MAKING THE LINK BETWEEN BIM'S BENEFITS AND IMPLEMENTATION

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Despite the attention paid to measuring the perceived benefits of Building Information Modelling (BIM) increasing its adoption throughout the construction industry, important links between implementation, support and benefits have received little focus. This paper explores how the conditions of implementation define the benefits of BIM adoption. The findings from two case studies implementing and using BIM are presented and compared. The first is a large urban regeneration project and the second is a healthcare project. A well-recognised model of system success was mobilised from the field of information systems (IS) to reveal that irrespective of project size and type, without sufficient support that addresses business process reengineering implementation is focussed on technology and technical process. Focus is on the disconnections between organisational level BIM implementation and project level BIM implementation. An incendiary issue for both cases was BIM awareness amongst project participants and stakeholders, however, the effect of this on implementation success varies within each case study. In using the DeLone and McLean Model to systematically examine the system at a point of reconfiguration, benefits are captured relative to the implementation approach. This study highlights the significance of these interdependencies and argues for a more comprehensive approach to BIM benefits capture that recognises this to usefully inform implementation strategy development.

Keywords: BIM, implementation, benefits, assessment

INTRODUCTION

A building information model is the digital representation of a built asset and its components ‘in a virtual assembly of interconnected database objects and associated metadata in a coordinated, scaled 3D model’ (Davies and Harty 2013b). Intuitively, this implies the application of various technologies to fulfil the elements of this definition and central to it is the use of 3D modelling software.

However, if the definition of the term BIM has or is to have a contributory effect on its adoption and implementation it should reflect the anticipated shift toward an information centric approach to design, construction and operation that includes both process automation and improvement (Dowsett and Harty 2014). Davies and Harty (2013b) comprehensively define BIM as ‘the process of users designing buildings, individually or in collaboration, using a variety of ICT tools (3D CAD, databases, interfaces) and associated business processes to represent and manage information in the model’. This also captures the synonymy of BIM and collaboration and implies that a fundamental implication for a number of, if not all, stakeholders is some level of business process

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Dowsett, R and Harty, C (2016) Making the Link between BIM's Benefits and Implementation. *In*: P W Chan and C J Neilson (Eds.) *Proceedings of the 32nd Annual ARCOM Conference,* 5-7 September 2016, Manchester, UK, Association of Researchers in Construction Management, Vol 1, 35-44.

reengineering will be required to use BIM as a collaborative mechanism (Morlhon *et al*., 2014; Ashcraft 2014)

A large number of studies attempt to measure the benefits surrounding the implementation of BIM methodologies and processes but the predominant focus of these studies is on financial metrics that put a focus on the business case for the implementation of BIM (Barlish and Sullivan 2012; Becerik-Gerber and Rice 2010; Giel *et al*., 2010). However, a critical necessity of management practice is to balance short-term and long-term organisational capabilities to adapt and evolve with regard to competition and industry requirements and it is well understood within the BIM implementation literature that BIM requires more than simply technology adoption (Howard and Björk 2008). Yet there exists no formal repeatable measurement framework that delivers iterative and transformative results for process improvement or promotes the process-oriented understanding of BIM and the extent of change necessary to achieve it.

Within this study BIM implementation has been conceptualised according to two assumptions drawn from the literature; firstly, that BIM is congruent with the definition of an information system consisting of technologies, people, and processes (Jung and Gibson 1999; Jung and Joo 2011), and secondly, that the implementation of information systems is the process of reconfiguring a complex set of technologies, actors and activities within existing systems comprised of various existing organisational, cultural and social characteristics (Harty 2008; Poirier *et al*., 2014; Taylor 2007). This is particularly important in the assessment of implementation success when considering that many implementation initiatives are a process of 'learning on the job' in which innovations are shaped and dictated by these existing system characteristics (Barrett and Sexton 2006). In light of this, the failure to successfully implement BIM is most commonly a consequence of insufficient focus on the organisational and social aspects of implementation (Erdogan *et al*., 2008).

METHOD

Employed from the field of information systems the DeLone and McLean IS Success Model is used within the context of this research as a framework to comprehensively capture the positive and negative effects of BIM use on projects and how these have been affected by its implementation. The model has been applied, tested, reviewed and adjusted a number of times within a variety of IS contexts in response to both its utility as an assessment framework and at the request of the authors who encourage its modification to suit the context of use (DeLone and McLean 1992; Seddon 1997; Halonen 2011; Petter *et al*., 2008).

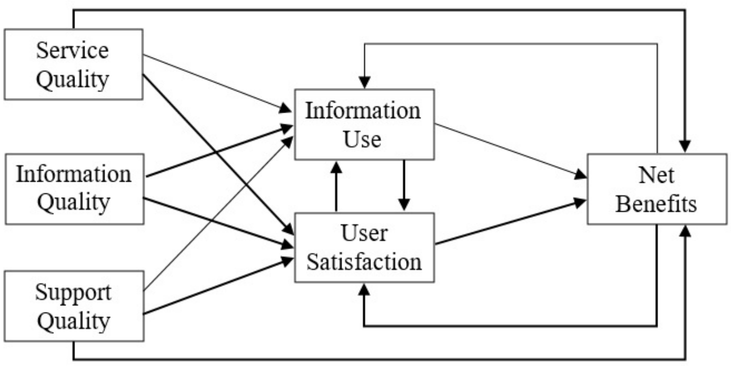

Figure 1: DeLone & McLean Model (Adapted)

An important factor to consider in using the model was how to translate the constructs into operational terms. For both case studies a series of semi-structured interview questions were developed to investigate each of the six quality constructs of the DeLone and McLean model made specific to BIM through a critical review of the literature. A conceptualisation fundamental to this study is that the implementation of BIM is the reconfiguration of technologies, activities and actors, therefore both the constructs and questions investigating them were designed to reflect this.

For the purposes of this study, Intention to Use and Use constructs were integrated into Information Use to reflect the information-centric principles of BIM and the disparate uses of this information by each stakeholder. In addition, Service Quality was replaced with Support Quality to reflect the effect of organisational and cultural context on the success of the system.

The design of the interview schedule enabled a systematic investigation of the constitutive elements of implementation and their quality into an observable system.

Questions regarding System Quality referred to the technical quality of the BIM system (e.g. efficiency and functionality); Information Quality referred to system outputs (e.g. relevance and informativeness); Support Quality referred to system support (e.g. adequate training and protocol effectiveness); Information Use referred to task based activities (e.g. nature and appropriateness of use); User Satisfaction referred to the attitude of the user (e.g. enjoyment and decision-making satisfaction); and Net Benefits referred to improvements in individual and organisational capabilities (e.g. overall productivity, cost/time savings).

Interviews ranging from 60-90 minutes in length were conducted with design team members and project leads to investigate project performance in relation to implementation of BIM on each. Interviewees in Case Study 1 consisted of the core design team interfacing with a specific design component: CLT contractors, MEP engineers, BIM Manager, Design Development Manager, and the BIM Consultant. The decision to focus on one design component was made because the case forms part of a larger study in which this project was used as a pilot to test the suitability of model and the methodology employed. Interviewees in Case Study 2 consisted of the core design team consisting of Architects, Interior Designers, Structures, and MEP disciplines.

The case studies examine BIM implementation at project level using the DeLone and McLean model to systematically construct a narrative of implementation and to investigate the interdependencies between its constitutive elements and accounts of net benefits. The analysis process resulted in three interconnected components. Firstly, a narrative of the cases providing an in-depth account of the implementation process and its impact on project success, secondly, the categorisation of the empirical data into the six constructs of the DeLone and McLean IS Success Model to provide a thematic map of the constituent parts of implementation, and thirdly, using the narrative interdependencies between each construct were then established to capture the relation between the conditions of implementation and project success.

FINDINGS

The findings presented are an overview of the context of implementation for each case study and its effect on the benefits experienced on the projects. To illustrate the potential of the DeLone and McLean IS Success as a means to systematically link the more process-orientated conceptions of BIM implementation to the particularities of the empirical data the findings focus on the most significant benefits of system use. This is also to illustrate the repeatability of the model in future studies to address the limitations of previous cost/benefit analysis methods that cannot capture context specific implementation issues.

Case Study 1 Project description

The first case study presented is a large urban regeneration scheme in the first-phase of a five-phase programme providing residential units, retail and business space, community, culture and leisure space, an energy centre, a park and public realm. The project is also utilising cross-laminated timber (CLT) as a structural design feature. The design team consists of interorganisational disciplines.

The client/contractor aspires to implement BIM through to FM with the original bid for BIM developed by project leads to secure external BIM consultant for the project who was appointed during the detailed design stage after design team appointments ad been made. Their first task involved conducting a number of workshops to determine client BIM objectives and aspirations and their requirements for BIM methods, workflow and deliverables though the stage at which BIM was adopted meant that the majority of these aspirations were not met or intended to be met in this phase of the project.

The consultant was responsible for developing the BIM Execution Plan (BEP), and to set up BIM protocols, standards, and model audit cycle requirements. The documents are located within the document management system (DMS) and are available to all project participants. Given the size of the project and the level of capabilities that are aspired to these documents are in constant development with input from design team members, primarily the BIM managers (whose experience varies considerably) within each discipline.

Their specific role within the project is BIM Coordinator, which involves federating the models received by the design team for the purposes of clash detection and coordination within Navisworks Manage. This also involved configuring a series of predefined Saved Viewpoints for levels, grids, risers, lifts and stairs within each building to define search sets in each building for clash tests. Some 3D views of design issues are saved and 'redlined' for project team review.

In comparison to Case Study 2 there is no company-wide BIM implementation programme for project-level system configurators to refer to for existing protocols.

Case Study 1 Findings

According to the interviewees the most valuable contribution to the effective use of BIM on this project relates to the efforts made by the BIM Consultant to develop protocols that support the ongoing development of the model.

The model audit cycle stipulated within the BEP supports the standard and timely production of a 3D federated model that facilitates, early clash detection, easier interpretation of design intent and a faster design review. One interviewee described the model audit cycle and federation process developed and supported by the BIM consultants as:

> 1….one of the better led parts of the design process because it's been formalised and it's structured and every two weeks everyone re-issues and there's process and a protocol…

However, despite the appointment of the BIM Consultant having had a positive impact on the use of BIM within this project there are still fairly obvious constraints at a managerial level that have prevented the effective use of BIM for design activities. Much of which originates from a fairly vague brief that has considerably limited the extent of change the BIM Consultant could make:

> 2.…their brief to us was very vague, more or less, 3D, 4D, 5D, 6D would be a requirement but not essential, like a stepping stone, growing capabilities on this project to improve the next phase etc.

In effect, the implementation of BIM has involved overlaying a BIM methodology onto a traditional design programme so whilst there are improved capabilities in terms of task automation and more information of a better quality this is constrained by programmatic misalignment that prevents information exchanges at the most appropriate times. For example, early design issue identification was a commonly cited benefit of working within a BIM environment that occurred as a result of both the functionality of the technology but also the support provided by the BIM consultant to federate and manage models received according to the two-week model submission defined within the BEP. Yet by not clearly defining the information exchange process to reflect the front-loaded BIM process understood within the literature issues can be identified that may not necessarily be of critical importance. In which case, early design issue identification is by-product of a 3D environment rather than an intended process and there have been negative consequences. This had a direct impact on the amount of additional work the team members had to conduct in order to meet the constantly changing requirements and in some cases resulted in delays in package completion and was a particular issue for the CLT Consultants whose design progress is heavily reliant on the early receipt of information for prefabrication:

> 3.…the benefits of BIM have not been fully realised since the coordination and clash detection processes are…happening later in the 3D process than would be useful for our design development…

More importantly, the amount of work varies depending on the discipline, their roles and responsibilities, which is something that did not appear to be considered either in contractual terms or appointments prior to the start of the project. To mean that, disciplines were appointed without existing technical capabilities and ultimately held the rest of the team up such as MEP, and other disciplines were being asked to produce information beyond their contractual obligations. In effect, without a clear understanding of strategic intent varying degrees of change toward a BIM methodology happened within the project depending on team member technical capabilities and innovative cultural traits. For example, quite late on the MEP team appointed a BIM Manager whose primary task was to manage the model rather than assist in the development of new processes; in contrast the CLT Contractors developed new workflows liaising far more with the project BIM Consultant to ensure compliance with project requirements and to improve existing practices for future work.

BIM as a method of working was implemented on the project after the design team had been appointed so there would inevitably be a learning curve for each discipline to varying degrees and a regularly occurring and potentially incendiary issue evident throughout the interview data was that there was no consensus of understanding of the plan to adopt BIM. Uncertain BIM deliverables and no clearly stipulated client information requirements makes it difficult for each discipline to strategise their approach to information delivery making the duration of the BIM-enabled design programme difficult to define so whilst there maybe improvements to design solutions. When these issues are presented within the DeLone and McLean model the importance of the effect of these antecedent conditions on the system, and consequently project performance becomes available to system configurators in a comprehensible format to understand how and why the project performed the way it did, as shown in Figure 2.

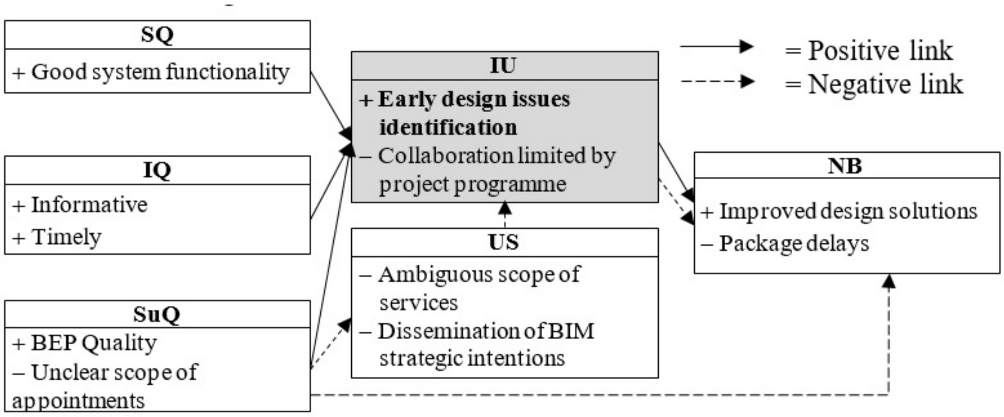

Figure 2: Case Study 1 Information use case - early design issue identification

In effect the project has followed a techno-centric approach to BIM implementation in which capabilities have improved but are limited in their scope by the constraints of a traditional design programme.

Case Study 2 Project description

The second case study is a hospital refurbishment project expanding the emergency department within an existing hospital to improve clinical effectiveness and reduce patient waiting times. The design team consists of intraorganisational disciplines. The organisation has a company-wide BIM implementation programme with a dedicated BIM Group that develops protocols and processes for project-level dissemination.

BIM was driven by the architects for two principle reasons: firstly, within healthcare projects it is difficult to get clinicians to understand 3D space using 2D drawings, and secondly, to improve the process of equipment specification. The architectural team developed a BIM Strategy Plan for the project that sets out the objectives and goals for BIM use on this project based on a template made by the BIM Group. However this is limited in its extent because client expectations for BIM were not apparent therefore, the aspirational BIM use for the project is to Level 2 BIM for the design team only adopting only the collaborative principles of Level 2 BIM: 'Full delivery of Level 2 BIM information is not intended.'

The key initiatives in place to fulfil this are the consistent use of modelling software by all design team members to produce a model every two-weeks for federation and to also use dRofus as an information management tool for the ongoing development of room data sheets and equipment quantification.

Case Study 2 Findings

The primary benefits of using BIM identified within this project relate to the discrete technical aspects of the system, such as automation of manual processes and improved understanding of design intent related to the functionality of the technology employed.

However, satisfaction with system implementation varies among the interviewees depending on their role and task responsibility. For example, architects and structures benefit from the visualisation aspects of using the technology for the purposes of design interpretation, which contributes to design quality but they are not benefitting from early receipt of information from the MEP engineers. MEP engineers have benefitted from minor productivity improvements from using the technology where it is most appropriate but these do not make a significant impact to their design process. They are frustrated that BIM has been implemented without sufficient consideration of their own design process in that the coordination of information can only happen if the information is there in the first instance, which is a process problem not a technological problem and related to requirements elicitation and the development of an information exchange process that supports this. Essentially, the implementation of BIM has only extended as far as the application of technology and the benefits of doing so tend to be limited to discrete productivity improvements rather than improved collaboration and coordination.

The main benefit to BIM use on this project relates to the architects and the improved consultation meetings they have with the clients but the effect of these benefits on other disciplines has not been fully considered within the context of the project as a whole. For example, the architects can now adjust the design to a greater extent than they would previously but what this means for the MEP engineers is that they are constantly having to catch up with the architects design programme. Moreover, there is no change control procedure in place so to identify any changes made so they:

> 4.…either have to do it the old traditional way and export it into another format to do an overlay and use two different colours or do a comparison within Navisworks just to see what's actually changed (MEP CAD/BIM Manager)

In which case the interfacing disciplines have to spend additional resources to compensate for the improved technical capabilities the architects now have. Furthermore, the consequence of no change control procedure is that some of the work interfacing disciplines are working on may become abortive which has a knock on effect to productivity and design progress.

> 5.…they might be coming near to the end of doing all those changes but we have to issue more out now saying, actually that layout's changed, here's our new model. So they, it's back to the drawing board for them kind of thing. (Architect Technician)

Clarity over roles and responsibilities and ultimately collaboration at the start of the project to define these would have been a useful contribution to improve the scope of benefits afforded from improved information use but the organisational context, in terms of existing business processes prevented this.

Perhaps most significantly, is that the team could only approach the implementation of BIM from a techno-centric perspective due to resourcing at an organisational level. The architectural leads attempted to secure consultancy service support from the BIM Group but this was denied on the grounds of insufficient credits. What this has resulted in is a collection of disciplines using the same technology, experiencing different levels of process improvements that have not been aligned or integrated effectively and in some cases may worsen the issues the technology was intended to benefit.

By examining the use of BIM on this project using the DeLone and McLean model fundamental differences between disciplines' work practices and processes have emerged against the context of implementation to highlight shortcomings and areas for improvement. These were then distilled into construct measures and used to populate the model providing a graphical illustration of the measure of focus and how the implementation of the system has affected this in terms of net benefits.

Primarily, there was no period of time prior to project commencement to determine where and when process conflicts may happen that would negate the benefits using BIM technologies. Consequently, they had no means to develop a sufficient strategy to reconfigure processes and technologies to deliver the anticipated benefits and no resourcing allocated to support their reconfiguration.

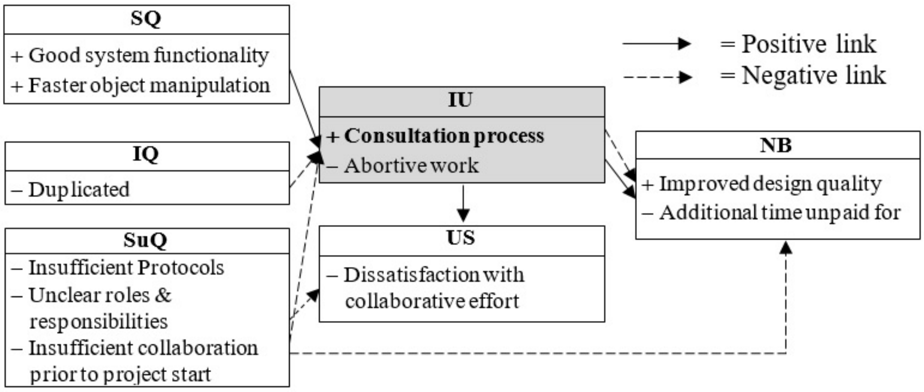

Figure 3: Case Study 2 information use case - improved consultation process

Essentially, the more significant benefits to information exchange anticipated from working in a BIM environment are left unrealised because the fundamental process changes required to do so are constrained by the organisational and cultural environment of the project. The implementation process proceeded in a relatively ad hoc fashion and as the interviewees discussed, would have benefitted from a systematic approach to implementation that would explicate how the actors, technologies and activities should be reconfigured to effectively deliver the projects information requirements.

DISCUSSION AND CONCLUSION

As the literature and case studies demonstrate, the benefit that the technology affords is dependent on changes made at an organisational and cultural level to enable the effective implementation of collaborative processes and practices; essentially, creating an environment that supports and facilitates effective change management.

Neither case study employed any kind of implementation framework. BIM implementation happened on a relatively ad hoc basis and both organisations learnt by trying. The understanding of how actors in the system collaborate and communicate, such as the design programme, cash flow, information requirements, and contractual appointments, happened too late for any effective changes to be made. These reoccurring themes throughout both the literature and the case studies augment the argument for a more comprehensive methodology to assess BIM implementation.

Both projects followed a techno-centric implementation of BIM but for different reasons. In Case Study 1 BIM implementation proceeded from a techno-centric understanding of BIM at an organisational level evident in their conscious decision to focus more on technical process development through the appointment of a BIM Consultant and the technical responsibilities they carried out. In Case Study 2, BIM implementation followed a techno-centric process because this was the only option available within the organisational and cultural constraints of the project. What this means for improving implementation is that unless the potential incendiary organisational and cultural issues can be identified to a certain extent investment decisions for implementation are made relatively arbitrarily (Irani 1998).

Using the model has allowed connections to be made between the level of actor-technology engagement required to achieve the success measures and the antecedent cultural and organisational factors that affected that engagement; the factors that contribute to the production of information, how that information is used and the net benefits of using that information. Respondents often criticised the structure of the project programme as a significant impediment to information use; if all stakeholders that have an effect on the way information is exchanged are not signed up to an information-centric BIM methodology and adjust their practices accordingly, information producers cannot utilise the technology effectively to fulfil the potential benefits they can see might happen.

Furthermore, by assessing the project benefits in parallel to the implementation approach users challenge their perceptions and understanding of BIM. They become more cognisant about their impact on the design process, more aware of BIM implementation as a business process reengineering initiative, more aware of the importance of clear strategy and coordinated processes, and finally more aware of the organisational and cultural factors that prevent, enable or expedite these.

The use of the DeLone and McLean Model has the potential to systematically link the more process-orientated conceptions of information systems to the particularities of the empirical data whilst maintaining utility as a generalisable approach to BIM benefits assessment in future studies. In other words, to a greater or lesser extent each construct within the model addresses one or other of the key concepts discussed within the BIM implementation literature. Moreover, the utility of the model constructs in addressing these concepts comprehensively and systematically means that what would previously have been isolated emergent issues can now be categorised and delimited to their interdependent system aspects. To mean that remediating initiatives can be applied rationally in terms of the inherent organisational and cultural constraints of the system rather than in an ad hoc fashion as was experienced in both case studies. From this critical success factors can then be identified along with key performance indicators to measure progress and design new processes relative to the project context that can explicate the aspired benefits of BIM.

The iterative approach to implementation that the model is intended to facilitate then becomes a starting point from which to redesign organisational functions processes into a collaborative environment and engender value in simultaneous and interdependent improvements.

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