MODELLING THE COST OF CORPORATE IMPLEMENTATION OF BUILDING INFORMATION MODELLING

Oluwole Alfred Olatunji, PhD Student, University of Newcastle, Callaghan, NSW 2308, Australia Oluwole.olatunji@newcastle.edu.au

ABSTRACT

The popularity of BIM has improved in the past years. However, its adoption and implementation rates are still slow. Apart from overt limitations regarding yet undefined market drivers; many potential BIM users are still speculative because of a number of concerns. Arguably, there is need to define comprehensive frameworks for initiating and servicing BIM adoption and sustainable implementation, both in term of cost and non-cost indices. A process model for BIM implementation is discussed using different organization structures. This is indexed on skilling, hardware, software, on-costs, indirect costs and marketing costs. A regression model is also developed to explain the relationship between these variables. The study concludes that BIM implementation has some fuzzy characterizations which are not explained in the mathematical model. Some areas for further study are recommended.

Keywords: BIM adoption, BIM implementation, organization structure.

1. INTRODUCTION

Building Information Modelling (BIM) has a huge potential as a novel initiative that can incentivize radical changes in construction practice paradigms. Its benefits have been conceptualized in a wide range of literature on the applications of Information Technology in construction. Specifically, significant evidence from literature underlines BIM's support for process defragmentation (Steinkamp and Dionne 2009)). It also facilitates collaboration and thorough integration of construction systems, tools and teams (Brandon et al. 2005)). As indicated by (Hiremath and Skibniewski 2004), process integration improves the deliverables of electronic data management system than other previous options. Some studies have accentuated these as BIM ideals. They have done this to demonstrate its benefits, some of which are documented as intelligent design, object-oriented concepts, auto-quantification, virtuality, simulation, project visualization and simultaneous (real-time) access to data repositories, among others (Norbert et al. 2007)). To these, (Luciani 2008) added that BIM applications and benefits span beyond initiating construction procurement, rather a reliable tool for packaging lifecycle information and allied innovative initiatives.

Past studies also suggest at least three directions of thought regarding BIM implementation and the realization of its benefits, although it is not yet fully adopted for deployment on all types of construction projects in many parts of the world. One of these is that BIM is a new concept and its realization is many years out (Hardin 2009). In support of this proposition, some studies concluded that as our world has found itself in an era of infinite information being driven by sophisticated technologies, the construction industry needs to step up its web of skills and commitment on enhancing integrative conventions and practices through digital innovation (Gameson et al. 2004; Sher et al. 2009). Another line of thought has expressed modest scepticism about the feasibility of BIM adoption, and the subsequent realization of all its potential benefits. This is because there are serious technical limitations hampering its adoption and deployment, Examples of these include interoperability between software applications (Holzer 2007) and its legal limitations (Olatunji and Sher 2010). Consequently, vitally significant evidence suggests that the industry still seems cautious about BIM implementation. This is partly triggered by the fact that:

1. Individual conventional disciplines in construction are already pitched to different thresholds of IT absorption and usage.
2. The complexity in the nature of construction triggers the need for a common frontier to facilitate universal uptake at a specific minimal level, and to at least sustain same over some period of time.
3. The industry still requires enduring structures to facilitate a strong link between IT adoption both at discipline levels and minimum standard at the industry level; and in relation with other industries.

Observations by (Storer et al. 2009) indicate market reluctance to adopt BIM. However, (Aranda-Mena et al. 2009) argued that one of the best ways to go is to explore the business structure of BIM. This may not yield a conclusive result unless business models are mapped out and integrated to reflect significant agents that drive industry's awareness and uptake of digital technologies. This position is supported by (Gu et al. 2007). The authors argued that the construction industry requires a comprehensive outlay of discipline-specific process models to analyse0 market determinants and BIM implementation strategies both at macro (industry) and micro (corporate) levels. To achieve this, implementation at both levels has to be encompassing, tactical, orderly and systematic. This study aims to model the cost of implementing BIM in an organization. The objective is to map out the cost of acquiring systems and new set of skills to manage project-specific goal through interactions between technologies, project teams, institutions and marketing conceptualizations.

2. CONCEPTUALIZING ORGANIZATIONAL RESPONSE TO CHANGES IN PRATICE TECHNOLOGIES

2.1 Organization Structure Models

Organizations have different service and structural identities. (Olatunji 2010) has identified network, functional, matrix and divisional models as conventional organization structures which are relevant to construction business models. These structures react differently to changes in Construction Business Systems (CBSs) – CBS has been conceptualized by (Gann and Salter 2000). Network organizations are structured to dispel physical boundaries between system users. The goal is to keep teams within reach strategically regardless of geographical positioning, and this includes the use of digital micro-world technologies and deploying ideologies of integrative communication and values. This best describes organizations that provide integrated services, especially those in virtual enterprises (Ahuja and Carley 1999). The emphasis is to make organizations compact, fluid and adaptive. Some benefits of networked business model include ability to visualize moments of rapid changes and quickly adapt to process re-orientation. However, change as a philosophy is a complex risk that may be non-linear (Cai et al. 2004). Networked organizations therefore need rugged, complex and context-sensitive skills to drive both internal and external interests in moments of system changes. According to (Jarvenpaa and Ives 1994), the major challenges of shifting from fragmented business models to this model include (1) how to develop a workable architecture and manage flexible and efficient information repository that is interoperable between networks; (2) establishing new values, attitudes, and behaviours on sharing information in concentric formations; (3) building databases that can support integrated networks, and; (4) protecting ownerships, personal freedoms and privacy. To achieve these, each component of Integrated Product Delivery Systems (IPDS) has to be trained and equipped to service BIM as a prime determinant of project success. Strong indications from market reports suggest there are unique windows of opportunities to grow new disciplines in this field, especially regarding deploying innovative initiatives in e-network systems.

Functional organization model is characterized by specific lines of command across defined and independent skill specialties and responsibilities (Price 2007). Its goal is to trigger skill integration to achieve project-specific interests, while the main benefit is that it reinforces integration and value sharing in streamlined functional business frames. This is evident in many process models in project delivery literatures, and the challenge has been the need to develop and sustain a stronger platform that enable improved collaboration between project teams (Gu et al. 2007). Current optimum maturity level of BIM uptake suggests the industry still grapples with the limitations of functional model, perhaps due to strategic reasons (Dean and McClendon 2007). Skill gap in construction necessitate multi-skilling and functional model emphasizes division of labour. This is fragmented and can be counter-productive when important functional skills are lacking, insufficient or not complementary (Kalay 2001). Moreover, this model is vulnerable to internal conflicts because members of project teams could honour self-interest and discipline bias rather than objectivity in collaboration. Co-ordination is yet another limitation of this model and this is one of the single largest catalysts of strategic reluctance to BIM adoption. To palliate this, actors in functional models need all sense of confidence in BIM by emphasizing its positive impact on potential role change that BIM is likely to trigger as its adoption rate improves.

Matrix model is built on conventional philosophy of project teamwork. The aim is to bring skilled individuals together from different focus areas within the same or different organizations to drive specific-project goal(s). Actors in this model have two lines of bias: they are responsible to their line manager and the project's line of command (Asopa and Beye 1997). The model is driven largely by specific technology to manage project information and collaborative initiatives. However, it is vulnerable to a phenomenon called 'matrix muddle' – a counterproductive syndrome that is caused by duplication and confusion when the matrix suffers from efficient framework for managing flow of information. Another limitation is how to determine appropriate methodologies for facilitating thorough collaboration and value integration between actors. Many studies have reported this challenge as a major issue with conventional philosophy of teamwork and have recommended BIM as a workable option (Baiden and Price 2010; Lee-Kelley and Sankey 2008; Scott-Young and Samson 2008).

On the other hand, divisional organization structure is aimed at facilitating project goals and to respond to external pressures. Its coverage often focuses on three areas: product development, marketing strategies and geographical interests. One of the main limitations is that it supports fragmented processes. Other issues include co-ordination, collaboration and frustration arising from internal crises. Potentially, BIM has an attractive prospect in digitizing information packaging in construction. Although rhetoric, some perspectives put it as construction's last chance to reduce the gap between it and other industries (Carmona and Irwin 2007). However, the reality is that construction organizations are structured differently; so is their reaction to changes. Change, as a complex philosophy, is inhibited by uncertainties. Interestingly, Information Technology is not alien to construction system, some organizations only need to upgrade existing systems and engage new initiatives of business and behavioural re-engineering (BBPR). To this, (Sher et al. 2009) add skilling, while (Bleiman 2008) recommend a reconstruct of fragmented procedures to integrated service delivery and marketing initiatives. Figure 1 below illustrates change agents that drive corporate implementation of BIM.

2.2 Cost Determinants of BIM Implementation

Organizations need new skills to drive BIM. To develop these skills, personnel must be trained to deploy new technologies and demonstrate certain ethical requirements. Because organizations are different in structures, they will require different training packages to manage BIM in line with varying business interests. Moreover, different categories of staff will require different training, and when necessary be able to adapt to changes that BIM implementation may trigger. According to (Shah 2009; Zyskowski 2009), BIM implementation trainings are always in two ways: start-up and in-line training. While start-up training precedes implementation, and this could involve new recruitments, in-line trainings are periodic and continuous. The bottom line is how to define appropriate methodologies for determining what to learn *(environment, context, content and structure)*, how *(mode, resource and institution)* and when *(duration and time)*, and relate these to business goal(s) and market interests. At any point, employers may recruit new staff members with appropriate skills and experience to drive new BIM initiatives.

Some literatures on corporate response to technological changes (e.g. (Love and Irani 2004) position hardware and software application in the heart of strategic compliance to specific IT adoption. As BIM is an application-based innovation, its uses are developed to comply with specific hardware requirements. These items differ from product to product and developer to developer. According to (Briand et al. 1998), The costs are driven by nature of project, market forces and maintenance arrangement. While some establishments may need to procure new items, some users only need upgrade existing applications. This condition can also affect the cost. To this, (Shah 2009; Zyskowski 2009) added services as another cost determinants. Both software and hardware components are driven by electric power, internet access and continuous technical support, all of which have different cost factors and could be partly dependent on the contract arrangements between software developers, vendors and end-users. To limit uncertainties, another cost variable is risk indemnification. Depending on specific needs, different insurance products will be necessary. Technical supports from other organization, in terms of consultancies and research, may also be required.

Putting the theoretical framework of this study in a logical perspective, since construction organizations are different in structures and business identities, they will definitely require different strategies to adopt BIM. As shown in Figure 1 below, regardless of structural differences in construction organizations, similar outcomes can be achieved when agents of change are applied to appropriate degrees and in manners best suitable for the specific business interest. For instance, all organizations do require suitable strategies to generate appropriate degree of skill to drive BIM. Aside, they also need to re-define their marketing concepts in line with BIM standards. They also need to service their new business model with the right technology and process re-engineering concepts.

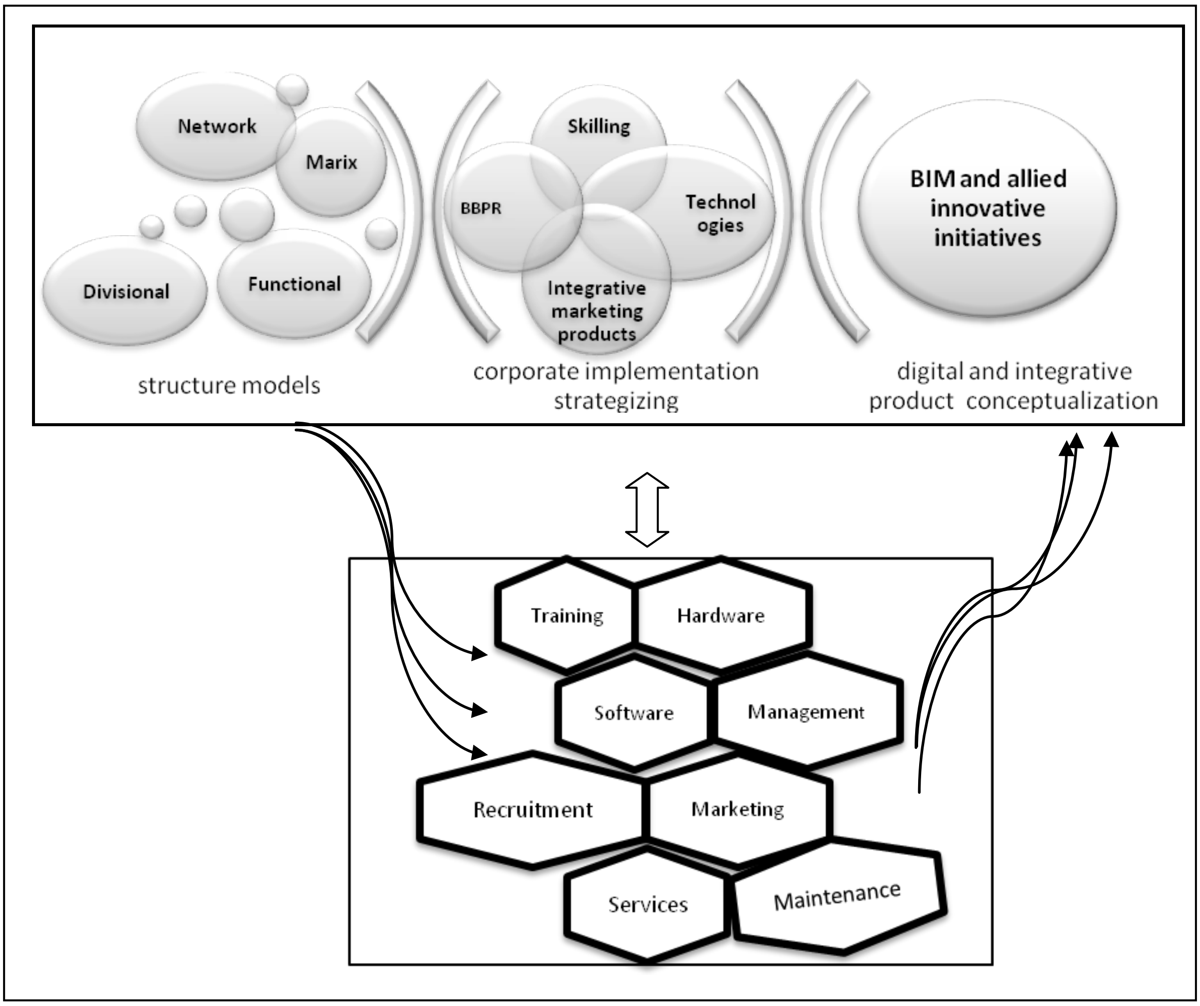

Figure 1: Change agents and drivers of BIM implementation at corporate level

3. RESEARCH METHOD

This research is similar to the procedure and rationale reported in (Olatunji 2010). (Olatunji 2010) relied on focus group discussion to explore strategic reactions of Australian estimators to BIM adoption. Analogous to this study, the goal is to articulate contributory concepts and rationales that drive organizational response to technological changes across identified divides of structure models. The procedure starts with approaching participants to provide consent before taking part in the study. Firms that operate specific structure models, two for each model, as earlier defined in this study were approached for participation. In the end, 24 participants took part in the study and findings are articulated in Table 1 below. These include industry practitioners comprising of Integrated Project Delivery (IPD) experts (Architects, Quantity Surveyors and Design Engineers), software developers and vendors, and international recruitment agencies that are currently experimenting BIM adoption in Australia. As high level of BIM expertise is not very common, simplistic quantitative methods were therefore considered unsuitable for the research. A similar procedure was reported in (Brewer and Gajendran 2009). Apart from articulating robust experience shared by participants, secondary data were also explored to create a cost model for the implementation to BIM, and specific focus was concentrated on training, hardware, software, services, contingencies and recruitment. The findings from this research are reported below.

4. DISCUSSIONS AND FINDINGS

The aim of this research is to develop conceptual and regression models on corporate implementation of BIM. A total of 6 variables, identified from literatures, formed the framework for the models. Analysis reveals that average software costs are responsible for about 55% of the total implementation costs; this is about 250% of hardware costs, and about 300% of training cost. The average total cost of services, recruitment and contingencies added together is about 5%. Specific findings on these variables are described as follows:

Training

Participants agree that training is a vitally important component of BIM adoption at any level, and the context and content must align with business goals. Evidently, different staff levels would require different training schedules; ditto different organization structure. As reported in Table 1, Staff levels are grouped as technical, support and administrative and executive staff members. Participants agree that generic learning modules for technical staff, regardless of their organization, should focus on (1) modelling techniques, innovations and technologies (2) methods of collaboration in IPDSs (3) web-based repositories and integrative process. In addition to these, network modelled organizations need a reflective model on Integrative lifecycle informatics (ILI), a phenomenon that teaches how lifecycle information is engineered and utilized. On the hand, organisations that operate in functional structure require additional module on methodologies for strategizing value integration in IPDSs. Divisional model organizations require additional training module integrative communication, teamwork and setting goal in IPDSs. In place of this, matrix model organizations require a module on understanding the drivers of success in IPDSs. These arrangements confirm some of the concepts that are reported by (Thomsen et al. 2010).

Analysis also indicates that administrative and support staff members do require some custom-made training to conform to BIM initiatives. Such include modules on internet-based and adaptive management, HR management in IPDSs and methodologies for packaging marketing strategies for IPDSs. Additional context that could be relevant include additional modules on BIM concepts, applications and innovations, and adaptive IPDS management for networked and functional model organizations respectively. Moreover, divisional and matrix model organizations require additional training model on articulation of value integration in IPDSs and integrative project goal setting respectively. Generic modules for Construction Business Executives (CBEs) include how to reconceptualise the drivers of decision making in IPDSs, managing integrative systems and econometrics of IPDS. Both functional and network model CBEs require additional focus on utilising BIM market research while divisional and matrix model organizations require reflective training on adaptive strategies for deploying BIM concept and motivation in IPDS respectively.

Available data suggests that the cost of training ranged from $50 to $6500 per participant, and were undertaken between 18 man-hours to 480 man-hours. Although, duration seems to be a major factor for managing training costs, however this is not as important as program packaging. Apart from training content, other exigencies could be involved which affect cost. 65% of the trainings were delivered through webminars and were arranged mostly by logistic and vendors of software applications. Average training costs for each participant are $2050 for technical, $1588.67 for administrative and $3245 for Executive staff members. Network structured organizations are cheaper to train. Analysis shows that the average costs are $650 for technical, $520 for administrative and $816 for Executive staff members. Divisional and functional are slightly more expensive with an average of 12.25% above training costs for networked organizations. Meanwhile, these costs are not static, they are likely to change from place to place and they depend on bargaining prowess of the organization.

Hardware

Hardware is yet another cost determinant in corporate implementation of BIM. Although, many organizations do have workable technological systems that may only require minor upgrading, data was collected to reflect actual technical requirements of components that can drive BIM applications effectively. Generally, most Office and dedicated management applications are run on Vista/XP/Windows 7, 160GB HDD, dual/quad/multi-core processors, 32-bit, OpenGL Graphic Card, 2 – 12GB RAM, 17 – 30’’ monitor and other accessories as deemed necessary by hardware consultants. As this can serve most administrative purposes, technical staff members may require higher hard drive capacity up to 320GB and RAM capacity up to 20GB and 64 bit systems. This could be the same of slightly lower for Executive staff members.

Software

There are several software applications for BIM. However, the most popular among this are Autodesk Revit, ArchiCAD, Vico and many others. The costs of these applications vary geographically and are dependent on product packages. Generally, technical officer do require BIM application(s), CAD applications/viewers, Office applications, project specific applications, databases and libraries. This could be slightly different for administrative and Executive staff members as they will only require BIM viewers, CAD viewers, Office applications, project-specific applications and libraries.

Recruitment, Services and Contingencies

Depending on nature of business and BIM deployment strategy, analysis reveals that organizations may need the services of Drafters, Interns, Modellers, BIM managers/co-ordinators, IPD managers, IPDS marketers, System managers, IPDS marketers and Director to oversee Integrated/contemporary marketing. As services, some cost factors will go for Internet, Power, Office accessories, Backups, storages, conveniences etc while contingency costs could include Consultancy, research, insurance

Regression model

Secondary data are retrieved from participants and internet sources. Variables are then sorted and regressed using Statistical Package for Social Sciences (SPSS) version 17. The outcome of the analysis is reported as equation 1. The model has strong explanatory powers and will predict the average cost of implementing BIM per participant. This can thereafter be discounted in relation to organization structure and nature of staff. This model has not been validated – it may generate different results under different circumstances. Notwithstanding, it can be used for budgetary purposes. It can be applied to implement both as short and long-term milestones.

$$\mathrm{T}_c = 0.000000000005882 + 0.480_{Tr} + 0.336_{Hd} + 0.689_{St} + 0.021_{Sv} + 0.031_{Rc} + 0.053_{Ct} \qquad \textbf{… Eqtn 1}$$

Where T_r stands for Training, H_d is Hardware, S_t is Software, S_v is Services, R_c is Recruitment and C_t is Contingencies

5 CONCLUSION

The popularity of BIM has improved in the past decade, such that it promises several radical benefits when it is fully implemented. Three proponents of thought regarding this have been presented in this study, and focus has been concentrated on dynamics of its corporate implementation. Four structure models of CBSs were explored to elicit the relationship between corporate settings and drivers of BIM deployment. As listed as Table 1 and Equation 1, results from focus group discussions and secondary data have been used to develop conceptual and regression models on the cost of BIM implementation. These results are indicative of the fact that different organizations will require different implementation strategies. As this mathematical model has not been validated, it is recommended that additional studies be carried to further strengthen this study. Specific case studies will be required to define other variables which are not explained in Equation 1 above. This will also become more relevant when specialized situations demand that BIM be deployed to meet peculiar project or business requirements.

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Table 1: Breakdown of agents of change in implementing BIM adoption in an organization

Model variables		***Network structure***	***Functional structure***	***Divisional structure***	***Matrix structure***
Training:	Technical staff members (project team professionals)	• BIM modelling techniques, innovations (gaming, simulation etc.) and technologies • Methodologies of collaborative behaviours in Integrated Project Delivery Systems (IPDSs) • Integrative processes : Advanced web-based repository			
		Integrative lifecycle informatics	Strategizing/ engineering value methodologies in IPDSs	Communication, teamwork and goal setting in IPDSs	Understanding drivers of success in IPDSs
BIM philosophy, applications and management	Management, Senior Administrative and Support Staff	• Internet-based and adaptive management • Managing human resource in IPDSs • Packaging flexible marketing strategies for IPDSs			
		BIM concepts, applications and innovations	Adaptive IPDS management	Articulating value integration in IPDS	Integrative project goals
	Executives (Directors etc.)	• Reconceptualising the drivers of decision making in IPDSs • Managing complex integrative systems • IPDS econometrics e.g. Rate of Returns, IPD and lifecycle budgeting, Development economics, cost of information and information modelling			
		Utilising BIM market research		Adaptive strategies for deploying BIM concepts	Motivating collaborative excellence in IPDSs
Hardware Meet, at least, the minimum requirement that can drive all necessary applications.	Technical staff members (project team professionals)	Most BIM software applications will be driven by Vista/XP/Windows 7, 320GB HDD, dual/quad/multi-core processors, 64-bit, OpenGL Graphic Card, 4 – 20GB RAM, 17 – 30’’ monitor and other accessories as deemed necessary by hardware consultants.			
	Management, Senior Administrative and Support Staff	Most Office and dedicated management applications are run on Vista/XP/Windows 7, 160GB HDD, dual/quad/multi-core processors, 32-bit, OpenGL Graphic Card, 2 – 12GB RAM, 17 – 30’’ monitor and other accessories as deemed necessary by hardware consultants.			
	Executives (Directors etc.)	Most BIM software and project specific applications will be driven by Vista/XP/Windows 7, 250GB HDD, dual/quad/multi-core processors, 64-bit, OpenGL Graphic Card, 4 – 20GB RAM, 17 – 30’’ monitor and other accessories as deemed necessary by hardware consultants.			
Software There are many options to pick from. The bottom line is ease of use and technical support	Technical staff members (project team professionals)	BIM applications, CAD applications, Office applications, project specific applications, databases and libraries.			
	Management, Senior Administrative and Support Staff	BIM viewers, CAD viewers, Office applications, project-specific applications.			
	Executives (Directors etc)	BIM application/viewers, CAD viewers, Office applications, project-specific applications, databases and libraries.			
Recruitment	Technical staff members (project team professionals)	Drafters, Interns, Modellers, BIM managers/coordinators, IPD managers, IPDS marketers, System managers			
	Management, Senior Administrative and Support Staff	IPDS marketers.			
	Executives (Directors etc)	Director of Integrated/contemporary marketing			
Services		Internet, Power, Office accessories, Backups, storages, conveniences etc			
Contingences		Consultancy, research, insurance			