Technology Adoption and Management Innovation in Construction

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ABSTRACT

This paper examines the adoption of object-based modeling software across design and construction team members during project delivery. Drawing on insights from sociology, management theory and innovation studies the paper investigates changes surrounding technology adoption and subsequent management-based innovation. Using empirical data from a case study, analysis focuses on adoption of software, the evolution of new digital and social networks and subsequent innovations in management. The paper has three main contributions. First, it identifies related literature and examines change processes surrounding software adoption and the management innovations that are triggered. Second it explores rigidities in existing routines that challenge adoption and deployment, highlighting innovations that reconcile change conflicts. Third, it shows how the concept of management innovation in construction is valuable to an understanding IT adoption processes.

INTRODUCTION

As continuous changes surrounding the information technologies (ITs) applied to construction spawn new threats and opportunities, there is growing scholarly and professional interest in IT adoption processes and the deployment of novel management approaches that can strengthen evolving (and often ad-hoc) AEC (architecture, engineering and construction) practices. Much recent research attention has focused on the impact of building information modelling (BIM) technologies – both relative to barriers (e.g., Berstein & Pittman 2004) and opportunities (e.g., Arayici *et al.* 2011). However, despite the consequences of the (often radical) change processes surrounding technology adoption, associated management requirements are not fully understood or documented.

Against this backcloth, the paper draws insights from sociology, management theory and innovation studies to develop a richer understanding of IT adoption in dynamic and uncertain project environments. The literature review focuses on the absorptive capacity that links adoption change processes to innovations in management structures, practices and processes. Using empirical data from a case study the paper illustrates the phenomena surrounding software adoption, analyzing key change processes. Resulting management innovations are identified, highlighting those that helped resolve conflicts between traditional and emergent: learning structures, design routines and practices, and collaboration processes.

In the following, the literature is reviewed to which the research relates. After describing the case study context and methodology, findings from empirical analysis are presented. The paper is concluded with a discussion of the research findings relative to existing management strategies, identifying avenues for further research.

CONCEPTUAL BACKGROUND

The potential implications of object-based software adoption across multidisciplinary project teams are vast. Where software is mandated contractually, all disciplines can be affected – whether directly engaged in its use or indirectly due to model-based collaboration or object-based workflows), including architects, engineers, contractors, suppliers and manufacturers. The adoption of object-based modeling software has implications not only for the development of skills but also for how new digital and social network exchanges impact existing work practices.

BIM and technology adoption. The adoption of modeling software must be considered in the context of BIM. BIM is defined by Eastman *et al.* (2008) as a 'modeling technology and associated set of processes to produce, communicate, and analyze building models'. Thus BIM is not simply a technology; it involves strategies relating the processes and people that allow its use (Succar 2009); it is therefore more accurate to refer to BIM as a methodology (Jupp 2013). BIM-mediated projects can encompass a variety of object-based modeling software that center on the generation and integration of discipline-specific datasets in a format required for a particular design or construction task. Network-based integration can therefore include both design and delivery team members. Thus, digital interaction between stakeholders is almost always embedded in, influenced by, and in turn impacts on the wider (project-based) social network.

In any domain, when an alternative technology-driven approach emerges, it may take many years until the time that it completely replaces the old approach and becomes the industry standard. The concurrency of two core approaches to construction (traditional versus BIM) will exist for some time. This has important managerial implications for today's projects as their co-existence obliges the alignment of both turbulent (emerging) and stable (existing) practices. Benner and Tushman (2003) illustrate the relationship between administrative and management innovations within organizations and their potential to increase successful technology adoption. In a project setting this relationship may be more complex, since 'managerial' attention must span multiple stakeholder organizations to overcome impediments to the integration of software whilst also dealing with task interdependencies, knowledge accumulation and stakeholder relationships. Organizations task with the adoption of a new software whilst concurrently designing and delivering a project is therefore replete with challenges, largely due to the tensions between 'stable and familiar' and 'dynamic and uncertain' knowledge environments (Khanagha *et al.* 2013).

Related research on technology adoption as an organizational learning process emphasizes the need for having sufficient resources, motivation, and capability for successful adoption. Within organizations, existing routines tend to be efficiency-oriented and focused on the organization's key expertise (Gilbert 2005). The issue of inertia is therefore factor, where excessive attachment to traditional practices makes development of new capabilities difficult (Khanagha *et al.* 2013). Studies show that there can be a general unwillingness to allocate the required level of financial and attention-based resources to the introduction of ITs (Volkoff *et al.* 2007). Incentive systems may also be a barrier where even with required learning capabilities and resources they may reduce the motivation of individuals to engage.

The effects of these factors on organizations are widely reported in other industries however there is a lack of research on how they manifest in construction. Harty and Whyte (2010) have shown how in a construction setting, the tendency to support existing stakeholder business approaches and practices can result in reverting to established ways of working at the project level, depriving projects of a favorable environment for experimentation and knowledge accumulation.

Adoption change processes and innovation. During adoption, change processes will gradually emerge from necessary requirements to adapt approaches to learning and knowledge sharing, routines and workflows, information management, (re-)allocation of resources, and incentive systems. The nature of change and challenges it presents are varied (see Holzer 2011). However, beyond their description, research is nascent relative to the innovations occurring in practice relative to appropriate management actions and functions.

Outside the construction domain a number of researchers have provided unique conceptual perspectives on the notion of IT-driven change processes. Geels and Kemp (2007) consider the fundamental change processes that occur in socio-technical systems of innovation, distinguishing between three change processes: reproduction, transformation and transition. *Reproduction* refers to incremental change processes along existing trajectories. *Transformation* refers to a change in the direction of trajectories, related to a change in rules that guide innovative action. *Transition* refers to a discontinuous shift to a new trajectory and system.

From this perspective, for AEC organizations to cope with the change processes surrounding BIM technology adoption, innovations in management strategies must provide novel solutions to unique network-based digital and social problems so as to transform and transition. Damanpour and Evan (2012) elaborate the ways through which technological change mandates organizations to adapt structures and practices to maintain the balance between technical and social systems. They argue that technical systems are 'generated and controlled by social system[s]' and that management innovations can positively influence technology adoption. Although relatively new, the concept of 'management innovation' is defined as the introduction of 'new to the firm' structures, processes, and practices (Birkinshaw *et al*. 2008). The factor of novelty therefore sets a distinction between change and management innovation. A change is a management innovation only if it modifies 'regular and predictable behavior patterns' or 'organizational routines' (Nelson and Winter 1982, p.14) that give gestalt to new structures, practices, and processes (Khanagha *et al.* 2013).

RESEARCH SETTING AND DESIGN

The research case focused on an Australian university construction project and for anonymity reasons is referred to as 'CS-1'. The development was among the first wave of BIM-mediated projects and a 'pathfinder' in terms of its adoption of the object-based parametric modelling software Digital Project (DP) by all core project team members. The functionality of the DP software included its use for: generative surfaces design, parametric 3D surfaces, free-style surface modeling, project organization, design to fabrication, dynamic sectioning, revision tracking and part comparison, and integration with Microsoft Project. The project was governed by bespoke concession agreements that mandated DP adoption with tailored definitions of roles and responsibilities. A case study approach was adopted (Yin 1984) and data collection involved analysis of project documents and semi-structured interviews with core team members. 13 participants were interviewed across five companies (see Table 1).

Table 1. Interviewees

Organisation	Title	
Client	Project Manager	Design Team Manager
Architectural Firm	Design Technology Director Project Architect Architectural BIM Modeller	Design Director Architectural BIM Manager
Structural Engineers	Structural Project Director	Structural BIM Modeller
Services Engineers	Services BIM Manager	Services BIM Modeller
Contractor	Project Engineer	Construction BIM Manager

Interviews took place between Nov. 2011 and Aug. 2013. Interviews took approximately one hour and recordings were subsequently transcribed and verified. The study covers the design and pre-construction stages of project delivery between 2010 and 2013 (see Figure 1). A key consideration in case selection was the opportunity it provided to review adoption change processes against the backcloth of an explicit mandate to deploy a software new to the majority of team members. The IT 'lock-in' inherent in project contracts makes it particularly useful for exploring the shifts and innovations that occurred as a result of IT adoption.

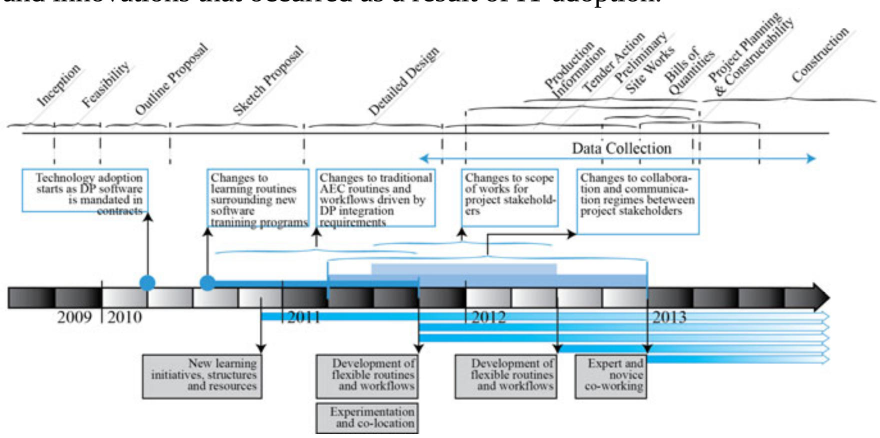

Figure 1. Adoption timeline; showing critical events and management innovations

The semi-structured interview approach meant that a range of topics related to the research could be covered. Interview questions surrounded two key topics: (1) drivers of and barriers to software adoption relative to the management of technological, process, and policy changes; and (2) where change processes were identified the impact of management innovations were explored. Although a longitudinal approach was impractical, retrospective data was collected via project documents and using the respondent-driven critical incident technique (Flanagan 1954). Critical events that had a positive or negative impact on adoption were mapped along a timeline. Interview analysis involved thematic classification of transcriptions, where one (or several) code(s) were assigned to passages. Codes were selected to reflect the passage and grouped based on similarity. From the data analysis, adoption and change processes were mapped with management innovations, and several recurring themes identified. An illustration of events in the period between 2010 and 2013 are shown in Figure 1.

FINDINGS

This section describes working practices in relation to DP adoption and the sequence of change processes, identifying related management innovations.

Adoption and change processes. Change processes surrounded four aspects of adoption, namely changes relating to: 1) learning and knowledge sharing, 2) routines and workflows, 3) collaboration and communication, and 4) scope of works.

Learning and knowledge sharing: Training workshops were initially implemented to support the DP software adoption process. A three day workshop was held to up-skill designers and technicians. The project management team had not anticipated (beyond mapping the impacts of DP relative to training, licensing and supporting infrastructure), its potential impact on traditional ways of working. Initial training activities did highlight DPs capacity as a disruptive technology and intercontinental exchanges for knowledge sharing accelerated the transformations of work processes and information management protocols.

Routines and workflows: As anticipated, findings highlighted that stakeholders emphasized the impact of traditional routines surrounding design processes, activities and workflows on DP adoption. A few new processes were referred to as 'contract specific directives' that provided structured workflows for decision-making, model-based collaboration and model development. This also included new routines for data exchange due to the geographical location of the lead architectural firm in the US. These changes were perceived to be a result of the lead architect's existing expertise with the software and their authority within the project. The conflicts between old CAD-based work routines and the combination of new wireframe and object-based modeling routines, both documented and emergent, were stated to be a source of ineffectiveness in the software's adoption. The problems referenced in relation to these changes seeded further change processes surrounding local network-based integration, and more flexible approaches to information management.

Collaboration and communication: Early in the adoption process, the project team realized that utilizing the DP software required the active engagement of all its members due to the joint decision-making required when interpreting the wire frame geometry relative to object-based modeling. Integration of the DP software therefore changed the interactions of stakeholders requiring daily multidisciplinary design meetings. The single model environment supported by the DP software meant that close cooperation from all project stakeholders was essential during project stage gates. The need for daily modifications and updates to building systems and sub-systems was much more extensive than what project team members were routinely exposed to when dealing with standard 3D modeling technologies.

Scope of works: Changes to the way model-based collaboration occurred were in part intensified by changes to core design team roles and responsibilities which were seen to arise due to the modeling processes instantiated by the use of DP across a global project team (located in Australia, US, and Hong Kong). Traditionally, and contractually, AEC roles follow discipline-specific responsibilities, defining a stakeholder's scope of works. Due to the learning requirements and knowledge intensive processes of DP adoption it was evident that traditional lines were often blurred and stakeholders were required to go beyond their scope, crossing into another discipline's responsibilities. It was observed that responsibilities extended as a result of adoption and delivery processes occurring in parallel and the time pressures of project stage gates.

Resulting management innovations. The above findings illustrate the impact of change processes arising from the adoption of a software core to project delivery. Reluctance within formal project management roles to intervene in adoption-based change processes was reported as adoption by each stakeholder organization was perceived to be outside the bounds of client-side project management responsibilities. Further, due to inexperience with the use of DP across a global and virtual project team, the need for a dedicated IT management role was not recognized and BIM management responsibilities were covered in an ad-hoc manner and the role was formalized during the detailed design stage. The recognition of the various change processes identified in Section 4.2 motivated 'new to the project' structures, practices and processes – identified here as management innovations that facilitated software adoption.

New to the project practices and processes: Two management innovations related to new project practices and processes were identified, namely learning processes and knowledge sharing practices, and coordinating collaboration.

- *Learning processes and knowledge sharing practices*: A number of learning-oriented processes were supported including rolling programs of secondment between firms and participation in one-on-one training sessions using active design tasks thereby combining knowledge sharing and design practices. Online support systems from third party consultants were also established as were connections with international networks of DP experts. In some instances these networks facilitated new R&D initiatives and furthered the professional qualifications of project stakeholders using technology-led problems as the basis of Master's and PhD research projects, forming new incentive structures.
- *Coordinating collaboration:* Experimentation surrounding collaboration and information management was initiated by project team members in the early stages of the software's adoption. As the first step, to secure development of flexible routines and workflows, interdisciplinary teams were formalized via information exchange protocols and project-based intra-nets. This reduced difficulties surrounding the coordination of file sharing and increased the motivation of individuals to engage with the software. However as stakeholder awareness of the mismatch between tradition and new ways of working grew, smaller informal groups organized to develop new more structured routines and workflows that was based on a hierarchical approach to information management that supported rather than impeded collaboration. This was positively perceived as it supported interdisciplinary innovation.

New to the project structures and processes: Three management innovations related to new project structures and processes were identified, namely the co-location of stakeholders, communication processes, and 'side-by-side' work programs.

- *Co-location*: Once a level of expertise in DP was established across the project team and supporting resources were in place, members became more comfortable with managing changes to digital and social practices, particularly as new stakeholders cycled in and out of the project. From a performance perspective, the software's introduction inevitably controlled the speed of delivery due to high-levels of learning and experimentation. The co-location of design and construction team members was established to facilitate and further progress, enabling experimentation with DP and associated processes and protocols. This was perceived as a turning point for the project as it increased understanding about the different ways members were using the software.

- *Communication processes*: One of the main challenges to interdisciplinary working was seen to be the development of a common language among stakeholders. During the early stages of software adoption this was compounded by the technology-based uncertainties and knowledge gaps that reinforced differences between individuals with different professional backgrounds. With co-located working came communication of common project goals and related design activities which was seen to assist in the synchronization and forming of coherent understandings about modeling activities. Sharing common understandings and improvements in the alignment of new collaborative routines and approaches to information management helped overcome knowledge gaps. In building common ground, interviewees perceived that the team had the ability to develop new practices by trial and error.
- *Side-by-side work programs*: With the aim of allowing higher levels of productivity without requiring proficiency in the DP software, a side-by-side program of co-working between expert DP technicians/modelers and senior design professionals (novice DP users) was established when co-location of project stakeholders was established. These two-person teams developed new micro-routines and workflows between them.

CONCLUSIONS

Despite the insights that the extant literature offers on the relationship between technology adoption and management innovation, research has yet to fully understand these phenomena in a construction project setting. Overcoming the paradoxical demands of emerging and existing technologies necessitates avoiding managerial constraints. Further, while prior work has shown the effect of administration and structure on an organization's ability to exploit old certainties and explore new possibilities, little emphasis has been devoted to understanding these adaptations at the project level relative to its structures, processes, and practices. Through this object-based modeling software adoption story, it was demonstrated that, when traditional routines, or even hybrid ones, become ineffective or unsustainable, it is necessary to ensure innovations in the management of project structures, practices and processes.

The paper contributes to construction IT research by providing insights into the relationships between adoption change processes and management innovation. The aim of the paper was to contribute to better aggregate conceptualization and theory building so as to move toward development of more meaningful practical guidance. Whilst the research focuses on a single case study and limits the generalizability of findings, at the same time it provides an opportunity for deepening an understanding of IT adoption processes and consequences for project management. From this perspective, it was observed the project team was dealing with two platforms, one which was known and certain, the other embryonic and unfamiliar. Without innovations in structure, practice and process, stakeholders may not have able to relate the technology (and their emerging knowledge) to existing routines. Through structural adaptations and subsequent development of new practices and processes appropriate to the application of the DP software, project team members accomplished collective experimentation that led to the software's integration. The findings have implications for the literature on BIM technology adoption. While prior studies have discussed the antecedents, processes, and consequences of BIM adoption on hybrid ways of working (Harty and Whyte 2010), productivity and efficiency (Arayici *et al*. 2010) and return on investment (Jupp 2013), the change processes and management innovations explored in this paper are mostly overlooked. The findings highlight important project management requirements for successful IT adoption in construction and a fertile area for future research.

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