Evaluations of BIM: Frameworks and Perspectives

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ABSTRACT

This paper examines the evaluation of BIM-enabled projects. It provides a critical review of the three main areas of measurement, namely technology, organization/people and process. Using two documented case studies of BIM implementation, the paper illustrates the benefits realized by project owners and contractors, and illustrates a lack of attention relative to contextual factors affecting the adoption and deployment of BIM. The paper has three main contributions. First, it identifies and discusses the lack of and difficulty surrounding standardized assessment methods for evaluating BIM-enabled projects. Second, it proposes a conceptual model that includes *contextual attributes* and demonstrates how the proposed framework reaches beyond simple evaluation to encompass the documentation of BIM's benefits, lessons learned, challenges and adopted solutions. Third, it shows how the framework can account for existing business processes, organizational process assets, and enterprise level factors. The paper aims to provide a conceptual basis for evaluation and a starting point for benchmarking.

INTRODUCTION

With increasing levels of BIM adoption, there has been growing interest in the development of BIM evaluation methods, assessment tools and performance metrics at the project and organizational level. Evaluating the benefits and costs of BIM implementation at the project level is multi-dimensional and dependent on a number of factors (Jupp 2013). The use of (standard) evaluation frameworks and measurement metrics can assist users and organizations in the analysis of a project's implementation of BIM and its subsequent performance. This study discusses some of these frameworks, highlighting four aspects significant to BIM evaluation, namely: technology, organization/people, business process, and the project context. Specifically, we argue that the inclusion of the "project context" dimension provides valuable situation-dependent information and enables a more holistic and robust evaluation of BIM-enabled projects. We use two existing case studies reported in the literature (see Khanzode *et al.* 2008, Eastman *et al.* 2008, McGraw Hill Construction 2012, and

Christian *et al.* 2011) and synthesize the benefits observed by researchers, focusing on the perspective of the project owner and contractor/subcontractors. The cases highlight the significance of project context, as well as the challenges and innovative solutions that leverage the potential of BIM.

EXISTING METHODS EVALUATING BIM IMPLEMENTATION

Different BIM maturity and capability models and metrics have surfaced in the architecture, engineering and construction (AEC) sectors for evaluating BIM implementation and performance. BIM maturity is aimed at measuring an AEC firm's capability to deploy BIM within the organization and/or on a forthcoming project. A number of different types of maturity measures focus on the technological and organizational transformation as well as an organization's progress in implementing a BIM initiative (Autodesk 2012).

The BIM Capability Maturity Model (NIBS 2007) provides a spectrum of tangible capabilities to determine the current maturity of a BIM implementation along a spectrum of maturity. The different evaluation criteria used in this model mainly refer to three broad areas: 1) information content (what information and at what level of detail or richness will be represented or is currently available), 2) technologies that support information exchange or transaction (e.g., interoperability, timeliness, delivery method), and 3) organizational/business processes that the BIM implementation will support (e.g., roles/disciplines, life cycle, change management).

Succar et *al.* (2012) uses five metrics for BIM performance measurement including: BIM Capability Stages, BIM Maturity Levels, BIM Competency Sets, Organizational Scales, and Granularity Levels. BIM performance measurement is calculated with respect to a set of competencies that are technological, process and policy related. Researchers at Stanford University have developed the Virtual Design and Construction (VDC) Scoreboard (Kam *et al.* 2013), which evaluates the maturity or performance of VDC in areas of planning, adoption, technology and performance and are further divided into 10 divisions. Each division has a total of 56 measures that are evaluated quantitatively or qualitatively. Scoring is based on a percentile system with different rankings delineating: Conventional Practice, Typical Practice, Advanced Practice, Best Practice and Innovative Practice (Kam *et al.* 2013). Indiana University has developed the 'IU BIM Proficiency Matrix' to evaluate BIM expertise and experience on its new projects. The matrix is designed to assess the BIM expertise of tendering consultant(s) and contractors on all university building projects. The assessment is undertaken using eight categories: physical accuracy of the model, IPD methodology, calculation mentality, location awareness, content creation, construction data, as built modelling, and FM data richness (Indiana University 2012).

A variety of other frameworks have been developed that broadly evaluate the benefits of BIM. However these four frameworks specifically target performance evaluation and provide a framework for conceptual theory building and useful guidance on what and how to measure, compare and benchmark BIM performance and implementation. Some of them are also valuable in gauging organization transformation and organizational maturity for BIM adoption.

TOWARDS AN EVALUATION OF BIM-ENABLED PROJECTS

Researchers have developed various methods that define a so-called 'iron triangle' approach to the evaluation of BIM-enabled projects, targeting the assessment of technology, organization and process. Such a three-pronged approach is useful due to the relatively low levels of BIM adoption by the AEC industry. For example, Kam and Fischer (2004) considered BIM evaluation from a product, organization and process (P-O-P) perspective. In the UK, BuildingSmart defines aspects of technology, people and process as significant to BIM implementation, and argues that incremental and integrated change is needed in these areas to reap its benefits (BuildingSmart UK 2010). Staub-French *et al.* (2011) utilize a similar approach in the technology, organization and process/protocol (TOPP) framework when analysing BIM best practices. Whilst these approaches are useful in analysing implementation and performance of BIM projects, a "project context" dimension is lacking or only implicit in existing approaches. Project context is needed to provide a more holistic and robust evaluation of BIM-enabled projects.

The proposed framework is shown in Figure 1 and includes the four dimensions: Technology, Organization/People, Process, and Project Context (TOPC). We argue that the inclusion of project context allows for the consideration of a range of project-specific issues and thereby provides a useful starting point to evaluate BIM-enabled projects in a more consistent manner. Furthermore, these dimensions are interlinked and their interrelationships should be taken into account when evaluating BIM implementation and performance. In the following we briefly describe each of these dimensions.

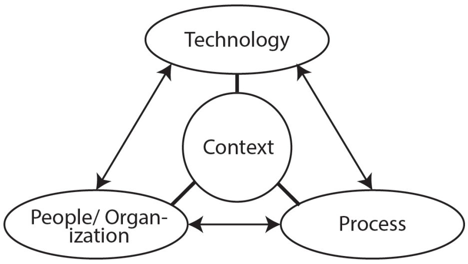

Figure 1. Technology, organization/people, process, and project context (TOPC) framework for BIM evaluation

Technology

Technology, and in particular software, is the key enabler of BIM projects. Some of the main issues that must to be considered include: how the project team will exchange and share information, what level of detail the information is shared, how the information is stored and updated and accessed. The decision to use particular IT (including software and hardware infrastructures) for an organization is a long term strategic decision and investment requires careful analysis of existing business processes, training and education capabilities. At the project level, the main consideration may fall into decisions as to what level of collaboration needs to be achieved and how IT will support better design, construction, hand-over and O&M decision-making.

People/Organization

The specific issues around people and organization fall into different facets: assembling the right project team, timeline of involvement of key parties, assigning roles and responsibilities, defining BIM deliverables, identifying levels of BIM education and expertise, BIM training and support, and sourcing required expertise from external BIM service providers, consultants, or software vendors. Managing the required changes to organizational structures, work practices culture and mindset are seen by many in industry as perhaps the hardest barrier to overcome.

Processes

BIM requires a new business approach and integrated interdisciplinary processes that go beyond existing practices. Many assume that BIM is a new way of doing business in the digital world; however it is not due to the deployment of new IT *per se*; more significantly, it is due to changes in business processes, collaborative methods, and information sharing. The project team must be willing to work collaboratively across all design and delivery phases, so as to exchange reliable structured information in the required format. While some business processes are discipline specific many are interrelated. Decisions, especially those made during the design stage, can have far reaching consequences for fabrication, assembly, onsite construction and ultimately O&M. Open and extensive collaboration requires that the project team clearly define their workflows and information handover procedures, protocols surrounding model progression, and information accessibility, use and reuse.

Project Context

The project context is the environment in which the project is undertaken and would influence the approach to BIM implementation and its subsequent performance. It refers to the characteristics, resources and descriptive measures of the project such as the client type, project type, project size, expected duration, budget constraints, project complexity, size of project team, procurement approach adopted, and availability of resources to support BIM. Project context can also include elements external to the project, including levels of BIM readiness or maturity within local or regional supply chains, BIM regulations, local authority and state/federal government support for BIM, presence or absence of technology service providers, etc. As is the case for the implementation of new ITs in general (see DePietro et *al.* 1990) industry characteristics and structures can also present opportunities or constraints to the deployment of BIM.

The contextual environment also makes each project unique. The uniqueness stems from a variety of different sources, including: owners, owner needs/objectives and project goals, legal, regulatory and industry environment, organizations (designers, contractors, suppliers, etc.), location and work environment, procurement methods etc. The project team needs to identify workable solutions to address these unique project challenges. Many BIM-enabled projects have a few general and common goals, often stemming from the client or developer. A number of major projects have used BIM and IPD with the objective of reducing time delays, cost overruns, and litigation. These projects typically have a mandate to deliver a high-quality facility with an aggressive target cost and time frames. However each project also has unique site-specific and regulatory challenges. Thus a project's overarching goals are important to establishing the drivers of BIM. For example, Christian *et al.* (2011) illustrate in their case study on the Sutter Health Centre how the client drove the application of BIM via the investment of billions of dollars to expand and improve the health care facilities believing that BIM was the central enabler to improvement.

The project context dimension and the contextual variables that act on that environment influence how a BIM-mediated project environment is managed, as well as its performance across each project phase is assessed. Consideration and analysis of project context should therefore help formulate appropriate BIM deployment strategies. This could also increase an understanding of the characteristics and pre-conditions of best-performing BIM projects and practices. Thus it is necessary for BIM evaluation frameworks to incorporate the context-dependent dimensions.

EVALUATING BENEFITS AND CHALLENGES OF BIM

The benefits of and challenges to implementing BIM across different types of projects have been well documented. Benefits can be realized from BIM implementation across the design, construction, and operational phases of a facility's lifecycle. It is not however always an easy task to quantitatively assess the benefits to each stakeholder or to compare performance across projects.

Whilst it is beyond the scope of this paper to develop metrics across all aspects of context identified in the previous section, the proposed TOPC framework (Figure 1) could be used as the basis for defining metrics, quantifying benefits, documenting problems and challenges faced by individual organizations and collectively by project teams. We use two case studies reported in the literature to demonstrate the framework's different dimensions relative to the benefits of BIM to the owner and contractor/subcontractor, and to highlight the significance of project context.

Case 1: Camino Medical Office Building, Mountain View, California

In studies on the Camino Medical Office Building by Khanzode *et al.* (2008) and Eastman *et al.* (2008), the authors show that the client (Sutter Health) was under pressure to upgrade and replace older facilities, and had a primary goal to reduce the project duration so that the centre could be operational as soon as possible. The project team evolved from the traditional project delivery approach to IPD to allow for more effective 3D modelling, design and construction integration, and a reduction in inefficient processes. Sutter Health included an *Incentive Fee Plan* in the contract which was an important factor in facilitating successful collaboration. Benefits to the owner, general contractor and sub-contractors on this project are summarized in Table. The project was not without challenges, however. Not all participants had the required BIM skills, resources and experience and it took a while for the project team to learn how to effectively collaborate. The project also experienced delays from permitting agencies and regulatory bodies (Eastman *et al.* 2008).

Table 1. Benefits to owner and contractor/subcontractors (Khanzode *et al.* 2008)

Benefits to the Owner	Benefits to General Contractor (GC) and Sub Contractors
• Zero change orders related to field conflict. • Owner has accurate as-built model for facility management purposes. • Savings of $9M and 6 months to the owner. • Guaranteed Maximum Price (GMP) project and the mechanical contractor alone gave back about $500K over his approximately $9.4M contract due to savings on field labor.	• Virtually no onsite conflicts for systems/components modelled using BIM. Subcontractors resolved issues in design and detailing stage, which resulted in more efficient construction. • GC's superintendents were able to spend more time planning the job; about 10-15 hours dealing with field issues in the 8 months of MEP construction as opposed to the typical 2-3 hours per day. • GC was able to maintain a cleaner, safe and efficient site throughout construction of MEP systems. Only one recorded injury as opposed to a national avg. of 8 injuries for work of this scale. • Improved workflow; more off-site pre-fabrication, just-in-time material deliveries, and efficient field coordination and installation. • All trades finished work ahead of or on schedule. Mechanical contractor estimated improvement in their field productivity between 5 to 25%. • All plumbing and medium/low pressure ductwork was pre-fabricated. None of the plumbing and at most 50% of the ducts would typically be prefabricated. • Subs were able to use lower-skilled labor for field work compared to other projects where higher-skilled field labor is necessary for installation. • Mechanical contractor had to carry out less than 0.2% of rework in the field.

Case 2: Sutter Medical Centre: Castro Valley, California

The Sutter Medical Center Castro Valley (SMCCV) is a well know BIM implementation study. McGraw Hill Construction (2012) and Christian *et al.* (2011) have undertaken detailed investigations into this state-of-the-art hospital. The SMCCV is a modern 130-bed capacity hospital that was built adjacent to the existing Eden Medical Center in Castro Valley. The project had a number of site-specific and permitting challenges with an aggressive target cost and schedule from the outset (Christian *et al.* 2011). A set of project goals were therefore associated with design completion, project cost, project completion, healthcare delivery innovation, environmental stewardship, and transformation of design and construction delivery model for complex healthcare facilities (Christian *et. al.,* 2011).

Table 2: Benefits to owner and contractor/subcontractors on Sutter Medical Centre (Source: McGraw Hill Construction 2012; Christian *et al.* 2011)

Benefits to the Owner	Benefits to the GC and Subcontractors/Trades
• The project had 555 RFIs, roughly 70% below traditional baseline. 55% of RFIs were closed the same day and 20% within a few days they were opened. Project of this size would typically see more than 2000 RFIs. • Project met its aggressive goal, finishing within budget and its five-year time frame was 30% faster than forecast under traditional methods. Traditional delivery would require at least 7 years for a project of this size.	• GC and Subs reviewed the multi-discipline model on an ongoing basis and identified and resolved hundreds of constructability issues. Substantially less field changes, RFIs and rework was required • Maximized prefabrication/ preassembly from the model • Structural steel, rebar, sheet metal, piping, and major electrical conduits were all fabricated directly from the model. • Many trade contractors and suppliers were able to preassemble systems before bringing them to the site. • Construction waste was extremely low. There was virtually no cutting on site and very little welding. • 60% reduction in rework and 8% boost in productivity in MEP and framing work.

Case Summary and Discussion

The benefits realized by the owner, contractor and subcontractors in each of the above case studies are due to the interactions between the technological aspects of BIM, the collaborations between organizations, the integration of work processes around BIM, and the unique project context and situation-based constraints. Project context, in particular the owner's goals and requirements surrounding the target cost, schedule, and facility operation, as well as the constraints imposed by permitting and regulating bodies as well as site conditions provide both opportunities and challenges for BIM deployment. Some owner organizations such as Sutter Health and Indiana University now have considerable experience in the permitting, financing, design and construction processes around BIM. Aggressive project scheduling, fast tracked project delivery, value enhancement through reduction of waste and rework, and boosts in productivity are increasingly becoming the norm rather than exception on BIM-enabled projects.

These case studies also indicate that early planning by the client and project/ BIM management team with regards to modeling requirements and processes for generating, assessing, sharing and exchanging information are key contextual drivers. For example, in another project reported by Mortenson Construction (2009) on the Tulalip Resort project, the Plan Room Computer was a key location and work environment used by both office and field staff as a live and interactive means to communicate and collaborate. The room became the primary source of information on the project, facilitating shared server access and accurate versioning of discipline-specific and federated models.

CONCLUSIONS

BIM evaluation and performance measurement are valuable tools for AEC practitioners as users and organizations. However, there is still a lack of a standard methodology and assessment criteria for assessing the BIM implementation at the project level. In particular, the metrics for evaluating tangible benefits such as the return on investment are proving to be difficult to implement (see Jupp 2013).

Methods and frameworks for evaluating BIM-enabled projects may be more useful if project context is considered in parallel with technological, organization/people and process criteria. The inclusion of the context dimension provides valuable situation-dependent information and enables a more holistic and robust evaluation of BIM-enabled projects. The two BIM case studies from the literature highlight its significance, particularly the owner's goals, objectives and other project-specific constraints. These factors influence the implementation and management of the necessary infrastructures to support BIM technologies, organizations/people and processes.

Until such time when the BIM methodology becomes an industry standard, the standardization of related performance measures will continue to play a significant role in the BIM adoption process. A standardized method that accounts for contextual attributes will facilitate continuous improvement, the benchmarking project performance knowledge sharing across the facility's lifecycle and enable best practices to be showcased to potential clients and other stakeholders inexperienced in BIM. The TOPC evaluation criteria identified in the paper are critical for evaluating BIM-enabled projects and achieving this goal. Whilst the development of metrics that can provide meaningful assessment of the context dimension is the subject of going research, it is arguably the most significant aspect relative to benchmarking BIM-enabled projects in this transitional phase.

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