MOVING FROM STATIC TO DYNAMIC MEASURES OF BIM SUCCESS

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Existing methods to measure the quantitative and qualitative benefits of building information modelling (BIM) have predominantly been designed to support the business case for the adoption of BIM and in most cases have proven its benefits. However, following the government mandate of Level 2 BIM on all centrally procured construction contracts by 2016 BIM has continued to gain momentum. As such, the motivation to adopt BIM is less about return on investment and more about competitive advantage within an industry where clients are becoming increasingly aware of the benefits BIM methodologies can bring to their projects. Accordingly, measurement methods should also change tack and refocus attention from static metrics associated with action that has already taken place to the ongoing activity of implementation. The approach to performance measurement within this paper is predicated on the understanding that project success and its measures are indicative of the configuration of BIM as a system that stretches beyond the boundaries of technology application. The Delone and Mclean Information System Success Model has remained a useful tool to assess the successful implementation of information systems since its introduction in 1992. In this paper, the authors extend its use to assess the success of BIM implementation on a large urban regeneration project to provide a means for effective system improvement, further realisation of benefits, and improved return on investment (ROI) in subsequent phases or projects. An interview protocol developed using the six constructs of the D&M model was used to assess the experience of ten design team members using BIM to coordinate a specific design component within a large urban regeneration project. Through the thematic analysis of project team interviews, normative BIM benefits to design processes were identified; however, these benefits have highlighted an inextricable link between the successful implementation of BIM and project context. Late engagement of BIM consultants, uncertainty over strategy intentions, learning curve of the software, parallel 2D and 3D design development, and programmatic issues associated with early clash detection have been recognised as limiting factors to BIM benefits realisation on this project.

Keywords: benefits evaluation, BIM, implementation.

INTRODUCTION

Building information modelling (BIM) is the process of designing buildings using a variety of information communication technology (ICT) tools (3D CAD, databases, interfaces) and associated business processes to represent and manage information within a 3D model (Davies and Harty 2013). Moreover, BIM is synonymous with collaboration, which in the context of construction will inevitably require the reconfiguration of complex set of actors, technologies and activities into an information system (IS) that can facilitate this.

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The list of purported benefits of BIM is extensive; improved quality control, on-time completion, reduced waste through reduction in re-work from early coordination, improved scheduling, early clash detection, productivity improvements, increased opportunities for pre-fabrication, fewer requests for information (RFIs), fewer change orders, early design error detection, less skilled workforce required reducing costs, improved safety performance through construction simulation, interoperability – technically, culturally and organisationally, and more (Barlish and Sullivan 2012; Azhar 2011). But the validation of these benefits is limited with only a small number measured in isolation (RFIs/no. of clashes/change orders) to quantify the ROI of implementing BIM (Barlish and Sullivan 2012; Becerik-Gerber and Rice 2010; Giel *et al*. 2010). Furthermore, methods to measure the benefits and ROI were specific to the context of the project and organisational strategy making them unrepeatable. This paper argues that whilst these measures are valuable in their own right they understate the process of IS reconfiguration required to achieve the outcomes they are measuring. The research problem this paper aims to address is the investigation of a more holistic approach to measurement that pays closer attention to the process of implementation as a means to improve the benefits of BIM.

LITERATURE REVIEW

Historically, IS performance measurement, within most domains, has employed relatively prescriptive and instrumental methods to develop a business case for system adoption or to determine a suitable implementation strategy at an individual organisational level. Within the context of BIM-enabled construction, the existing approaches to measuring the benefits of BIM also reduce the measures of success down to technically discrete variables. To mean they are universal, impose a predefined value of BIM for the user to interpret, require routine practices that focus on stability and control whereby meaning remains static and consequently system configuration adapts to the measures. Measurement in isolation within the context of construction can be too rigid to fulfil the fundamental purpose performance measurement, which is: to discover and verify gaps between actual and required performance, to improve individual, organisational and implementation management performance capabilities such as critical management support, resource allocation and technical support in order to close that performance gap. In this instance, evaluation in conjunction with measurement is potentially a better approach. Evaluation is context dependent and can be self-determined by the users; pertinent information emerges, system value is created and unanticipated information is essential for adaptability and growth. Furthermore, the value of the system to the users evolves and system configuration co-adapts with the measures required to assess performance (Wheatley and Kellner-Rogers 1999). More specifically, a shift in focus to IS performance measurement at project level supports technology specification alongside collaboration and information sharing necessary to realise the purported benefits of BIM (Dehlin and Olofsson 2008).

Cost and time parameters usually trump value and quality of design processes, in part attributable to their ease of quantification but also to the normative vision of profit as a measure of business success. Although they are important in their own right cost and time parameters are dependent on the value and quality of design processes that are less comprehensively understood, more difficult to define and measure, and require wider consideration of their impact within social, economic, technical and ecological problems to determine their success. Improved processes that utilise innovative tools and technologies to meet triple-bottom-line requirements are important to avoid cost and time overruns. Yet, the complexity, uncertainty, instability, uniqueness and value-conflict associated with traditional construction do not allow a measure-manage approach to be effectively utilised. Especially within the context of the early implementation of BIM; its unbounded (Harty 2005)and systemic (Taylor 2007) nature, and the resulting complex assemblage of actors, technology and activities change throughout projects making it difficult to agree a definite criterion of measurement without underrepresenting the system and contorting performance to that which is being measured (Gann and Whyte 2003). Conversely, if the determinants of success (for example, the level of actor-technology engagement required to reduce RFIs) can be identified these may be leveraged and controlled to achieve the success measure, such as providing a technical support network to facilitate the successful use of the technology.

Gann and Whyte (2003) define a rational-adaptive approach that accepts complexity and the difficulty in understanding future trends, but through the use of tools and techniques that map past, present and possible future outcomes to assist in developing a general course of action make success a more probable consequence. With regards to BIM some elements are easily measurable, such as the number of requests for information (RFIs), clash detection results, etc. but what these measures actually represent is the mutually dependent production and use of information, the success of which is context reliant and consequently very difficult to measure. Using the tangible inputs and outputs of BIM-use as a proxy for process investigation presents a rational-adaptive approach to measurement and a more meaningful representation of BIM success. Moreover, by conceptualising BIM as an information system and adopting a rational-adaptive approach to measurement, frameworks of analysis can be rationally appropriated from the IS discipline. The Delone and McLean IS Success Model (2003) has been extensively used and evaluated (Myers *et al*. 1997; Seddon *et al*. 1999; Petter *et al*. 2008) and may prove significant when attempting to measure the success of BIM implementation. The DeLone and McLean (D&M) model was developed in response to a lack of defined information systems success measures that are compounded by indirect human, organisational, and environmental factors. They developed a taxonomy of IS success identifying six variables of interdependency; Systems Quality (SQ), Information Quality (IQ), Intention to Use (IU), Use (U), User Satisfaction (US) and Net Benefits (NB) (DeLone and McLean 2003).

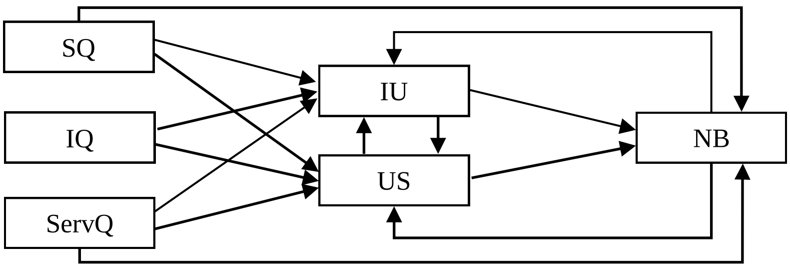

Figure 7: DeLone and McLean IS Success Model (2003)

As a process model, it identifies the development of a system, the use of a system, and the consequences of system use whilst supporting contextual variance, as such the authors encourage and expect different appropriations to maintain utility of both constructs and measures. Therefore, assessing the relationships between System Quality, Information Quality, Use, User Satisfaction and Net Benefits throughout a BIM project provides an ideal context within which to test the model's effectiveness in assessing BIM implementation success. It is also an opportunity to assess whether the improved information quality and coordination associated with BIM use improves design processes and which variables in what sequence constitute benefit causality and augmentation.

RESEARCH APPROACH

Within this study 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. For the purposes of this study, Intention to Use and Use constructs are integrated into Information Use (IU). Questions regarding SQ referred to the technical quality of the BIM system (e.g. efficiency and functionality); IQ referred to system outputs (e.g. relevance and informativeness); ServQ referred to system support (e.g. adequate training and protocol effectiveness); IU referred to task based activities (e.g. nature and appropriateness of use); US referred to the attitude of the user (e.g. enjoyment and decision-making satisfaction); and NB referred to improvements in individual and organisational capabilities (e.g. overall productivity, cost/time savings). Individuals were selected based on the significance of their design processes and information production to the successful design of the project's Cross Laminated Timber (CLT) component (described in the following section). Transcripts were then thematically analysed to provide a narrative of system implementation and specific benefits within each construct were identified based on the BIM benefits literature and classified referring to the D&M Model taxonomy of IS success.

Table 1: Interviewee Roles/Company

Company	Role
CLT Contractor	BIM Manager / Project Manager / Project Director
Client	Project Designer / Development Project Manager / Design Manager
MEP Engineer	BIM Manager
BIM Consultancy	BIM Consultant

By focussing on one design component, a reasonably comprehensive collection of qualitative data has been achieved, allowing a detailed analysis of BIM system success in supporting the design of CLT. It also provides a context-specific means to examine the relevance of the Delone and Mclean IS success model in BIM benefits measurement. In short, the first objective in studying design processes associated with CLT is to develop a methodology for capturing the performance of BIM implementation within a project. The second objective is to explain the influence of BIM methodologies on existing design and construction processes, and to investigate the idea that the successful implementation of BIM (the reconfiguration of actors, processes and technologies) is dependent on the organisational context in which it is applied. The actors, technology and processes that are self-evident throughout the process of mapping the case study are loosely categorised into five of the six constructs - User Satisfaction is difficult to ascertain at the beginning - to compare to the interview findings. After which, less obvious aspects of system configuration that are integral to the successful implementation of BIM are discovered, categorised into the model constructs and used to identify significant interdependencies of system success.

CASE STUDY

The case study project is the first phase of a five-phase urban regeneration project providing residential units, retail and business space, community, culture and leisure space, an energy centre, a park and public realm located in London. At the time of interviewing, the project was moving through technical design (Stage E) to the next milestone of first package issue for tender in August 2014. As client, contractor and operator, the project owner aspires to maintain the value of information produced throughout the project to improve the operation and maintenance of the buildings at handover. As one interviewee described 'unlike a lot of developers, we actually retain the building, and we run it'. A critical aspect of the design in meeting the environmental targets aspired to by the client is the use of CLT as a carbon negative material to replace traditional materials such as steel and concrete where feasible. The intention is to use the material cost effectively, taking into consideration its constraints on a project of this type to ensure buildability and to avoid negative impacts on project programming. However, it brings with it a set of new coordination issues alongside the implementation of BIM, such as; the need for robust front-loaded design collaboration amongst interfacing disciplines and completed designs ahead of start on site to allow for offsite manufacture (BRE, 2011).

Mobilising the model - System Scoping

In terms of System Quality, the client has specified the use of Revit to enable model coordination and to allow model interrogation/clash detection in NavisWorks. The design team members must refer to the model and information development protocols published by the client to meet the level of Information Quality they aspire to, which is models quality assured in graphical, information and Level of Definition (LOD) content as defined in the BIM Execution Plan (BEP). With reference to Support Quality, the client has appointed an external BIM consultant to develop the BEP that contains the protocols, methods and workflows for the design team to follow for this stage of the project. With regard to Information Quality, the client expects the design team to share, distribute and re-use the models and their associated data and documentation for the purposes of 3D coordinated model reviews leading to Net Benefits associated with Clash resolved models, such as reduced waste/RFIs etc.

FINDINGS

Generally, the technical aspects of the BIM system are well regarded. System functionality is good in terms of improved design capabilities in the form of faster object manipulation supported in its ease of use. Interoperability between systems is good for those that use them; data is accurate, current and relatively easy to access and whilst the interviewees believed that design solutions had improved, the project suffered programme delays as a direct result of BIM implementation. The details of which are described in the following paragraphs.

Late engagement of BIM Consultants

BIM is a relatively new concept for many members of the design team and the purpose of appointing the BIM consultant was, in part, to develop consistent BIM use.

'…my involvement has been…getting involved with workshops, we then just try and help them establish the brief and just listen to them and see what they really want. And I think that's, even today…that brief's still evolving.' (BIM Consultant)

However, late engagement of the BIM Consultant during the design development stage (Stage D) and uncertainty surrounding their scope of services has reduced their ability to inform the effective implementation of BIM. In hindsight, information requirements could have been compared against existing technical capabilities to develop an implementation strategy that considers imbalances in technical capability.

Furthermore, strategic intention may have been better understood or developed through earlier engagement with the BIM consultant to develop and implement the Employer's Information Requirements (EIR). A number of workshops were carried out to establish the clients requirements at the point of their engagement and an EIR was created but this happened too late for it to be effective.

'Quite late on we created an EIR for them, but the EIR hasn't been used on this project.' (BIM Consultant)

At the point of interview it was still in development and combined with the fact that the scope of services for each project team member had already been defined meant that it was not used on this project. In a sense, the project is being used as a learning curve for the client and the lessons gathered from this project should be used on subsequent phases, though in reality this does not appear to be happening. Subsequently, the brief was too vague which perhaps had a knock-on effect to consultant buy-in and adoption of the BIM processes. A vague brief from the client may indicate a vague understanding of the requirements for the successful implementation meaning that the groundwork that must be in place to enable the use of BIM throughout the project lifecycle is not there. Scope of appointments did not contain the relevant information and consultants found themselves being asked to deliver BIM related work that they may not have factored into their bids, therefore providing a reasonable basis from which to resist additional work associated with it. Furthermore, the BEP was introduced during the detailed design stage when traditional processes were already embedded within the project. The consequence of which is resistance at a local level, specifically from the MEP engineers, of which MEP BIM Manager believes could be overcome with a better understanding of BIM related documentation to motivate the adoption of new working practices:

'…I do think the BIM execution plan is not often understood by engineer…if they had more of an understanding of what's happening such as levels of details and when their due on a project and so they understand that…pipes can be a generic size…but then as you move up the chain you start to refine that…' (MEP BIM Manager)

In this instance, whilst the BEP was considered an enabling factor for successful BIM use late engagement of the BIM Consultants, as a negative aspect of Support Quality, affected Information Use in that they could not advise the client on aligning the project programme with BIM methodologies.

Uncertainty surrounding strategy intentions

Attitudinal changes to the underlying principles of coordinated design delayed the effective use of the model. As the client Project Manager alludes to:

'…I get the feeling that a lot of the design team are holding back on wanting to send information out, because it might be wrong…hanging onto it and trying to refine it yourself doesn't actually benefit the wider team…' (Client Project Manager)

This is potentially a consequence of poor dissemination of strategic intention resulting in design team expectations of information delivery out of alignment with client expectations of what was to be received:

'…in terms of strategic intention, I think there's definitely, there's a gap. There are certainly different aspirations from within the design team that aren't necessarily aligned with overall (Client) aspirations for using BIM on the project.' (Client Project Manager)

As a negative aspect of User Satisfaction, dissemination of strategic intentions negatively affected Information Quality and subsequently Information Use.

Learning Curve of the software

Without a set of clear strategic intentions it is very difficult for the BIM technologies to be adopted effectively since the design team require a period of adaptation that client has not factored into the design process:

'…clients see the benefit of using the tools but usually they don't appreciate the difficulty to have all partners using those tools…sometimes the project has specificities that will require some adaptation period…' (CLT Project Manager)

This means that software functionality has been limited to 3D design for the purposes of coordination rather than discipline specific analysis within the modelling programme and the impact of this on each discipline differs. For example, integrating a coordination stage within the CLT consultant's workflow was not particularly difficult. An advantage specific to their work package is that they only needed to indicate where their walls need to be to show the impact on other disciplines:

'…once we've passed that stage we'll keep within the confines of our areas and anything that happens in there won't affect that outside of there…it's a comfortable position to use BIM for us knowing that more complex details we do it outside of it.' (CLT BIM Manager).

In addition, the organisation was already in a position to adopt the new technology and its associated processes with relative ease since the project manager had extensive experience in the use of Revit and understood the methodologies that need to be in place to utilise the systems capabilities.

'…I know Revit quite well, I've done studies on it, I've taught it, I was able to sit down, spend a bit more time at the beginning thinking about how we were going to do this…setting out a plan of how we were going to get each of these things put together and how we were going to incorporate each piece of information.'

Conversely, the MEP BIM Manager, whilst convinced of the positive changes to their workflows, they are frustrated by the reluctance of Engineers to submit unfinished solutions necessary to fully realise the benefits of coordinated design.

'They don't understand that it's much easier once something's in to amend that item which doesn't require 50 drawings changing, you do it once on the model, all drawings update themselves, everything is changed.' (MEP BIM Manager)

In this respect, inconsistent technical capabilities as a negative measure of User Satisfaction identifies an interdependency with Support Quality and would indicate a need to assess user capabilities specific to the client aspirations of BIM prior to project commencement.

Parallel 2D and 3D design development

An important factor affecting the success and use of BIM within this project has been related to the concurrent 2D and 3D design development. In addition to the 3D system and design development requirement a concurrent 2D drawing issue, commenting and design development process is running. As such, the workload has doubled for many of the disciplines newly adopting 3D software, specifically for the CLT designers:

'…what we understood was that we were to continue as we would normally as a consultant developing the design through workshops and two dimensionally but there

would be this concurrent system being run by (the BIM Consultant)…to start with it occurs as double the work for us…' (CLT, Project Director)

Specifically for the CLT designers the area in which they would see significant benefit in having coordinated models is with an early clash detection process with M&E. As a prefabricated element, it is costly to make changes on site therefore it is important to resolve clashes earlier than in other forms of construction. However, 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…the coordination of the project was slightly different we could be using, and I think we're getting there now, the 3D process from which 2D can be taken.' (CLT, Project Director).

In spite of the reduced benefits for the CLT contractors, the collaboration between the design team has happened earlier in the programme with most impact on MEP design processes. The MEP BIM Manager referred to this process as 'reverse engineering', predicting the extent of services they will be designing inside the building to determine builders work hole sizing within the slabs for early commencement on site. Without the use of the BIM protocols to deliver quality information for coordination, the interviewee did not believe it would have been possible to achieve the same level of coordination:

'I think without BIM it would have been an easy task to do but, at the same time, it would have been very wrong. (MEP BIM Manager)

In this respect, Information Quality whilst good and a consequence of good Support Quality has not been utilised effectively and limited Information Use. Responses regarding User Satisfaction indicate that users were unaware of what they should be delivering and when, consequently an improvement in the clarity of BIM deliverables as a measure of Support Quality would be beneficial to the success of the system.

Programmatic issues

The standard project goals of on time and on-budget completion that are inherent in a traditional approach were applied to this project and as the CLT Project Manager describes the transition to BIM being the lead in coordination has never been fully made. Especially if a consistent understanding across the design team over what the model will be used for does not exist:

'…BIM is always trying to catch up...in this project…especially in terms of the coordination of services there wasn't full understanding at some point that BIM will take the lead in terms of coordination.' (CLT Project Manager)

Moreover, when a consensus of understanding finally transpires the impact on the project programme is negative. From the perspective of the CLT engineer, initially the MEP engineers understood the technology to be used as a *'…recoding tool to see in the end of it and not as a working tool.'* this coincides with the BIM consultants observations of process inefficiencies within the MEP discipline that *'…they're modelling and they're producing 2D drawings…'*, and also the Client Project Manager's *'…they still draw their designs and work stuff up in 2D, and then translate it into 3D.'* Therefore, when the design team reaches a point of consistent technology adoption and utilisation there is a sudden increase in design capabilities that are not considered against the project programme:

'...this lack of preparation or understanding maybe of the way it works, BIM works, has produced delays on the programme that hasn't been fully assessed.' (CLT Project Director)

In this instance, although System, Information and Support Quality positively affect the design solution through clash detection and coordination the project programme has limited their benefit on the prefabrication of CLT. Users advocated the inclusion of model milestones within the design programme to ensure high-risk interfaces are resolved earlier and negatively associated their absence with Support Quality.

DISCUSSION AND CONCLUSION

We argue that a much more nuanced and qualitative understanding of measurement is required to examine the benefits of BIM, which explicitly recognises its position as a proxy for more complex interactions. This paper has explored the utility of the Delone and Mclean IS Success Model as a means to achieve this. By categorising BIM into a system of six quality constructs the state and circumstances of its use can be investigated systematically to determine interdependencies significant in achieving the aspired project benefits. Empirical evidence can be systematically collated to develop a reasonable challenge to existing attitudes and embedded practices that might be preventing technology adoption, process change and practice change. Figure 1 shows the use of the model focussing in on one benefit described by the interviewees. Early design issue identification has allowed the client to implement contingency strategies earlier in the design process. By using the D&M model, positive and negative impacts of this can be identified and steps can be taken to reconfigure the BIM system toward a more positive outcome. Aspects of System Quality and Information Quality shown in Figure 2 indicate a positive relationship with early design issues identification. Faster communication of easily interpretable information means that interdependent design elements that would normally be configured later in the project can be adjusted earlier to reduce risk, time and cost, improving the final design solution. However, without an EIR or a Model Element Table (MET) some issues can be identified that may not necessarily be of critical importance. This puts added pressure on the design team and delays the delivery of packages. Despite this, the protocols and processes that are defined within the BEP do make a supporting contribution to this factor of Information Use.

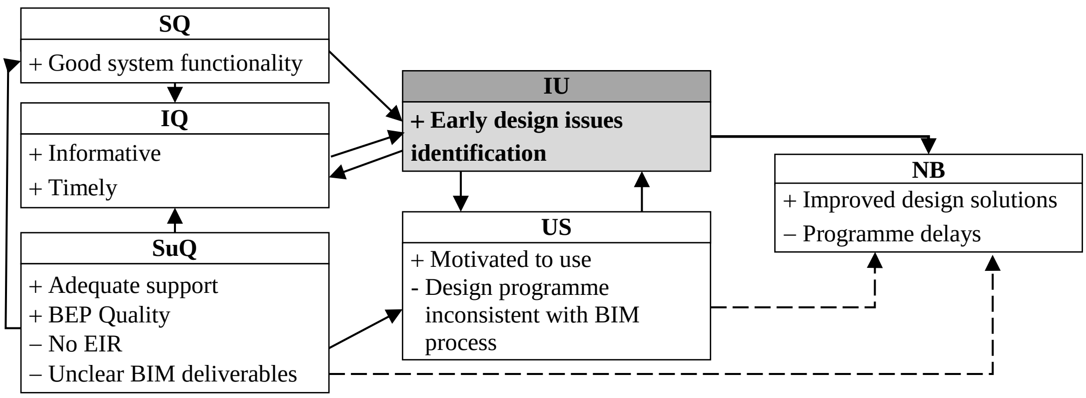

Figure 2: System interdependencies - Early design issue identification

The intention is that the method and model applied in this instance can be used on subsequent projects to comprehensively inform and support change management initiatives that are tailored to stakeholder organisational circumstances. Through using the Delone and McLean model as a means to develop the interview protocol circumstances of system configuration and their impact on performance could be ascertained. The results of which have been useful to the BIM consultant in advising the client how they should approach the implementation of BIM on subsequent phases. Further work would include iterative application of the model at regular intervals within the project. However, it should be assumed that this is subject to change depending on criticality and it is anticipated that lessons learnt relevant to project success will cumulatively lead to implementation success.

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