THE IMPACT OF IMPLEMENTING BIM ON AEC ORGANISATIONAL WORKFLOWS

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Abstract
The seemingly elusive pursuit of completing projects predictably, within the constraints of cost, time and quality requires the aggregation of information and integration of various project team member work processes. BIM has been put forward as a possible approach for achieving this aim, albeit with attendant challenges, prominent among these is the need for streamlining intra-organisational workflows. This study therefore sought to develop and understanding of how implementing BIM impacts organisational workflows with a view to enabling professionals make more informed decisions about adoption and implementation of BIM. Semi-structured qualitative interviews were conducted with three consultancy companies in Johannesburg, South Africa. Data in form of transcriptions and notes were descriptively coded in two cycles, and analysed thematically. This study found that resistance to change and high set-up and training costs are key impediments to the successful implementation of BIM. Furthermore, there were experiences of a loss of productivity during training and the development of standards, disconnects between project team members collaborating at lower of higher maturity compared to others, change in the sequence of project team activities, and the creation of new roles, such as a BIM coordinator/manager to facilitate the adoption and development of organisation specific standards and documents. These challenges can lead to varying patterns of adoption and implementation and consequently, a lack of interoperability of inter-organisational business processes. The findings are instructive on the need for unified industry strategy to facilitate the diffusion of BIM in the South African construction industry as in countries like the UK.

Keywords: BIM, Collaboration, Delivery, Maturity, Workflows

1 Introduction

The nature of the Architecture Engineering and Construction (AEC) industry is such that constant interaction through communication and sharing of information between various professionals is essential for successful delivery of projects (Crotty, 2012). Project delivery involves complex processes that require extensive collaboration for efficient management, amid global industry challenges to completing projects predictably, within the constraints of cost, time, and quality (Crotty, 2012; Fang and Marle, 2013). Further, as a result of the separation of design and construction functions, and the continued specialisation of construction industry practices into more specific fields of operation, the industry has grappled with its fragmented nature and project delivery processes (Nawi *et al.*, 2013). This is coupled with severe difficulties in aggregating construction information dispersed among project stakeholders (Latham, 1994; Egan, 1998; Nawi *et al.*, 2013). Consequences of these are sub-optimal levels of project performance. In the United States, evidence show that these challenges contribute to about 15.8 billion dollars yearly losses through inefficiencies (Gallaher *et al.*, 2004).

As solutions to these challenges, the integration of multiple stakeholder work processes, and a shift from traditional competitive delivery methods towards integrated design and construction methodologies have long been advocated (Latham, 1994; Egan, 1998). Importantly, the use of integrative and collaborative technologies have been argued, and shown to be capable of providing the impetus for the required change (Howard *et al.* 1989). Building Information Modelling (BIM) is one such 'technology'. A process of developing digital representations of construction components elements to simulate planning, design, construction, operation and maintenance of structures, BIM when implemented enables the rendering of several views of data about a structure in 2D (Simple CAD), 3D (Visualisation), 4D (Schedule), 5D (Cost), and 6D (Operations and Maintenance) in an aggregated model, and collaborative environment (Deutsch, 2011). Notwithstanding that Building Information Modelling authoring tools have been in existence since the late 20th century, clients and project teams have only recently become conscious of its benefits in delivering projects (Linderoth, 2010). Implementing BIM has been shown in practice to facilitate increased efficiency (Deutsch, 2011) increased productivity of professional organisations (Crotty, 2012) while also improving communication and collaboration (Wong et al, 2011). Without doubt, the associated benefits are the main drivers of its adoption and implementation within the construction industry (Cao, 2015).

However, there are several barriers to successful implementation of BIM in the construction industry (Migilinskas, 2013; Arayici *et al.*, 2011). These include *inter alia*, the need for changing procurement culture (Rowlinson *et al.*, 2010), need for changing or adapting intra- and inter-organisational work practices and workflows (Porwal and Hewage, 2013; Bryde *et al.*, 2013), lack of clarity of stakeholder roles and responsibilities on BIM projects and varying degrees of experiential knowledge of BIM among project teams (Porwal and Hewage, 2013). This implies that organisation and project team work practices need to be aligned to BIM requirements to achieve success. Nonetheless, evidence from literature shows reluctance towards shifting from traditional work methods to adopting innovative approaches to project delivery among industry professionals (Arayici *et al.*, 2012). This may be attributable to deficient understanding of BIM adoption and implementation implications. A lack of knowledge about how implementation enables, and on the other hand, constrains organisational work practices may hinder wider adoption, and its successful implementation on projects. This study therefore seeks to develop an understanding of how professional service providers in the South African construction industry have implemented BIM within their organisations, and of how the implementation enables or constrains organisational workflows. This will enable implementers to make more informed decisions about how to implement BIM to realise the benefits accruable from its implementation.

2 Literature Review

Succar (2009) however, describes BIM as a set of processes, technologies and policies that work together to produce a methodology for digitally managing project information through the whole life cycle. Furthermore, Sebastian (2011) argues that collaboration between project stakeholders is the main premise on which BIM relies. Therefore, the key ideas that cut across these definitions are information aggregation, integration and collaboration among project stakeholders through the use of appropriate technology. This is at the core of the appeal of BIM to the construction industry. Nevertheless, it is important to note that BIM's potential for enabling more efficient project delivery processes is a major driving force behind the growth in implementation, and indeed government demand, as in the United Kingdom (Cao, 2015). As Barlish and Sullivan (2012) put it, clients are willing to utilise BIM once they understand its capabilities and benefits. The benefits include improved efficiency, communication and collaboration, increase in productivity, reduced project cost, time and rework (Migilinskas, 2013; Wong *et al.*, 2011; Cao, 2015). It is therefore evident that BIM implementation can positively contribute to project success and overall industry performance.

However, implementing BIM does not lead to guaranteed project success. Its implementation comes with attendant risks and challenges as is common with similar innovations. In fact, at the initial stages of adoption and implementation within organisations, it is likely to cause conflicts in the status quo, and temporarily reducing performance. The resolution of these challenges brings about transformation into a new status quo. This is depicted in Satir's model of change in Figure 1 below (Cameron and Green, 2012).

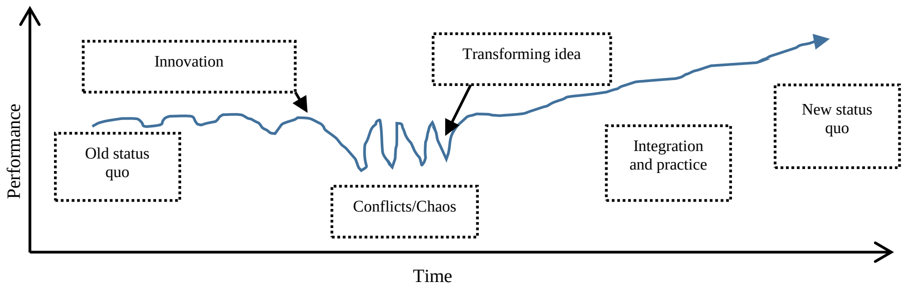

Figure 1. Satir's model of change (adapted from Cameron and Green, 2012)

To elucidate on this, the following section highlights evidence in literature, of challenges to successfully implementing BIM.

2.1 Challenges to successful implementation

Khosrowshahi *et al*. (2012) in consonance with the views of Linderoth (2010), posit that the slow adoption of BIM by organisations can be attributed to a lack of preparedness to make the required changes necessary for implementing BIM, combined with the misunderstanding of their roles and responsibilities on such projects. In a case study of a Swedish company, Linderoth (2010) found that the diffusion of BIM would depend on how well it fits in with user roles, responsibilities and competencies. Yet, the levels of BIM use across organisations and professionals vary greatly (Eadie *et al.*, 2015: Khosrowshahi *et al.*, 2014). Other challenges are fear of changing roles, responsibilities and work practices (Elmualim and Gilder, 2014). Kiprotich *et al.* (2014) in a South African study found that the BIM use in South Africa is largely isolated, and only to the extent of simple 3D modelling (visualisation) applications. A summary of BIM implementation challenges is show in Table 1 below.

2.2 Benchmarking BIM implementation capability and maturity

There have been a few attempts at benchmarking levels of collaborative working with BIM. Taylor and Bernstein (2009) employed a 4-level categorisation of BIM use into visualisation, coordination, analysis, and supply chain integration while Succar *et al.* (2012) developed five stages of BIM implementation maturity (initial, defined, managed, integrated and optimised).

Table 1. Challenges militating against successful implementation of BIM

Challenges militating against successful implementation of BIM	**Singh, *et al.*, (2011)**	**Lawrence *et al.*, (2012)**	**Porwal and Hewage (2013)**	**Dossick and Neff (2010)**	**Elmualim and Gilder (2014)**	**Rowlinson *et al.*, (2010)**	**Khosrowshahi and Arayici (2012)**	**Owen *et al.* (2010)**	**Rekola *et al.* (2010)**	**Gu and London (2010)**	**Becerik-Gerber and Kensek (2010)**
Industry's reluctance to change existing work practices/workflows	**x**		**x**		**x**		**x**			**x**	
Need for changing or adapting intra and inter organisational workflows/work practices			**x**	**x**	**x**			**x**	**x**	**x**	
Lack of clarity of stakeholder roles and responsibilities on BIM projects	**x**	**x**			**x**				**x**	**x**	
Need to train staff on new technology					**x**		**x**		**x**		**x**
Need to establish new process or workflows for delivery of projects					**x**			**x**	**x**	**x**	
Varied readiness to implement BIM across stakeholders	**x**		**x**							**x**	
Varying degrees of experiential knowledge and understanding within project teams							**x**		**x**	**x**	
Difficulty in maintaining completeness, quality and consistency of shared models					**x**				**x**		
Cultural barriers towards adopting new technology/cultural division within teams				**x**							**x**
Undefined fee structures						**x**					**x**
Difficulty in measuring costs/benefits of BIM implementation		**x**	**x**								
Software interoperability and data exchange issues									**x**		**x**
Lack of understanding of BIM capabilities, challenges		**x**									
Need for change in procurement culture						**x**					
Reluctance towards adoption due to time required to produce and maintain complete models							**x**				
Lack of understanding of other team members' workflows on BIM projects									**x**		
Ineffective collaboration among team members (modelling and model utilisation)											**x**
Need for investment in new IT infrastructure											**x**
Insufficient legal framework											**x**
Competition and lack of common interests among BIM authoring tool vendors											**x**

Nonetheless, in order to facilitate the achievement of the UK government's mandate that BIM be used at maturity level 2 for all public projects by 2016, the British Standards Institute (BSI) has developed the PAS 1192:2013 specification. It describes the levels of collaborating with BIM (BML) in generic terms as:

- BML-0: Unmanaged CAD with the use of 2 dimensional (2D)
- BML-1: Requires collaboration tool to provide a common data environment and established standard data formats. Cost data to be managed by standalone packages with no integration.
- BML-2: Collaborative environment to be of 3D form, held in separate discipline BIM authoring tools with attached data managed by Enterprise Resource Planning (ERP) Approach may also utilise 4D and 5D capabilities.

- BML-3: Fully open processes and data integration enabled by web-services. Compliance with relevant data exchange standards, managed by a collaborative model server.

2.3 Review synthesis

Building Information Modelling (BIM) is potentially useful for improving AEC industry performance. However, several associated risks and challenges need to be identified and mitigated. Consequently, successful implementation is not guaranteed. Therefore, it can be surmised from literature reviewed, that informed adoption and implementation decisions for AEC organisations in South Africa requires an understanding of its implications on their organisations workflow. This is the central focus of this study. The theoretical underpinnings of this study are in activity theory (understanding changing patterns of human activity on impact by technology) and role theory.

3 Research Methodology

3.1 Philosophical assumptions

This research is informed by subjectivist philosophical assumptions, where social phenomena are seen as being created from the perceptions of social actors and with a focus on individual meanings (Saunders, 2012; Creswell, 2013). The focus of this study is on developing an understanding of the experiences of professional service providers in implementing BIM within their organisations. A subjectivist ontological position is well suited to achieving this in that it emphasises conduction of research among people rather than about objects (Saunders, 2012). In consonance with this philosophical leaning, and with literature on studies with similar foci with this study, an interpretivist epistemology, albeit with a largely deductive approach to reasoning, is appropriate as is supports methods of knowledge gathering in participants' natural settings (Saunders *et al.*, 2012; Creswell, 2013). This is to facilitate an understanding of their experiences from their own point of view.

3.2 Research methods

Following from the philosophical choices made, this study is designed after the qualitative research tradition. This is suitable for exploring a problem in-depth (Creswell, 2013). Further, current research in the domain is mainly qualitative in nature. Gu and London (2010) employed focus group interviews (grounded theory strategy); Balish and Sulivan (2012) used cases studies, while Linderoth (2010) used semi-structured interviews with participant observational methods.

3.2.1 Data collection method and participant selection

Conversations are one of the best ways of obtaining systematic and in-depth knowledge (Kvale, 2008). Therefore, one-on-one semi-structured interviews, with professionals representing selected organisations, were considered the best way to collect data. In order to focus on unique case contexts, a heterogeneous purposive sampling technique was employed with snowballing (field referrals) to select participants for the study. Further, participants for this research were selected from consulting professional service providers in South Africa. This comprises Architectural, Quantity Surveying, and Engineering organisations. The selection criterion was mainly evidence of adoption and implementation BIM within the organisation. 3 interviews (2 Architectural and 1 Quantity Surveying organisation) were conducted, analysed and presented in the following sections. Notes and audio recordings were taken during the interview sessions to ensure all information is captured. The audio recordings were also transcribed (verbatim), while handwritten notes and researchers preliminary reflections from the interview were summarised into analytic memos, one per interview (Miles *et al.*, 2014).

3.2.2 Method of data analysis

Data in form of notes and transcripts from the interviews were analysed thematically. Thematic analysis followed a two-step procedure. Texts were coded using broad descriptive codes (Miles *et al.*, 2014). First, notes and transcripts were read while also highlighting relevant portions of the material, and assigning descriptive words of phrases (pre-defined or developed as analysis progresses) to the highlighted chunks of textual data and refining same as analysis progresses. Second, codes were developed into key themes for each highlighted text (groupings or more finely coded) while considering interpretive themes from theoretical or practical positions of the study (Miles *et al.*, 2014).

4 Preliminary Findings and Discussion

4.1 Data Analysis and Findings

Table 2 describes the contexts of each organisation that participated in this study as the context is important to understand when analysing the data.

Table 2. Participant organisation contexts and implementation strategies

Case 1 (Company A)	Case 2 (Company B)	Case 3 (Company C)
Context		
• Medium sized **Architectural firm** (staff is about 60nr) • Based in, Johannesburg • Established in 1945 • Projects are based in South Africa and internationally	• International **Quantity surveying firm** (head office in the UK). • The Johannesburg office is one of 90 branches. • Established first international branch in 1982 • Projects are based in South Africa and internationally	• Medium sized **Architectural firm** of about 200 employees • Based in Johannesburg with a branch office in Nigeria. • Projects are based in South Africa and internationally
Implementation strategies		
• Motivation for implementing BIM: improvement of job delivery workflows efficiency, competitive advantage, keeping up with evolving industry trends. • Implicit policy to implement BIM on all projects. • Each person in the organisation has access to the BIM authoring software and training • New computers and software licenses were purchased to facilitate adoption of BIM. • Formal implementation plan was drafted for training and implementing standards • BIM manager was hired to facilitate transitioning to BIM.	• Motivation for implementing BIM: improvement of job delivery workflows efficiency • They have not implemented BIM in South Africa as part of a project team, but they have in the UK • Their staff have had training on how to use BIM authoring software • Organisation has achieved a capability for BIM level 1 here in South Africa but operating at a Maturity level between 0 & 1.	• Motivation for implementing BIM: competitive advantage, keeping up with evolving industry trends. • In-house expert to coordinate BIM implementation and use internally (documentation management). • Staff have had access to the BIM authoring software and had training • The firm has achieved implementation Maturity level 1. • Formal implementation plan for achieving BIM maturity level 2 has been drafted). • Willing to start working towards BIM maturity level 3

Case 1 (Company A)	Case 2 (Company B)	Case 3 (Company C)
• Achieved a capability for BIM level 2 but presently operating at maturity level		

Cases *1*, *2* and *3* (shown in Table 2) represent experiences of BIM implementation from three organisations that are some of the most prominent professional practices in South Africa and will therefore be treated as key informants. It should be noted that since *Company B* (Quantity Surveying) have only implemented BIM as part of a project team in the UK. However, the staff have undergone training to acquire the capability to participate in BIM projects in South Africa, at least to BIM level 1. This is not farfetched as the diffusion of BIM naturally starts with lead design firms long before other allied professional organisation. Furthermore, while *Companies A & C* have only been operating at BIM level 1, interestingly, the momentum for level 2 BIM implementation (information sharing & coordination) has begun already (BSI, 2013). This is a significant development from Kiprotich *et al.* (2014)'s report of only isolated use of 3D modelling and visualisation applications of BIM in South Africa. Yet, these efforts are limited to intra-organisational drive for collaborative practices. Expectedly, as in the works of Wong *et al.*, (2011) and Cao (2015), the main motivation for implementing BIM for all the companies are the associated benefits (see Table 3).

Table 3. Experiences of benefits from Implementation BIM

Case 1 (Company A)	Case 2 (Company B)	Case 3 (Company C)
• Problem solving • Improved design workflows • Implementation of BIM being worthwhile • Design clash detection • Time and cost savings • Improved communication, collaboration and integration within the organisation and with allied professionals • Increased productivity and efficiency • Capability for executing larger projects	• Cost savings • Time savings • Design clash detection • Quick resolution of conflicts • Improved accuracy • Competitive advantage • Increased delivery speed • Increased productivity and efficiency	• Increased demand for firm's service • Increased efficiency • Able to execute projects quicker and better • Design and construction risks are detected earlier • More work done at lower cost compared to competitors • More work is done earlier in the delivery process. • Improved collaboration among teams • Design clash detection • Increased Productivity • Increased project turnover

There are several commonalities in the experiences of the three organisations regarding the benefits from BIM implementation. These experiences are similar to the findings in existing literature (Wong *et al.*, 2011; Cao, 2015). BIM is perceived as being able to assist in problem solving, improving efficiency and increasing overall productivity. While all three organisations attest to increase in productivity, Company C further links this to increased turnover.

Table 4. Challenges to Implementing BIM

Case 1 (Company A)	Case 2 (Company B)	Case 3 (Company C)
• Mind-set shift • Resistance to change • Time consuming training • High software and update costs • Disconnect between consultants: where other consultants don't implement BIM, interoperability becomes an issue • More efforts required to develop good quality • Presentations when compared to traditional CAD	• Resistance to change • 'BIM is all about technicalities' • Huge training requirements • High cost of BIM authoring software • 'BIM is mainly economically viable for large scale projects' • No BIM specialist in company's SA office • Technological advancements reduces relevance of experiential knowledge • Implementation is being driven mainly by BIM champions from large practices	• Time consuming training • High software and update costs • Disconnect between consultants (lack of interoperability) Project team members' silo mentality' • Need for allied professionals to start evolving their design skill

Companies A & C report very similar experiences of challenges to implementing BIM (see Table 4). Importantly, resistance to change within their organisations and disconnect with other professionals (lack of interoperability of organisational business practices) are key challenges identified. These are two of the most prominent challenges to implementing BIM and can be deterrents to increased adoption and implementation within the construction industry. Collaboration through BIM is only as effective as the weakest link in the project team makes it. Further, down times experienced when learning to apply new technology impacts negatively on productivity (Cases 1&3). Company B's report is from a different perspective as Quantity surveyors, the participant mentioned that the lack of a BIM expert to facilitate implementation is a challenge. These suggest, however inconclusively, that experiences of challenges vary by organisation type. Nevertheless, for all three cases a common thread of evidence was that of declining productivity as a result of a substantial amount of training that is required to facilitate BIM implementation.

Table 5. Impacts of BIM on organisational workflows

CASE 1	CASE 2	CASE 3
• Downtimes while training and developing new organisational workflows to implement BIM • More efficient design workflows • Better integration of team design processes. • Increased productivity and efficiency • Increased capability for executing larger projects • Creation of new roles (BIM coordinator or BIM manager)	• Improved efficiency and performance • Increased productivity and efficiency	• Downtimes while training and developing new organisational workflows to implement BIM • More is done earlier in the delivery process • More time and resources are spent on the design phase, i.e. model development phase. • Increased productivity and efficiency • Creation of BIM coordinator/manager roles • Design and construction risks are detected earlier

Participants have had both positive and negative experiences of BIM impacts on organisational workflows (see Table 5). One impact of BIM that is rarely reported in literature is experiences of downtimes while training or developing new organisational workflows to implement BIM. Misunderstanding this may mean that organisations that are unable to overcome these challenge have to roll back on the implementation. Perhaps more importantly, Company C emphasised the temporal shift in effort for design and construction activities. This implies that more work is done earlier in the delivery process when the cost impacts of change in employer requirements are minimal effects on dependent activities. Furthermore, the findings suggest that creation of a new role for BIM facilitation and coordination within firms is critical to the success of the implementation as in Porwal and Hewage (2013) and Sebastian (2011).

5 Conclusion and Further Research

This study sought to develop an understanding of how implementing BIM impacts the workflows of construction professional service providers in South Africa. This is on-going research. Nonetheless, thus far, the findings have far reaching implications. These impacts are structural and social in nature. Expectedly, the three cases presented associate several benefits with implementing BIM. Likewise there are experiences of many challenges that impinge on professional practice. The reports varied slightly due to the differences in level of capability and BIM maturity level within the organisations. Further, the requirement for in-house BIM facilitators or managers, expansion of professional responsibility, temporal shift in design and construction activities, and the need for new or restructured project documentation are enlightening. The results also reveal that BIM is being led mainly by design firms who employ in-house BIM experts to develop and maintain organisation specific standards and guidelines. This can lead to varying patterns of adoption and implementation and consequently, lack of interoperability of inter-organisational business processes. These findings suggest a need for unified industry strategy to facilitate the diffusion of BIM in the South African construction industry as in countries like the UK. This strategy may be driven by government or the private sector since it is clear that clients are the main drivers for BIM implementation, while also being the biggest beneficiaries of BIM benefits (e.g. aggregating and managing asset information). However, while there are competing arguments for or against either, the private sector, through entities like the South African Property Owners Association (SAPOA), which claims control of about 90 per cent of all commercial and industrial property in South Africa, are perhaps better positioned to drive a unified industry strategy for implementing BIM due to the sector's dynamic nature. This is an on-going debate. Future work will seek to expand on these ideas and document more experiences of BIM implementation in South Africa so as to increase the credibility of the research findings.

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