trend of CADD developments and the capacities of BIM. This study is aimed at exploring the opportunities and implications of the applications of BIM systems in construction. The objectives are: (1) to define the trends of growth in CADD and BIM systems in construction, and; (2) to project the opportunities and challenges that BIM system is likely to stimulate in the construction industry by year 2020.

2 Product Information Modelling and Implications of IT in Construction

The construction industry relies on the effective application of complex and multidisciplinary, but project-specific, information to achieve result in its product development processes (Abbott, Martins et al. 2007). However, designers are often faced with the challenge of inadequacies associated with the capacity and quality of information that design tools could conveniently provide. This could be aggravated by imperfections in the structure of clients’ requirements (Tarja et al., 2007). Unfortunately, with complex, dynamic and tersely informing technical briefs and exhaustive clients' requirements, project teams often require suitable and exceptional frameworks to initiate professional opinions with the capacity to effectively stimulate construction processes beyond these odds, risks and uncertainties. Moreover, project teams are often expected by clients to conceptualize and deliver value-added professional opinions in project designing, engineering, estimating and planning with expressed information on building components. This role must be in adequate consideration of several indices of project performance; including buildability, flexibility, functionality, cost effectiveness and so on (Fusell, Beazley et al. 2007 ).
Severally, there is evidence in many parts of construction history from Stone Age to modern times showing that many techniques and tools had been used to drive project performance through enhanced design, estimating and planning in the construction industry. Arguably, manual and CADD systems are the most popular of these mechanisms. Although, both systems have made their impacts, there are marked limitations that were associated with each of them. These shortcomings relates to the inability of design processes to initiate frameworks that support comprehensive information on all project components and their applications as well as encourage effective communication, value integration and innovation across all disciplines in construction project teams. Therefore, the industry has been in dire need of quality design information management system that is appropriate to effectively motivate accuracy to process, engineer, estimate and responsibly forecast project targets in relation to time. The purpose of this drive is to limit project risks and uncertainties across the entire project life. Evidently, the incapacity of the design systems to address these indices translates into major challenges in the construction processes.

On the one hand, the manual design system and procedure lack the capacity to perfectly and concurrently capture and present geometric and non-geometric information on design components. It is also time consuming and expensive to generate, manipulate, store and apply underlying information (if any). Other challenges of this design system include the capacity to facilitate simultaneous access, integration and collaboration of the design team across several multidisciplinary boundaries, and on time. The effects of the inadequacies of manual design system are better imagined than experienced. Among such nuisances having far-reaching damaging effects on construction project delivery include design delays, omissions, mistakes, errors, conflicts and lack of capacity to facilitate comprehensive information on project components as well as store same for onward transmission. Most times, projects are finished with less value than anticipated, if not abandoned or its purpose derailed with cost overrun, project delay, disputes and dysfunctional crisis. Unfortunately, the challenges of project performance in the construction industry are mostly blamed on inadequacies of design processes to initiate integrative construction process without errors, omissions and conflicts (Latham 1994; Egan 1998; Koskela 2000; Hansen and Vanegas 2003; Gorse and Emmitt 2004; Gruneberg and Hughes 2006). Thus, an alternative design method is imperative – at least to facilitate adequate capacity and sophistication that would enhance design process in terms of accuracy, timeliness, cost effectiveness, value integration and ability to store robust information about project components.

Interestingly, the adoption of the applications of information technology in construction has been an impressive alternative. Going by available historical data, the use of information technology dated back to 1931, long before the name ‘computer’ was adopted for ‘thinking machines’. CADD applications were used in Massachusetts Institute of Technology (MIT), United State of America. They were run on Intergraph, Accugraph, MacDonal Douglas GDS with IBM, Prime, Digital VAX, and SUN systems and Unix, and later on less comparative (in terms of strength) MS-DOS; with mainframe and min-computers. They were later used on micro-computers and IBM-PCs in 1976 and 1981 respectively (Langdon 2002). Until 1982 most CADD cost US$40,000 or much more. Figure 1 shows the trend of CADD developments in construction from 1931 to 2008.
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<th>Year</th>
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<td>1931 – 1981</td>
<td>CADD applications were used in Massachusetts Institute of Technology (MIT), USA prior to modern “computer explosion” and the subsequent proliferation of contemporary CAD applications. CADD applications were then run on “turnkey” systems. They were later used on micro-computers and IBM-PCs in 1976 and 1981 respectively, using MS-DOS.</td>
<td>This precedes AutoCAD times: Intergraph, Accugraph, MacDonal Douglas GDS were run on IBM, Prime, Digital VAX, SUN systems and Unix. Generally, the cost of software was very expensive; sophisticated systems were required and the expertises to drive the systems were rare and expensive.</td>
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<td>1982 – 1987</td>
<td>Different versions of AutoCAD (1.0, 1.2, 1.3, 1.4, 2.0, 2.1, 2.5 and 2.6) were released, each being vivid improvements over previous editions. Initially, they were run on low capacity IBM-PC and later on micro computers with most attributes still available in recent versions. Major ‘add-ons’ on previous versions include AutoLisp, Ketiv (ArchT), AutoArchitect (Softdesk), ArchPro, GeoCAD, DrawBase etcetera.</td>
<td>AutoCAD was demonstrated at COMDEX trade show. Although, 3D tools were part of the initial tools, overcoming 1-floor problem is a major constraint. The requirements' costs (software, hardware and personnel) were reduced. There were marked improvements in flexibility, user-friendliness, knowledge transfer and market growth</td>
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<td>1988 – 1997</td>
<td>Releases 9, 10, 11, 12, 13 &amp; 14 were introduced. There were major improvements on LISP, rendering and “paperspace” capabilities. Previous problems associated with compatibility of files created in various versions also solved. 3D Modelling was also enhanced through ACIS, while conversion of different units of measurement was made possible.</td>
<td>There was notable capacity integration which enables AutoCAD to run on both Mac and Microsoft Windows computers. “xrefs’ format enhanced collaboration and networking. Softdesk was absorbed, while Autodesk clients grew to a record 3,000,000 AutoCAD users.</td>
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<td>1998 – 2002</td>
<td>ArchitecturalDesktop versions 1, 2, 3 and 3.3; and AutoCAD LT, AutoCAD 2000, 2000i and 2000iLT, 2002, 2002LT, ArchitecturalStudio and Autodesk Revit. Building component entities, AXR language, object enabler, internet-based interoperability were initialized.</td>
<td>The cost of AutoCAD went down tremendously. It is now possible to drag and drop 3D objects from the internet. Floor slabs were introduced as improvement over previous editions with 1-storey challenge. Revit was absorbed.</td>
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<td>2004 – 2008</td>
<td>AutoCAD 2004, 2005, 2006 and 2007 were introduced. Support and upgradability of lower versions of AutoCAD discontinued as all versions are only available through subscriptions. AutoCAD components were invigorated to integrate 3D capabilities into smarter building system and initiate capacities for building cost analysis, automated components’ specification writing, building structural engineering, space planning, facility management and interference checking etc.</td>
<td>There are major improvements in design visualization, productivity (due to easy retrieval of information), increased coordination of construction documents, embedding and linking of vital information such as vendors for specific materials, location of details and quantities required for estimation and tendering, increased speed of delivery and reduced costs</td>
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Figure 1: Trend of growth of AutoCAD in the construction history ((Langdon 2002; Autodesk 2007 )
Arguably, interpretations and conceptualizations of information technology in construction are broad and indexical. This mostly depends on nature of business and purpose for which it was put to use. Evidently, CADD systems improve the capacity of design processes through enhanced information management system, innovative processes, accuracy, time and cost savings. However, before the advent of BIM, there was wide gap between design accuracy and project performance within different periods of CADD applications. Designs were in 2D or 3D formats, mainly developed with geometric data only. Simultaneous access to design server, simulation, project visualization, virtual enterprise and other possibilities now being deployed in BIM were absent. Moreover, before Autodesk absorbed Revit recently in 2002, ‘1-storey limitation’ and compatibility constraints were the major challenges in all Releases of AutoCAD. In fact, up to Release 14 of 1997, AutoCAD is largely 2D-based tool. In subsequent editions however, 3D enabler, ‘intelligent object’ components, internet compatibility features, AXR language were added to improve design visualization. ‘Xrefs’ were also added to improve networking and collaboration within the project team, while other benefits of this innovation multiply through interoperability and virtual enterprise. This marks the turning point hitherto upon which building information modelling (BIM) system develops.

Due to certain factors, BIM started as marketing tool for few firms that were able to recognize its concept and business drivers. Others seem reluctant to adopt this tool because clients were not fully aware of its desirable capabilities and the benefits they stand to gain as value on their investment when BIM impacts on their projects (Schevers, Mitchell et al. 2007; Olofsson, Lee et al. 2008 ). Perhaps, some vital organs of the industry could have been misinformed by some misconceptions arising from certain aspects of BIM applications' marketing backgrounds (Gu N., Singh V et al. 2008). Nonetheless, the construction industry seems not to fully understand the impact of these failures on her image and the future of professional roles and services. However, efforts are on-going by application developers, researchers and policy makers to improve the slow of BIM adoption and further define business factors that are inherent in BIM deployment (Lee, Wu et al. 2006; Fusell, Beazley et al. 2007 ; Gu, Singh et al. 2008; Guillermo, John et al. 2008; Succar 2008; Gu, Singh V. et al. 2008).

Interestingly, with earlier features of design manipulations (from 2D to 3D and 3D to 2D), project simulation, improved project visualization, automated design updating and innovative modelling are now better possibilities in BIM. Presently, BIM applications are being deployed to simulate construction project designs. With robust information bases underlying component objects, it has become easier to predict variable and major activities in project life. Possibly, in future, several alert systems are likely to be integrated into design models to sensitise developers, users and clients regarding use, overhaul and improved diagnostics. Moreover, while cognition and computing experts in CAD applications grapple with the challenge of embedding project components with robust information in form of detailed, functional, operational and application database manners that are desired by other professionals, separate applications are being deployed to facilitate cost estimation, specification writing, structural engineering of components, project planning, facilities management, automatic wood framing, space planning, HVAC ductwork and interference checking, checking compliance with Building Code and so on (Robert and Susan 2007).

Conversely, recent evidence shows the benefits of BIM deployment in project planning (4D) and cost estimating (5D) (French and Fischer 2000; Nigudkar 2005). Arguably, there are further positive indicators supporting future effective applications of ICT in
construction regarding vital and multi-various motivations to drive business and innovation across all fields and disciplines. However, cost benefits of this advantage is more likely to be a major disincentive in the short run, while the cost of change promised by BIM could be huge in the long run. Evidently, design and construction processes are more likely to improve when stakeholders see and deploy BIM as a tool of change, not limited to design but including construction, planning, estimating, facilities management and advanced cognition and simulation to transact ideas with the true spirit of collaboration, mutual understanding, and effective communication and sustain integration of the ideals of innovation and shared values (Norbert et al., (2007).

3 Research Methodology

Studies on the adoption and implementation of BIM are being given overwhelming attention in several industry-focused technical reports. Being an emerging technology, information used for the projections on the growth of CADD and BIM applications are limited to data retrieved from BIM application developers, technical reports and recent de-facto discussions. However, as the rate of adoption of BIM improves globally, there could be further access to empirical data on improvements in the prospects of CADD and BIM applications. On the other hand, observations based on BIM opportunities and challenges are based on its theoretical capabilities. These include its ability to generate accurate automated quantity measurement and facilitate robust information database for product components. Others include the propensity to enhance virtual enterprise through product model visualization before construction and promote effective communication, interoperability, value sharing between parties, innovation and genuine spirit of collaboration and teamwork in the project team.

As part of an ongoing research, the aim of this study is to project the opportunities and challenges that are inherent in the adoption of BIM application by 2020. (Sarshar, Betts et al. 2000 ; Abdul Samad (Sami) Kazi, Matti Hannus et al. 2007 ) have used similar strategies to make projections for the deployment of IT applications in construction in the early years of the 21st century. The limitation however, is that these assumptions are not based on primary empirical data. Meanwhile, issues relating to historical documentation and projections such as this are of greater importance to construction students, researchers and application developers who would be willing to explore further possibilities with BIM application and its impacts on project procurement.

4 Prospects of BIM in Construction in 2020

Part of the modest desires of government and public is that the construction industry optimises its capacity to improve project delivery through construction processes. Latham (1994) observe that construction cost could be reduced by one-third if processes leading to project delivery improve. Interestingly, there had been various attempts to explore the role information and communication technology plays in driving innovation, cost benefits and improved value integration in the construction industry. Abdul-Samad Kazi et al, (2007) study the roadmap for the application and adoption of IT in the UK construction industry. Moreover, Sarshar et al (2000) report the potential of IT in construction with projections that, by 2010, there could be a turning point in construction history. This timeline is expected to institutionize enhanced collaboration, integration, communication, teamwork, risk minimization through project’s (model) pre-construction simulation, analysis and visualization as well as exceptional
improvement in quality of service in terms accuracy, time saving, aesthetics, sophisticated and rigorous functional analysis of building components.

Moreover, there is wide gap between the already-achieved potentials of BIM and what has been achieved with Product Information Modelling processes of manufacturing industry. This challenge could be relative to the size of construction industry and the uniqueness of its products, compared to manufacturing sector. However, with the current wind of change promised in BIM, there are improved chances that the construction industry may no longer live by excuses relating to systemic complexities, product uniqueness, dynamism in clients' requirements and other limiting factors which impede project performance. Evidently, it is very unlikely that these barriers would be allowed to persistently hold the construction industry into ransom for ever (Hansen and Vanegas 2003; Norbert, Stephen et al. 2007). Efforts are being made by various institutions and governments to improve the adoption and implementation of BIM in many countries. These earnest desires for change are based on persistent pressure from governments, clients and members of public who have continued to show concern on the need to have better value-oriented, sustainable, energy-efficient construction industry where improvement of processes and procedures leading to project delivery in construction is inevitable. Figure 2 shows current BIM process network in construction project delivery.

Current opportunities promised in BIM include thorough integration of Architecture, Engineering, Construction, Time-line sequencing of planned schedules and Cost Estimating (5D) in a single environment. Incidentally, there are strong indications that, sooner that later, application of BIM would become more evident as revolutionized international benchmarks for project procurement in construction. While opportunities evolve to address some of the misconceptions regarding BIM applications, there are improved chances that BIM has the capacity to impact on the aggravating nuances of traditional construction methods. Further to these, many more of institutions and education providers are currently adopting teaching and research on BIM as part of their programs and structure for the future of the construction industry. The implication is that, in the next decade, further advances would be made into project visualization and simulation such that could embrace sophisticated technologies like automated alert systems in constructed facilities, robotics and manufactured construction. Perhaps, it could be possible to achieve building components - walls, doors roofs, floors, furniture that would alert users when servicing or change is due.
Conversely, while software developers are considering improving the compatibility indices of current 3D tools in use, conceptualising BIM to adapt to traditional procedures in the construction processes is a major challenge. Tse et al., (2005) report that the management of BIM procedure in design processes may become a new discipline in the future. Apparently, this is a possibility because, going by extensive drive for change and the implication on professional role, there could be inadvertent divide that would delineate professional roles in the industry according to technological capabilities. On the other hand, although, members of project teams reserve the responsibility to input their professional opinions as project-specific information in industry foundation classes (IFC) databases of projects, manipulating the IFC to conform to traditional procedures is another challenge (French and Martin, 2000). For instance, in traditional procurement procedures, cost consultants are used to using Standard Methods of Measurement (SMM) principles to generate Bills of Quantities (BoQs) and adapt same for cost analysis of projects. Unfortunately, filtering IFCs to conform to SMM ideals in generating cost estimates from automated quantities generated from IFCs has not been very easy (RiverGuide, 2006). However, in the next decade, impacts of BIM on procurement practices and ethos would become more evident.
Furthermore, there is the need to establish the compatibility of BIM with other CAD tools that practitioners in the industry are familiar with. Arguably, substantial investments in construction are focused on applications that specific isolated roles like estimating, planning, structural analysis, facility management and so on. The challenge, however, include the strategy to continuously convince practitioners in this category that deploying BIM applications make business sense both at short and long runs. Another significant barrier of the adoption of BIM is comparativeness of cost benefits and associated trade-offs when BIM is deployed as substitute to CAD applications design practitioners are familiar with. The setback could be more serious when these software applications can perform better individually than BIM would do collectively. However, overcoming compatibility constraints should not be too difficult in BIM. This is because its developers, Autodesk Revit, have outstanding records of solving related problems over the years (Langdon, 2002).

5 Conclusion and Further Research

The construction industry develops its unique products using complex information from different sources. Thus, the use of sophisticated tools with appropriate capacity to process, manipulate and present product information in construction processes is inevitable. This limits risks and uncertainties as well as saves time and cost in construction processes. Although, the use of CADD applications started in construction around 1931, evidence of significant improvement promised in BIM applications started in 2002. However, despite the barriers of BIM adoption, its exceptional prospects are outstanding. By year 2020, BIM is expected to improve construction product development process through enhancements in process management, time and cost savings, facilitation of robust information database on product components, virtual enterprise and product model visualization, effective communication, interoperability, value sharing between parties, innovation and genuine spirit of collaboration and teamwork.

More direct impacts of BIM are evident as defragmentation between parties and project teams improve through interoperability and virtual enterprise. Perhaps, as trade boundaries continue to diminish, role change is inevitable. Moreover, initial cost benefits at early stages of adoption may be in doubt, as firms may need to invest in procuring the appropriate hardware and software to drive BIM as well as train personnel for the new challenge. Evidently, there will be opportunities to adapt new skills in order to cope with new situations. However, this may imply that immediate cost benefits could be low, as firms need to prepare for some of the inevitable changes the adoption of BIM could bring. Consequently, there may also be the need to improve incentives for research on BIM, including appraisal of academic curricular in the short run in order to achieve the needed result - long-term framework for the improvement of project delivery in construction.

Finally, it is recommended that future research be focused on analytic evidence regarding empirical impacts of BIM on design process, procurement and professional roles. Meanwhile, the prospects of BIM to institutionize integrated construction processes would continue to indicate that project could be delivered better, cheaper and safer, while defragmentation improves between parties.
6 References


