Cross Discipline Knowledge Transfer for Concurrent BIM Adoption in an Engineering Organisation

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Abstract

The use of Building Information Modelling (BIM) in the design environment has been widely discussed within the field of construction. However, its effective use requires that all contributing designers meet the technical capabilities necessary to use this environment. A reliable development process utilising BIM to its full potential requires concurrent advancement of multiple disciplines working collaboratively. An investigation into how different disciplines are advancing their BIM capabilities within a multidisciplinary engineering consultancy is carried out to identify where improvements in this process may be made. New technology and process implementation are discussed and the construction industry's silo mentality is identified as a significant factor impacting this. The consultancy's BIM capability is evaluated through semi-structured interviews with discipline representatives involved in its implementation, outlining their experiences with implementation so far, and highlighting opportunities for greater knowledge transfer. Building Services and Physics were found to require most development as a result of the complexity of modelling within these disciplines and the lack of projects involving all disciplines equally. Other disciplines were found to be more BIM capable, but these capabilities are often lowered due to reliance on external stakeholders. This study contributes to the justification of BIM implementation within building design development and identifies the need for more effective adoption across the industry as a whole, not just within discrete areas.

Keywords: BIM adoption, Knowledge transfer, Multidisciplinary organisations

1. Introduction

Building Information Modelling (BIM) is currently being implemented throughout the construction industry worldwide. In the context of this paper, BIM refers to the collaborative working environment facilitated by developments in technology to support the concurrent contribution to construction project during their design phase. UK government targets for BIM are due to be enforced in 2016 (Cabinet Office, 2011), and the construction industry requires vast changes to its practises and cross-disciplinary processes for these targets to be met. Adopting new practises is challenging, and the identification of key areas impacted by implementation is the first step towards facilitating a more effective transition to new working practices. The AEC (Architecture, Engineering and Construction) industry is slow to adopt new working practises, and though the identification of the need to do has been made clear (Egan et al., 1998), these changes have not been as forthcoming as previously hoped. This is confounded in BIM implementation where the entire industry is impacted by its adoption.

This paper investigates how a multidisciplinary engineering consultancy currently uses BIM, exploring its cross-discipline capabilities, to determine opportunities for a more effective implementation strategy. The objectives of study are defined as the identification of drivers for change bringing about implementation of BIM as standard practise, definition of the barriers to effective implementation, evaluation of the organisations current capability (establishing shortcomings of its BIM implementation) and redefinition of the organisations framework for BIM adoption as a collaborative working tool.

This forms the early stage of a larger EngD study investigating the use of BIM as a lifecycle building performance management tool, requiring the design team to input performance-impacting parameters into a BIM model for later extraction and use. Prior to this capability, the design stakeholder must first understand the impact of their actions on the holistic design process, leading to eventual building operations.

2. Research justification

2.1 Slow rates of adoption

Adoption of new technologies and processes in the AEC industry is often hindered by complex relationships between stakeholders affiliated with a project (Hosseini et al., 2013). Each has their own agenda and sometimes incompatible processes hindering cross discipline collaboration. This is confounded by the difficulties faced when operating in a collaborative working environment, where a legal framework governing the responsibilities and liabilities of all parties involved has yet to be fully defined. The industry as a whole understands its need to improve the way it works, using “lessons learned” systems to assist in the amendment of operations (Mitra and Tan, 2012). Collaborative working and interoperability have become buzz-words that show to other practitioners that an organisation has recognised its need to be more effective in the work it undertakes (Ilich et al., 2006); however, their meanings lost amongst the ease of maintaining existing practises.

2.2 Drivers for BIM adoption within the AEC industry

While market needs maybe considered the overall driver for change within a certain industry, ultimately the local government states the requirements that industry must meet. The Egan Report (1998) proposed aspirational targets to implement industry wide changes to processes in order to remain globally competitive. The government BIM agenda (BIM Task Group, 2011) informed by these reports requires '*fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic) as a minimum by 2016'*.

Industry support for the implementation of BIM is widespread, with the RIBA 2013 Plan of Works, (the principle framework for project development management in the UK) recently revised to include BIM processes. However useful, industry initiatives provide guidance by which to develop BIM capabilities, but include little instruction in how to implement it in project settings or across entire organisations.

The organisations governed by industry standards and government regulation experience the benefits of BIM implementation (Liu et al., 2010), driving the organisational agenda put forward by its leadership team, and are representative of the driving factors of a typical multidisciplinary engineering organisation. The organisation assessed in this paper states its goals to be "*making BIM the default approach to building modelling and the production of construction information*" in order to increase efficiency and productivity and "*develop common standards across regions and disciplines to enable widespread adoption of the most effective techniques*". Successful adoption of a change in industry processes can be described using an iterative improvement cycle (Figure 1), showing that prior to change readiness, awareness needs to be attained. In stating its own targets, the organisation has taken the first steps towards deployment and improvement.

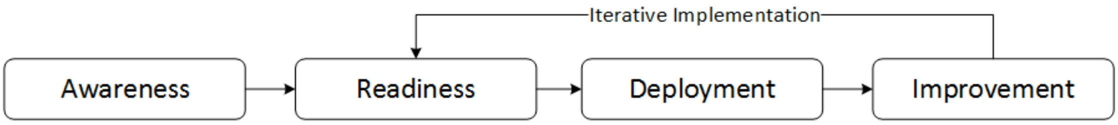

*Figure 1: Iterative improvement cycl*e

Disciplines within an organisation are subject to that organisations governance, but more reliant on its constituent individual's agenda. Within the organisation studied here, the capability each discipline performs at is unavoidably different, each developing their own capacity, specialising in distinct areas where the interoperability with other areas is an afterthought to the development of discipline specific standards. An ideal design environment would link all areas of development to bridge the silo developments to facilitate fully collaborative design and construction processes, where information is shared; however, this is still unobtainable given current industry legal and technological frameworks.

Arayici et al, (2011) suggest that careful consideration of individual experience can improve change adoption success by facilitating a bottom-up approach from within the organisation. This suggests that change adoption becomes a driver in itself, with innovation in one area spurring the implementation of new processes and techniques in another to meet the now more efficient concurrent practises.

2.3 Factors Affecting Successful Change Implementation

The successful implementation of new methods of work requiring consideration of people, processes and technology is well documented (Gu and London, 2010; Stephenson and Blaza, 2001). Some have suggested that it would be advantageous to include management in these elements to include changes to the structure governing these elements (Ruikar et al., 2005). Each of these elements are applied to the case study organisation to ascertain factors limiting its current adoption strategies.

Automation of inefficient practises will not yield a more efficient work process. Management of change is required to coordinate an entire organisation, and exists to consistently evaluate operations. Delegation of responsibility into hierarchical management systems and chains of command is necessitated by the convoluted working processes that organisations have developed (Josserand et al., 2006), and endorsement of systems and careful management of individual resistances can reduce many problems from the bottom up.

Processes define the way a certain task is completed and govern the interactions through which internal and external stakeholders contribute to a projects goal. Within the organisation assessed here, these have changed little over recent years, with the exception of partial automation. New processes need to be developed alongside technology adoption (Raineri, 2011), and existing processes must be rationalised with this reasoning supported by economic or efficiency gains. Attaran (2004) reasons that failure to identify ineffective processes almost guarantees an unsuccessful transition, potentially wasting resources improving a process with no reason to exist otherwise.

Individual resistance to change has been identified by several authors as a common hurdle to overcome when adopting changes (Gonçalves and Gonçalves, 2012; Henderson and Ruikar, 2010), and arises as a result of several factors. These could be previously negative association with change adoption or lack of perceived obligation to implementing such change

Technological capabilities define the capacity to adopt new technology, especially for integration with integration with legacy systems. Whilst easily met given the requirements for basic BIM implementation, the entire organisation needs to be able to access and use tools at an equivalent level of capability paralleled with its surrounding stakeholders. Concurrent access and contribution to a project by several stakeholders requires each contributor to work to common and agreed upon standards. Interoperability is slowed through incompatible systems, and the slowest link in the process is the one dictating the maximum output (Pala et al., 2012).

In addition to those described previously, factors such as product suppliers, specialist contractors and industry contemporaries outside the organisation have a large part to play in pushing and obstructing change. In the case study organisation, each discipline can work as separate units away from each other in order to carry out roles in different projects, but change implementation in each varies with influences from the discipline in which it occurs. External factors are especially impacting in the AEC industry, which requires collaboration between several partners in the delivery of complex projects, where the behaviour and requirements of one party affects the way that another works and contributes.

2.4 Silo Mentality

Fragmented approaches towards innovation and development within the construction sector are often attributed to its silo mentality (Froese, 2010), suggesting that concurrent development across all disciplines would lead to a more effective adoption strategy for new processes and technologies. In the context of project management, an engineering design may be considered a multi-project environment, involving different disciplines, each adhering to their own industry standards. In complex multi-project environments, the ability of a project manager to oversee development in all areas concurrently is limited (Patanakul and Milosevic, 2009), requiring delegation of oversight, and overlooking collective collaboration in favour of silo development.

Elonen & Artto (2003) go into detail, investigating the problems that multi-project environments can face and citing inadequate competencies at a project level and poor management of project-oriented business as significant problem areas, reducing overall capability. Within the AEC industry, Murphy et al., (2011) suggest that limited capability of project stakeholders plays a large part in constraining innovation and overall competency, furthering previous findings by Zou et al., (2007) in construction project environments. Sharing information between different disciplines offers the opportunity to implement new process/technology adoption (Arayici et al., 2011) as well as encourage the cross-discipline collaboration required to make BIM work.

2.5 Summary

For lifecycle BIM to be feasible, the capabilities in all BIM-based design contributing areas need to be consistent and equal. Sustainable building design is grounded in holistic design environments, where contributors to the design understand the needs and reasons behind others decisions. Synchronised project development may mean that the capability of one party to improve performance can be overlooked as a result of their incapability to contribute at the same rate as others. Using lessons from one discipline already using BIM in another at a lower level of implementation may improve the adoption rate through the pre-identification of potential pitfalls and problems that must be overcome.

3. Methodology

The organisation assessed in this paper contains disciplines operating both separately and collaboratively across a range of AEC projects. Its BIM capability is assessed following a two part investigation looking at project-based BIM implementation, and responses from semi-structured interviews with representatives of the organisations constituent disciplines describing their experiences in using BIM. The implementation structure for the organisation assessed within this paper is shown in Figure 2, enforced by a leadership team to which each discipline reports, while comprised of project teams.

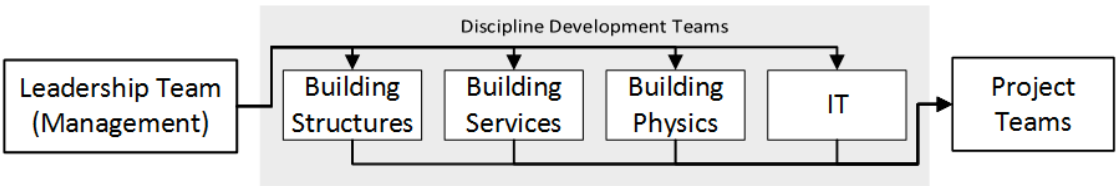

Figure 2: Organisation BIM implementation teams structure

3.1 Project-Based BIM Implementation

The first investigation scored exemplar projects according to their use of BIM concepts, technologies and processes against criteria defined in the NIBS (2007) Interactive Capability Maturity Model. Capability and maturity may seem interchangeable in the context of BIM implementation, but have different definitions (Succar et al., 2012). Capability describes the ability to perform a specific task or function, whereas maturity is the degree to which that capability is implemented.

Table 1: Project-Based BIM Implementation Results

Discipline	*Intelligence of modelled data*	*Interoperability*	*Data Exchange*	*Workflow*	*Cost data*	*Time data*	*Spatial location*	*Life Cycle*	*Customer Involvement*	*Organisation Score*	*Team Score*
Structures	*3*	*2*	*2*	*1*	*1*	*0*	*2*	*0*	*2*	*1.75*	*0.90*
	2	*2*	*1*	*0*	*1*	*0*	*2*	*0*	*1*	*1.50*	*0.60*
	2	*1*	*1*	*1*	*1*	*0*	*2*	*0*	*1*	*1.50*	*0.60*
Building Services	*2*	*1*	*1*	*1*	*1*	*0*	*1*	*0*	*1*	*1.25*	*0.60*
Average	*2.13*	*1.50*	*1.25*	*0.63*	*1.00*	*0.00*	*1.75*	*0.00*	*1.13*	*1.50*	*0.68*

Four single discipline projects were identified for evaluation from the “Structures” and “Building Services” disciplines (a skewed representation of the whole organisations capabilities, but proportional to the makeup of the implementation teams). Results of this assessment are shown in Table 1.

While limited, the conclusions that may be drawn from this preliminary investigation are that representation of “Structures” in the development teams is greater than that of other disciplines, and representative of the BIM maturity shown. Organisational maturity is greater than team maturity including external stakeholders; where lack of capability from outside the organisation holds back the team charged with delivering that project. In addition, limited project scope reduces the ability of the team to meet a level of maturity that is not required of them. These findings were used to guide the targeted questioning used in the later interviews and help identify the limitations currently encountered when using BIM during design development.

3.2 Semi-Structured Interviews

Interviews with representatives involved in BIM development and application within the “Structures”, “Building Services” and “Building Physics” disciplines were conducted, in addition to representatives of the “Management” team overseeing this, and the “IT” team implementing any system changes to necessary to facilitate them (see Table 2). Interview structure was based around four areas: the role of the respondent, their perceived discipline BIM capability, how they work with other disciplines within and outside the organisation and what they perceive to be the biggest barrier to overcome to move forward.

Table 2: Interviewee roles and disciplines

Interviewee	*Job title/discipline*
A	*Structural Technician*
B	*Systems Analyst (IT)*
C	*CAD & BIM Manager (Building Services)*
D	*Building Services Technician*
E	*Building Physics*
F	*Project Principal (Management)*

Understanding the organisation as it currently operates and identifying potential areas for improvement requires an opportunity for the interviewee to explain their reasoning. Respondent familiarity with the subject area is essential for an accurate portrayal of current implementation (Creswell, 2013), and those interviewed are members of the discipline development teams (Figure 2) meaning their understanding and experiences implementing BIM are established.

4. Interview Analysis

Thematic content analysis was used to categorize commonly encountered issues based on the NIBS (2007) categories. From these, common issues causing problems in implementing BIM throughout design development and across the organisation are identified, indicating the interviewee disciplines supporting these issues.

4.1 Collaboration

Interviewees A-D used the government definition of BIM, though all stated this was limited and BIM constitutes a number of definitions, primarily a process or series of processes more than a technology, indicating that individuals are prepared to experience reduction in efficiency prior to full implementation. Several respondents mentioned that general understanding of BIM by those not directly involved in its implementation was limited. While not impeding implementation, it highlights to need for the organisation to gain a thorough understanding of BIM as a concept rather than a technology.

Interviewee B identified that knowledge sharing between disciplines should be a forefront issue in BIM implementation, noting that the discipline divide often causes collaboration problems within small, non-integrated projects. In a project based environment the silo-mentality that forms between project teams and within discipline groups needs to be overcome for fundamental change to happen, where the goal of the teams should be to further overall capability and replicate beneficial developments made in one area across the organisation. Bosch-Sijtsema and Postma (2006) reason that innovation and development centred on a single project was difficult to distribute throughout the rest of the organisation and requires the support of all members of that organisation to transfer, echoing Interviewee B's point and suggesting that whole-project based environments advance process optimisation rather than innovation.

Several respondents mentioned the limited scope of collaborative works that should be prioritised during early design stages (Interviewees A & D). Interviewee D went on to enforce the notion that collaboration with less capable stakeholders can reduce overall design development due to their lack of competency (Interviewee D).

4.2 Information Transfer

Complexity of modelling for different purposes was perceived as too great for current BIM tools to manage (Interviewees A & E), with the scope for BIM integrated performance analysis (structural, energy, operations, maintenance etc.) resulting in common formats being unlikely to be developed. (Interviewee D). However, Interviewee B noted the possibility of using BIM as an information repository rather than a design/analysis tool, instead of the conventional industry norms of project extranets. Before this can be achieved, Interviewee C suggested that supply chain segregation preventing the effective gathering and storage of information for input into BIM environment would need to be overcome.

4.3 Standards & Interoperability

The use of proprietary formats within disciplines limit interoperability, resulting in additional work translating information (Interviewee A & F), but are required for discipline specific processes. Industry bodies specifying standards produce concurrent frameworks for implementation, but supply no integrated guide between themselves for use throughout the industry (Interviewee D) In-house standards will eventually overcome such limitations, e.g. standardised objects for use in multi-discipline models, but for extensive areas such as building services considerable work is required in developing these (Interviewee B).

4.4 Future Capabilities

Interviewee F complained that resources allocated to BIM implementation and development, were not being used successfully. Smith & Tardif (2009) identified ineffective resource use as a significant way that implementation is hindered within organisations. Interviewee D highlights that technological and process advancements take time to implement due to project length, requiring significant foresight by those overseeing change. Every discipline within the organisation is subject to this constraint and as a result, familiarity with existing processes can make alternative solutions seem more uncertain in comparison (Ford and Garvin, 2009).

4.5 Knowledge Transfer

Silo mentality is also apparent within the organisation, where development is limited to the development team with that purpose, and whose work is only noticed by other members of that team (Interviewee F). Better use of in-house knowledge and resources contributing to process improvements would benefit the entire organisation, not just the team that benefits locally. Interviewee C suggested that all members of project teams need to understand what is required of them and use the capabilities of other stakeholders to develop their own skills, but that some disciplines would require more disproportionate input from others.

5. Conclusions

Individual discipline capability varies, but is underpinned by a well-established "IT" infrastructure capable of change. "Management" requires more support to buy in fully to the idea of BIM as an efficiency improving process, while "Building Services" require the majority of work to meet the government targets. "Building Physics" currently has little interaction with other disciplines using BIM tools or processes, but foresees the benefits that could come with it as an information storage repository. Figure 3 indicates each disciplines current relative performance, but this does not account for project variation such as external stakeholder capability limitations and the availability of resources and training in BIM tools and processes.

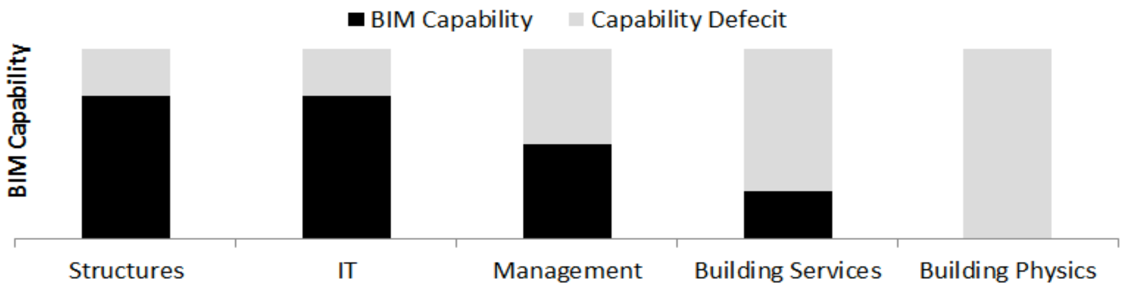

Figure 3: Relative discipline BIM capability levels

Recommendations for the improvement of BIM implementation within the organisation, also applicable to other similar industry practitioners, are that following standard processes at project onset would enable much faster progression than developing those processes in each project. Shared tools such as common object libraries and methods of exchanging files reduce unnecessary rework and improve progress effectiveness; however, these must be supported by those contributing to, and using them. This requires all project members to commit to a standard of practice at project onset. A recurring theme throughout this investigation was of the least capable stakeholder lowering the capability of entire project teams. A common standard of ability should not just be expected within the organisation, but with external collaborators, whose commitment to a common standard can reduce rework, slowdown and error. Skill sharing between disciplines outside of collaborative projects should be more prevalent within the organisation. It is evident that in organisations where each discipline has its own specific projects, opportunities for this knowledge transfer are limited; however, BIM is changing the design environment, affecting all members of the organisation. It would therefore be beneficial for all employees to understand what is expected of them once it is part of standard practises.

6. Future Work

Drawing from lessons learned during this investigation, further research will be performed on the implementation of cross disciplinary information sharing using BIM between building energy performance simulation, and the design of building systems requiring input from these simulations. Research related to performance management of buildings using this BIM embedded data will also be performed.

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