Organizing for digitalization through mutual constitution: the case of a design firm

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ABSTRACT

As the pace of digital change accelerates, so the ability of firms in the construction industry to organize for digitalization is becoming increasingly important. While extant research identifies the diffusion of digital innovations in firms as a non-linear process influenced by embedded contextual elements stemming from several complex social systems, it does not address the relationship between these social systems. A longitudinal embedded case of the process followed by one incumbent firm as it adopts building information modelling (BIM) is presented. Data covers a 15-year period and charts the adoption process at multiple levels: user, firm and institution. The case supports existing research by showing that BIM adoption in the firm is successful through a combination of actions involving 1) investment and leadership support, 2) standards and policies and 3) training and skills development. Drawing on Gidden’s Structuration Theory, it contributes to this research by finding that the adoption of BIM is facilitated by a mutually constitutive relationship between user, firm and institution. Firms play a central role in enabling this relationship, by both attending to and enabling endogenous user-led change while seeking to influence exogenous institutional change.

ARTICLE HISTORY

Received 10 March 2018
Accepted 12 October 2018

KEYWORDS

Digital technology; technological change; organizational change; building information modelling; institutional change; longitudinal studies; technological adoption

Introduction

Several recent reports predict that the products and production of the built environment will be transformed in the coming decade by a diverse set of technologies (for example HMG 2015, ICE 2017, World Economic Forum 2017). The AEC industry’s low-profit margins and productivity rates are said to make it “ripe for digitization” (Agarwal et al. 2015). Advanced applications of BIM, additive manufacturing, artificial intelligence and robotics, automation, the internet of things; big data and complex analytics and Blockchain technology are identified as some of the digital technologies that will drive the digital transformation of the built environment. Significant value could be generated by using these technologies in radical ways in combination with each other and across the life cycle of the built asset. While the industry has experienced technological change since the digital age of the 1950s, the speed and degree of the change driven by the predicted digital revolution are unprecedented. The digital transformation of the built environment will bring many challenges – both technological and organizational – whose impact could be profound: new technologies produce radical innovations that alter existing industry architectures by changing its power structures and business (Henderson and Clark 1990). For firms in the Architecture, Engineering and Construction (AEC) industry, the capability to adopt technologies and to develop digital innovations is becoming a key competitive differentiator (Christensen and Overdorf 2000). How then can firms in the AEC industry respond to the accelerating degree and rate of technological change predicted for the industry?

To generate insights into this question, this article turns to a growing body of research that shows that the adoption of digital technologies in AEC organizations is contextually embedded (Poirier et al. 2015). The diffusion of digital innovations is non-linear and influenced by an array of complex social systems, both cultural and temporal (Shibeika and Harty 2015). Institutional actors, the socio-cognitive environment and the market and production environment all influence the adoption and use of information and communication technologies (Jacobsson et al. 2017; Papadonikolaki 2017; Jacobsson and Linderoth, 2010). Recent research suggests that the relationship between...
these factors is also central, finding that they can be aligned or misaligned with the ICT which in turn influences its adoption (Jacobsson et al. 2017). This article develops this research by studying the nature of the relationship between these contextual factors from the organizational perspective, asking how firms can use these insights to organize for digitalization.

Process studies of organizational change provide a basis to develop insights into how firms can enable a radical and potentially transformative set of technologies to be adopted across the firm (Van de Ven and Poole 1995). As the pace of digitalization accelerates, organizational change is no longer an episodic exception but a constant and accelerating process (Shaw et al. 2017). The process of change presented here is theorized using Giddens’s structuration theory (1984), following in the tradition of several influential scholars studying organizational and technological change (for example Barley 1986, Orlikowski 1992, 1993, 1996, 2000) who describe how structure and agency have a mutually constitutive relationship whereby they shape and are shaped by each other. By drawing on structuration theory, the changing relationship between structural and agentic factors in AEC firms adopting new technologies is analysed.

This article proceeds as follows. It first reviews the process of digitalization and change in the AEC industry, drawing attention to embedded studies of digitalization. It then presents a longitudinal study of one established firm’s recent experience of adopting BIM across its organization to generate insights into how it organized for digitalization to mitigate the potential disruption created by a technology that it experienced as radical. From the longitudinal study of the process of adoption, three main phases are identified and described. Comparative analysis of these phases, suggests that Design Partnership developed mechanisms for creating alignment between users of BIM, the firm and institutions through mechanisms that fall into three broad categories namely: 1) investment and leadership support, 2) standards and policies and 3) training and skills development. The article concludes by suggesting that to adopt technologies effectively, firms should acknowledge the focal position they play in enabling the mutually constitutive relationship that exists between institution and users (of BIM).

**Digitalization and change in the AEC industry**

This article focuses on “digitalization” as opposed to “digitization”, drawing attention to the subtle but significant difference in the terms. Digitization is understood here as the technical process of “encoding of analogue information into digital format” (Yoo et al. 2010). In contrast, digitalization is a more recent term (whose usage emerged in the 1970s) referring to the wider context into which digital technologies are applied (Brenen and Kreiss 2014). While the consequences of digitalization in the AEC are not entirely positive, indeed the recent move to adopt BIM has revealed its “dark side” (Davies and Harty 2012) and current debates around cyber security risks presented in the digital built environment abound, the accelerating rate of digitalization appears inevitable. The emergence of novel digital technologies presents opportunities to generate digital innovations, created through the application of technologies. These digital innovations exist on a spectrum with radical and incremental innovations at polar extremes of this spectrum (Slaughter 1998). A radical innovation in the AEC industry marks a “breakthrough in science or technology that often changes the character and nature of an industry” and an incremental innovation as involving “a small change, based upon current knowledge and experience” (Slaughter 1998, p. 227). This study focuses on the “first use” of applications of BIM in a company, which is a key attribute of an innovation (Tatum 1989).

Turning to wider management literature, the correlation between technological and organizational change is well-established (for example Orlikowski and Scott 2008). Giddens’s structuration theory is used to theorize the process of change catalysed by new digital technologies (1984). A central tenet of this theory is that it draws attention to the changing relationship between structure and action, viewing it as a dualism rather than a duality, or as a mutually constitutive rather than exclusive one (Giddens 1984). This affords a contextual view which is evident in seminal studies linking technological with wider social changes. For example, Barley (1986) draws on structuration theory to explore how the introduction of new digital technologies into established organizational and occupational structures influences and is influenced by the institutional context in which they are embedded. A later, influential series of studies by Orlikowski (1992, 1993, 1996, 2000) draws on various aspects of structuration theory to explore the duality of technology in organizations. More recently, researchers use this theoretical perspective to highlight the paradoxical nature of digitization. Mazmanian et al.’s (2013) study of knowledge professionals’ use of mobile email devices finds that users’ experience an “autonomy paradox”, where they try to balance their...
desire for personal autonomy with their commitments to colleagues.

Similarly, considerable scholarly attention has been paid to processes of change and innovation in AEC firms. Research finds that the adoption of new technologies into AEC firms also drives organizational change (Peansupap and Walker 2007). The embedded view of the innovation process implies that technological change has necessitated and created wider changes across the AEC industry at multiple levels (Poirier et al. 2015). Organizational change is driven by planned and emergent processes and has been used by scholars to track the hybrid practices emergent in firms during BIM adoption (Gledson 2016). Winch constructs a similarly dualistic model saying that processes of innovation in the AEC industry are driven by bottom-up ‘problem solving’ emergent processes, or by planned and ‘top-down’ processes (Winch 1998). Early research focusing on the adoption of BIM across AEC firms, identifies a six-stage innovation process that is driven by the organizational decision to adopt an innovation (Peansupap and Walker 2007). More recent studies of BIM diffusion in firms elaborate this somewhat deterministic view to find that innovation diffusion in firms follows a more complex, nonlinear process, which is driven both by top-down and bottom-up change initiatives, influenced in turn by multiple factors, emic and etic to the firm (Shibeika and Harty 2015). This complexity is reflected in Loosemore’s (2015) recent innovation process model, which shows the innovation process in construction occurring through a range of activities that co-evolve through businesses, clients and governments. Because innovation processes are influenced by contexts that vary across the building process: for example, processes of innovation during design stages are said to be organic in nature; in contrast, during construction stages innovation occurs more systematically (Loosemore 2015). While these studies identify the process of innovation and change in AEC firms as necessary to the diffusion of digital technologies and draw attention to the emic and etic factors that influence this process, little research has been done into the relationship between these factors. This article draws on these insights to unpack the complex, multi-layered process that underlies digital diffusion in firms.

Building information modelling: a platform for digital innovation

The process of organizational change studied in this article relates to the adoption of building information modelling (BIM) in Design Partnership. As with past digital technologies introduced in the AEC industry, BIM has the potential to deliver efficiency and quality improvements and to extend the “art of the possible” (Gann 2000). Research has established BIM as a significant innovation (Murphy 2014). Its use can generate both technological and organizational innovations (Morgan and Papadonikolaki 2017). In contrast to previous technological change in the AEC industry, the data presented in this article suggests that applications of the technology studied here, BIM, have the potential to generate radical innovations that could disrupt the industry.

The extent to which BIM is experienced as radical is subjective and dependent on the innovating entity (Afuah and Bahram 1995). With digital transformation, firms will need to develop and apply increasingly radical, more advanced applications of BIM. These are described in Bew and Richard’s (2008) well-known maturity index where more advanced applications of BIM (Level 3 and beyond) can generate value for the operating expenditure of built assets (OPEX) in addition to the established benefits its use can generate in the capital expenditure (CAPEX) of built assets. Research has identified several competencies at multiple levels needed to adopt BIM (Succar et al. 2013). Recent research highlights the diffusion of these more sophisticated applications of BIM, for example in studying the hybrid practices that underpin emerging 4D uses of BIM (Gledson and Greenwood 2016). In these more advanced applications, BIM can be viewed as a digital platform, where it is associated with various other digital innovations (Cusumano and Gawer 2002). This draws attention to the combinatorial nature of BIM (Boland et al. 2007). This has been noted in research that describes BIM as an “unbounded innovation” requiring collaboration between many firms for implementation to be successful (Harty 2005), and that its use can create a wake of innovation across construction supply change (Boland et al. 2007). Subsequent research notes the interdependencies incurred in BIM-enabled working (Dossick and Neff 2010), a point enforced recently by Dainty and colleagues who argue that effective use of BIM demands, rather than creates, greater collaboration (Dainty et al. 2017). This is likely to become more significant as digitalization progresses. In an industry that struggles to work together, the collaboration needed to use BIM effectively may account, in part, for the slower than expected early rates of adoption of BIM (Bew and Underwood 2009). With digitalization, the interdependencies created by BIM and
need to collaborate across traditional boundaries are likely to become more pronounced as BIM becomes a digital platform for other digital innovations (Yoo et al. 2010). Therefore, understanding the adoption of digital innovations as a nonlinear and embedded process can generate increasingly significant insights for firms.

**Methods**

**Research design**

In keeping with the aim of this article, which is to study in detail the process by which a firm in the AEC industry organizes for digitalization, the data presented here is drawn from a single, embedded case study. This is a suitable approach for developing a detailed understanding of a process of change at multiple levels (Van De Ven and Poole 1995). As it is addressing research questions about which little is known (that is the relationship between multiple etic and emic factors affecting BIM implementation), an inductive research methodology is used which has the potential to be “creative and revelatory, to add new concepts and insights to our understanding of situations”.

An interpretive methodology is taken in this study, using a richly descriptive case study (Merriam 2002). Of the four possible different types of case study design, a single embedded case study design is used here (Yin 2009). It enables researchers to develop a deep understanding of the dynamics present within a single setting and is especially useful in studying longitudinal change processes (Van de Ven and Poole 1995). The case comprises an intensive, longitudinal study of one firm embedded within which are multiple levels of analysis: institutional (including government, standard setting organizations, professional associations); firm (taken here as the management and leadership of the firm) and users (represented in this study by engineers and other designers using BIM in their daily work, predominantly on projects). Attention was paid to a potential weakness of case study research which relates to its generalizability (Ferlie et al. 2005). While this case aims for theoretical, rather than statistical generalizability, its generalizability (or transferability) is improved by the “thick descriptions” generated during data collection (Lincoln and Guba 1985). The selection of the case was therefore critical to achieve theoretical generalizability and was driven by the ability to “shed empirical light about theoretical
concepts or principles” (Yin 2009, p. 40). The case study firm presented in this article, referred to henceforth by the pseudonym Design Partnership, is a well-established, innovative and high performing firm. Innovation is a competitive imperative for the firm, it has a track record of implementing digital innovations and aspires to be at the leading edge of digitalization in the industry.

Drawing on Van de Ven’s Engaged Scholarship model (2007), this study was developed in collaboration with Design Partnership. Engaged Scholarship is a participative form of research that helps develop understandings of complex, social problems. It views research as a collaboration between academic and business organizations rather than a solitary activity. This study uses Van de Ven’s model to undertake a collaborative research project to coproduce knowledge on a question of mutual interest. All stages – from identifying an initial research area, to refining the research questions, to data collection and analysis – were undertaken as collaborative endeavours. Data were, therefore, collected through deep access to the firm. This was enabled through a senior sponsor at the firm who also supported, guided, commented on and validated findings regularly throughout the study. Over a 15-month period, between July 2013 and September 2014, the author could access internal meetings, strategy documents, internal seminars as well as conducting semi-structured interviews with a range of personnel in the firm. During this time, she was embedded in the organization as a researcher, spending one or two days per week in Design Partnership’s UK head office. Thus, she achieved data triangulation and increased the credibility of the case (Lincoln and Guba 1985).

Data were collected using qualitative research techniques and drawn from several sources including interviews, archived information, internal meetings seminars and regularly updated field notes, as shown in Table 1. A total of 54 semi-structured interviews were conducted. Of these, 34 were conducted in Design Partnership where interviewees were purposefully drawn from a variety of professional disciplines and a range of roles and seniority levels in the firm. Additional external data was collected to build an institutional picture of events taking place during the same time (2000–2016). This included 18 interviews with external individuals’ instrumental in setting institutional policy and regulatory standards for BIM implementation, external media, websites and relevant conferences. Validation of the emerging results and later data analysis was carried out through regular meetings with Design Partnership’s then Director of Research and similar meetings with senior BIM policy figures. External media and the firm’s own journal and other external scholarly publications were also accessed thereby building a more accurate picture of digital working across the firm during the time-period studied through techniques of data triangulation.

In order to build a longitudinal view of the process of BIM implementation at Design Partnership and the institutional field over a substantial period of time, the author collected both contemporaneous and retrospective data. In collecting retrospective data, she maintained a critical awareness of the validity and accuracy of the data gathered. The recollections of informants gathered during semi-structured interviews, was particularly vulnerable to “informant inaccuracy” (Bernard et al. 1984). Such informant inaccuracy potentially has significant detrimental effects on the quality of data collected (Bernard et al. 1984). So, the impact of potential inaccuracy was minimized, she collected data from a number of sources, following Pettigrew’s (1990) advice for conducting longitudinal studies using retrospective data.

Data analysis

The approach to data analysis combines temporal bracketing and comparative analysis strategies, following methodological examples set by Barley and Orlowski in their 1986 and 1993 papers, respectively. The data analysis fell into three parts which are presented in the findings. The first was carried out using a temporal bracketing strategy, which is a suitable approach for analysing process data (Langley 1999). It involves identifying clear temporal breakpoints and phases in longitudinal research. The single case study, such as is used here, is suitable for this strategy (Langley 1999). From this, three phases of BIM adoption at Design Partnership were identified, driven by different firm strategies and reflected in changing industry and user actions. Drawing on the data sources presented in Table 1, descriptions of each of these phases are presented. The second stage of data analysis involves comparison between these three phases and suggests that three mechanisms that influence BIM adoption. These themes were identified from the data using thematic coding with the help of Hyperresearch (qualitative analysis software). Comparison with relevant theory that identifies contextual factors affecting the diffusion of innovations in the AEC industry validated these themes (Loosemore 2015, Poirier et al. 2015, Shibeika and Harty 2015, Gledson 2016, Jacobsson et al. 2017, Linderoth 2017,
Papadonikolaki 2017). The final data analysis, focused on events in Phase 3 (when BIM was diffused successfully in Design Partnership) and unpacks the relationship between the multiple levels. Three illustrative episodes are presented to describe this relationship.

Research results

The case study

Founded over 70 years ago, Design Partnership employs some 11,000-staff working from 38 countries. It is a multidisciplinary design firm, employing staff from various backgrounds whose work involves high levels of collaboration across disciplines, professions and organizations. It is sufficiently flexible to meet the demands of dynamic environments and has the capabilities needed to create complex products. It developed these capabilities through its highly skilled and innovative workforce.

Design Partnership is a leading firm in the AEC industry with a well-deserved reputation for innovation. It has been instrumental in designing and realizing many of the most ambitious landmark projects across the globe. Consequently, its work has been the subject of a number of scholarly studies including Edmondson’s account of its highly creative and novel work on the Beijing Olympics Water Cube (Edmondson 2012), also the subject of a teaching case at Harvard Business School. Other scholars have studied its innovative use of digital technologies to provide solutions (see for example Gann 2000, Criscuolo et al. 2007, Dodgson et al. 2007).

The institutional and organizational context for considering BIM implementation at Design Partnership is illustrated in Figure 1. This presents an overview of BIM adoption as a long-term process at Design Partnership from 2000 to 2016.

The time period of the longitudinal study covers a significant period in the implementation of BIM across the UK and global AEC industry. The three phases shown in Figure 1 were identified using a temporal bracketing strategy. Using this strategy, major events at firm and institutional level were identified that formed the start and finish of each phase, as shown in Table 2. For instance, Phase 1 of this study starts in 2000 and extends to 2005. These temporal boundaries were identified as in 2000 scholarly reports show BIM being used on “real world projects” (Grilo and Jardim-Goncalves 2010) and major publicly funded collaborative research projects were initiated (Avanti and Comet in the UK). In Design Partnership, management funded the creation of an internal Skills Network through which early users of BIM could share knowledge across the firm. The end of Phase 1 and beginning of Phase 2 in 2005 is marked in Design Partnership by the launch of the firm’s first global initiative aimed at collecting best practice across the firm. Although this does not equate exactly with...
events at institutional level, there were already indications of the forthcoming major global recession that impacted the AEC industry in 2007. The final phase spans between 2013 and 2016. It is marked by major events occurring at institutional and firm level in the form of the launch of the UK Government Mandate which catalysed the launch of a new BIM strategy in Design Partnership, aimed at achieving this mandate. The end of Phase 3 and this study occurs in 2016 when the mandate came into force and a number of objectives from Design Partnership’s strategy were achieved. Detailed descriptions of each of these three phases follow, collated through the range of data described earlier in this article.

**Phase 1: islands of automation (2000–2005)**

The first phase identified in this study marks the initial adoption of BIM in the built environment industry and at Design Partnership. At institutional levels in the UK, major collaborative research projects, Avanti and Comet were the first to explore the use of collaborative digital technologies in live projects. They involved consortia of major firms and other industry bodies. These are depicted on Bew and Richard’s BIM maturity index as marking the start of BIM level 1 (2008). These research projects made useful practical contributions to developing collaborative standards and work processes. They demonstrated the potential that BIM held for improving the efficiency of work practices and quality of output in the UK built environment industry. However, they also hinted at the scale of change needed to diffuse BIM-enabled working across the industry. As well as learning to use new and complex software, behaviours, cultures, standards and processes would need changing. The challenges of using a collaborative technology like BIM in an industry that remains stubbornly adversarial became apparent.

Inside Design Partnership, before 2000 the firm had adopted new technologies with minimal organizational intervention. For example, the transition from paper-based to digital drafting, using Computer Aided Drawing, was achieved through evolutionary methods. Based on this experience, the firm initially took a similarly hands-off strategy to implementing BIM across the firm. It employed a bottom-up approach that foresaw individual BIM enthusiasts driving BIM adoption across Design Partnership. A limited number of such individual enthusiasts had been using 3D technologies in practice for some time at Design Partnership. As one senior business leader and mechanical, electrical and plumbing (MEP) engineer commented, “my enthusiasm for digital working is very strong and deep-seated. I was drawing 3D services when I was 25!” (Interview, Firm Leader). The knowledge and skills of these early adopters were substantial, far in advance of many in the firm and industry.

During this period, scholarly research set in Design Partnership showed how engineering designers were using ICTs in their work. Whilst it found evidence of some engineers’ enthusiasm about the potential of ICTs, most were still relying on traditional interactions, talking to other designers to develop innovative ideas, solve problems and assess the quality of their work (see also Salter and Gann 2003). Design Partnership did have success in establishing an online skills network that connects individual early adopters of BIM, effectively creating an online community of practice. The firm had established skills networks in other areas of their business, connecting global communities of practice through a moderated online network which allowed practitioners to share best practice and undertake collective problem solving, offering potential solutions to issues designers were facing using BIM. While the skills network grew slowly initially, its membership has since expanded to 1500 people in the past 15 years. This early mechanism has endured well and proved adaptable.

During this initial phase, a lack of engagement amongst leaders and practitioners in Design Partnership led to minimal progress in adopting BIM.

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**Table 2. Temporal break points used to identify the 3 phases of BIM diffusion at Design Partnership.**

| Phase 1 (2000–2005) | Phase 2 (2005–2013) | Phase 3 (2013–2016) |
|---------------------|---------------------|---------------------|
| **Design Partnership** (users and firm) | **Institutional** | **Phase 1** |
| 2000: Skills network established | 2005 (start): 3D documentation initiative launched | 2013: New BIM strategy “Let’s get serious about our digital future” launched. |
| 2005: BIM starts being used in “real world projects” early collaborative IT project | 2008: major recession hits global economies including the AEC industry | 2016: Government mandate comes into force |
| 2013: Major standards published including BSI’s PAS documents. | 2016: Government mandate enforced in the UK, requiring BIM Level 2 to be used on all public construction projects | 2016: New BIM strategy launched. |

The firm had established skills networks in other areas of their business, connecting global communities of practice through a moderated online network which allowed practitioners to share best practice and undertake collective problem solving, offering potential solutions to issues designers were facing using BIM. While the skills network grew slowly initially, its membership has since expanded to 1500 people in the past 15 years. This early mechanism has endured well and proved adaptable.

During this initial phase, a lack of engagement amongst leaders and practitioners in Design Partnership led to minimal progress in adopting BIM.
The hands-off approach adopted by leadership proved insufficient to progress implementation of BIM.

The dominant perception of BIM in Design Partnership was that BIM was an irrelevance: as one senior business leader at the firm explained, “most people felt that BIM was nothing to do with what Design Partnership does” (interview with Firm Leader). Without the organizational and institutional structures in place, and the misalignment between the firm, the users of BIM and institutions, the adoption of BIM at Design Partnership remained confined to a restricted number of technological enthusiasts working in islands of automation.

**Phase 2: learning to implement**

The second phase identified in the adoption process occurs between 2005 and 2013. During this time, BIM attracted significant institutional attention as policy makers and industry leaders realized its potential but also the challenges that adoption presented and the scale of change needed. Early in this phase, from 2007, the industry experienced the impact of a major economic recession. Its effects were severe and construction output plummeted sharply. Survival became a struggle for a number of organizations, many of which made significant staffing cuts to stave off financial crisis and bankruptcy (Construction Industry Council 2009). Understandably, BIM implementation took a backseat during this time, but attracted attention once again with the publication of Government’s 2011 Construction Strategy (Policy Document A). In it, Government uses its position as procurer and client of the built environment to drive through BIM adoption by mandating its use on public sector projects from 2016. It also draws attention to the cost and time savings that could be generated using BIM. In an industry struggling with profitability and efficiency, this was an attractive proposition. The effects of this mandate can be seen at institutional level. The need for new industry standards and processes was recognized, and institutions began preparing new standards that enabled BIM working.

At firm level, the challenges of adopting BIM became apparent. As a business leader of Design Partnership recalled, adopting BIM routinely across the firm was going to require more deliberate organizational intervention than previous technological change:

> We thought that the move to BIM was going to be like the evolution to CAD and 3D modeling – that we’ll figure it out - but because BIM is about taking all the separate activities that we do and putting them together, it’s a much bigger deal… We understood that it [adopting BIM] is significantly different to technological changes that happened before. It would be a gradual process of adoption and it wouldn’t be easy". (Interview with Firm leader)

Managers recognized that the scale of the task involved in implementing BIM at Design Partnership meant that: “the evolutionary model was not going to cut it” (Interview with Firm leader). BIM implementation required changes reaching far beyond the IT department. As a Director in Design Partnership explained, the magnitude of the change and level of disruption to the organization meant that:

> Almost every member of staff needs to be told what it [BIM] means and that it’s going to change their job description – it is that disruptive. (Interview with Firm Leader)

A series of business initiatives undertaken during this phase informed this realization. The first of these is an internal report published by Design Partnership in November 2005, entitled 3D Documentation Transition (Documents 2). In this report, the use of 3D modelling, an important stepping-stone to BIM-enabled working, was mandated on every project. The report is based on studies of 40 projects that exemplify innovative working using early applications of BIM, namely 3D documentation. This early “discovery” phase provided opportunities to gather and share data and knowledge about use of 3D on projects. Interviews were undertaken vertically in project teams, and information was collected about lessons learnt, efficiency savings, and how the project was selected. The report emphasized the variance in practices found across Design Partnership’s offices and disciplines. For example, it discusses in detail the range of discipline-specific software available for 3D documentation in the building sector and the challenge of achieving interoperability between them. Software issues are linked to the 3D capabilities and outputs in the disciplines. Structural engineering is described as ahead of building services (or MEP engineering) in its use of BIM. This is put down, in part, to the lack of software suitable for MEP engineers. This variance led to many BIM-related initiatives springing up across the organization. In an effort to provide strategic coordination for them, Design Partnership established an internal built environment modelling (BEM) task force in 2007 comprising senior leaders from across its geographic and business markets. The acronym BEM indicates its wider remit incorporating a number of emerging and related technologies including BIM, Geographical...
Information Systems, virtual reality, parametric modelling and design optimization. The BEM task force operated for two years until 2009 and published a number of vision statements. Leading on from this, regional working groups were established to develop the current organizational strategy, launched in 2013. Additionally, a task force was put in place to address the many specific issues facing MEP engineers adopting BIM. The focus on improving staff’s technical abilities in using complex BIM modelling and analysis software was echoed in the wider organization as more staff were trained in its use. Towards the end of Phase 2, advanced users of BIM were offered intensive training in association with a leading university.

At user level in Design Partnership, technology was permeating many project practices. Interest grew amongst the users of BIM in the potential of novel technologies to aid design processes and outputs: opportunities were evident to use BIM in their work. A number of external studies and internal reports from the time show the variety of ways in which technology was being used in practice (Documents 6). For example, one study provides a detailed account of Design Partnership’s development of an electronic knowledge management system, or an expert “yellow pages” (Criscuolo et al. 2007). It focuses on the benefits such technologies can bring to firms, and discusses the importance of managing knowledge in professional service firms (Criscuolo et al. 2007). Published in the same year, Dodgson et al.’s study looks at the use of simulation technologies in Design Partnership, and shows how these technologies can foster innovation in inter organizational projects; technology is shown to be an important boundary object, enabling communication and coordination between team members working across boundaries (Dodgson et al. 2007). The use of structural analysis software enabled Design Partnership to design an innovative and complex diagrid structure for the roof at a major transport exchange in London (Design Partnership Journal 2/2012). On the same project, simulation technology was used to design lighting, to model for pedestrian flow, and to plan for construction logistics (Design Partnership Journal 2/2012). At another high-profile project in London, geotechnical technology was used to model ground excavations in a historically important site before construction. The proximity of the building to St Paul’s Cathedral and the London Underground system created a complex set of challenges for designing and constructing the foundations. Modelling technology was central in meeting these challenges (Design Partnership Journal 2/2012). Also in the City of London, designers of the 225 m Leadenhall building made extensive use of 3-D CAD modelling software to design the structure of the building’s frame. These models were later used during construction by the fabricators to manufacture the steel elements accurately and quickly (Design Partnership Journal 2/2012). These accounts demonstrated the potential of technology in meeting specialist design challenges. Despite this promise, other contemporary studies show the persistence of hybrid practices (Harty and Whyte 2010). Engineers working at Heathrow Terminal 5 were found to iterate between the physical and digital models, in order to develop physical solutions (Whyte 2013). They struggled to adopt ICTs in practice, drawing on digital and traditional ways of working to fulfil tasks (Harty and Whyte 2010). During Phase 2, BIM adoption in Design Partnership remained patchy, or as one senior manager said it was limited to “pockets of people who could see the light” (interview with Firm Leader).

Phase 3: infrastructure of support

The third phase of BIM adoption at Design Partnership occurs between 2013 and 2016. As one business leader put it, BIM adoption had become a “do or die” situation for Design Partnership.

It’s a very different climate in 2013 compared to 2005. Instead of BIM being a nice-to-have it is a must-have” (interview with Firm leader)

This sense of renewed urgency reflects wider institutional changes as laid out in the group of Documents 1. The UK Government mandate was laid out in the GCS report in 2010. Institutions began publishing policies and standards that were formed during Phase 2, facilitating the use of BIM in practice. Standards were introduced with the publication of documents such as PAS 1192-2 by the British Standards Institution in 2013 that laid out the specific requirements for achieving Level 2 BIM. The professional institutions aligned their routines with the use of BIM: for example in 2013 the Royal Institute of British Architects published a new Plan of Works to accommodate BIM-working (at all levels) in its project stages. As the author of the RIBA Plan of Work explained:

The whole plan now is to try and drive change through the institutes. Because obviously, the main professional institutes have something like 450 000 members. So, if the RIBA can have a document that is geared to architects, then obviously there is more chance of architects going, ‘Alright. Okay. I understand
BIM,’ and be less frightened about some of the things like soft landings or 5D or 6D or 4D. (Interview with Institutional Leader)

The Construction Industry Council also published guidance in 2013 that lays out collaborative protocols for using BIM.

Reflecting this, a step change occurred at Design Partnership in its approach to implementing BIM. Its Chairman launched its current strategy at its 2013 general meeting, indicating clearly that the implementation of BIM had become a key strategic issue for the business (Strategy A in Table 1). The objective of the strategy is to standardize BIM across Design Partnership with all work being routinely undertaken in a “BIM fashion” by 2014. The overall aim of this strategy is to accelerate the spread of implementation of BIM in Design Partnership. This strategic shift indicated that BIM was no longer the domain of a few technical enthusiasts but involved every member of staff in the organization.

A global team was, therefore, put together to implement this strategy across Design Partnership’s practice areas and regions. Senior staff were recruited internally and externally with expertise in using BIM to implement this strategy. The leader of the strategy group in the UK describes the task of this team as: “pushing BIM through all our working practices. To take it from something optional to something we do every day”. Considerable resources have been dedicated to the current strategy supported by senior leadership (Training Event B). It aims to create an infrastructure of support to enable practitioners to use BIM both routinely and creatively at work. As a member of the team implementing the BIM strategy put it:

We need to change our projects appropriately but urgently – we need staff to keep calm but act now.

We are trying to tell people how BIM will help them personally in their work. (Interview with Firm leader)

A range of mechanisms was used by the firm to catalyse this change. For example, users were provided with information and guidance, explaining the abundant terminology that surrounds BIM and detailing best practice in using BIM. Focused training was delivered that caters for different disciplines and levels of seniority. Existing organizational routines were adapted to incorporate BIM working, for example virtual design reviews were added into standard project reviews; extensive information and guidelines are available on producing BIM execution plans as part of the briefing process. The BIM task force is setting measurable targets and putting in place a number of quantifiable measures to measure progress at all levels that are linked to individual and business performance and reward (contained in Document 1). Targets include the number of projects with BIM execution plans and virtual design reviews and rates of staff training. A survey has been developed, based on the BIM Project Execution Planning Guide developed by Pennsylvania State University’s Computer Integrated Construction (CIC) Research Group (Strategy Meeting B), which measures various dimensions of BIM use on projects. Human Resources are developing individual performance measures of BIM relating to different job functions, production, management and leadership, which will be used for future recruitment and performances reviews.

Importantly, the current strategy recognizes and tries to accommodate variance in BIM use, highlighted during Phase 2 of this process. This variance is apparent in a number of dimensions in Design Partnership. For example, different business and service streams have different requirements that are fulfilled by a range of BIM software platforms:

Our practice streams work in different ways – they serve different clients and markets. And how BIM is implemented differs in each of those areas – the scale of the issues, the software platforms and so forth. (Interview with Firm leader)

Project leaders are identified as of importance in the adoption process because:

They are on the front line with clients and need to know exactly what they’re agreeing to. They are making some very big decisions on behalf of the company about whether we’re going to do ‘BIM’ on a project. (Interview with Firm leader)

While these issues remain problems for leaders in practice, they are being addressed through targeted project leadership training. This combines technical knowledge of BIM with business issues such as how to specify BIM in contracts, managing the cost and liability issues in using BIM, and how BIM is used collaboratively. The firm’s BIM working Group in 2012 for project leaders, addressing these specific issues and providing guidance for dealing with them, produced a detailed handbook (contained in Document 1).

**Comparative multiple level thematic analysis**

Analysis of phased data suggests that three broad areas evolve to enable the diffusion of BIM in Design Partnership at multiple levels. These three areas are 1) investment and leadership support, 2) standards and policies and 3) training and skills development. The evolution of these mechanisms across the 3 phases of
BIM adoption at Design Partnership is shown in relation to institutions, firm and users in Tables 3–5.

Investment and leadership support alter across the phases at all levels, as shown in Table 3. For example, in phase 1, limited leadership is shown at institutional level. In the UK, two major research projects are funded by government that helps establish the potential value of BIM enabled working for the industry. This evolves in Phase 2, where government intervenes by mandating the use of BIM and supports this with significant investment in the UK BIM task force. During the final phase, government continues this support and a growing number of institutional bodies – regulatory and professional associations – issue standards that generate a common platform for BIM use. A similar pattern is seen in Design Partnership’s approach to BIM diffusion. For example, in phase 1 it adopts a hands-off approach to BIM adoption and shows disengagement amongst leadership. During Phase 2, it becomes apparent that this approach of evolutionary change will not be effective in assuring widespread BIM use so some additional investment and leadership support is made available. However, during the final phase, BIM takes on central strategic importance for the firm: significant senior leadership is shown and investment made in ensuring BIM is used across the firm. This process is reflected amongst the users of BIM in the firm. Where a small number of technological enthusiasts were using BIM initially, this grows during phase 2 when an increasing number of practitioners at the firm are using BIM. However, it is during phase 3 when users feel sufficiently confident to use BIM in innovative ways and to learn from their mistakes and successes in using BIM.

A similar process can be observed with relation to the evolution of the development of standards and policies, as shown in Table 4. At institutional level, the lack of BIM standards available in the AEC industry severely restricts its widespread use across organizations. The data suggest that problems with interoperability had a significant effect on this. Catalysed by the BIM mandate, several professional bodies, like the RIBA and the CIC, produced guidelines for BIM use. Similarly, institutional standards agencies, such as the British Standards Institution, published a series of standards relating to various dimensions of BIM working (the PAS1192 documents 1–5, the sixth has been published subsequently to this study). Within Design Partnership, a similar pattern is evident: from having no firm standards during Phase 1, to the realization of the complexity and need for standards evident during Phase 2, a plethora of firm specific, centralized policies were widely available during Phase 3. These required and published guidance and standard forms for the stages and routines in using BIM to be present. Other firm policies were also aligned to encourage BIM working, for example the personal assessment criteria in Human Resources were redesigned to reward attributes associated with BIM working. The development of users reflects and influences this: the lack of standards and policies greatly constrained the use of BIM in practice during Phases 1 and 2, as the need technologies require interoperability between individuals and software. In Phase 3, the standards available at institutional and organizational level were central in enabling practitioners to work innovatively and collaborate across organizational and temporal boundaries.

The evolution of training and skills development also showed close alignment between the levels studied. At institutional level, during Phase 1, BIM was not part of most professional education and limited CPD training courses were offered. This changed throughout the process and by Phase 3 a number of

Table 3. The evolution of factors influencing the adoption of BIM: investment and leadership support.

| Users of BIM | Phase 1 | Phase 2 | Phase 3 |
|---|---|---|---|
| A limited number of “technological enthusiasts” are left to adopt BIM in their work. It is assumed that the work of these enthusiasts will lead to evolutionary adoption of BIM | Leadership becomes aware of the challenge and opportunities created by BIM and that the evolutionary method will not create widespread adoption. Some business investment is made in task groups and reports but this is scattered and decentralized | Feeling supported by the firm and their managers, users are increasingly confident in using and learning from their use of BIM |
| Design Partnership | A “hands-off” approach is taken to BIM adoption. The majority of leaders are disengaged in the process and do not view BIM as a strategic issue for the firm | A group of leaders begins to realize the potential and significance of BIM to the firm. Consequently, limited investment is made, providing support for UK Government uses its position as the biggest client in the AEC industry, to mandate BIM use on public sector work, therefore taking a strong leadership position | BIM becomes an issue of vital strategic importance to the firm (it is a “do or die” situation) and significant investment is made by the business to adopt it across the firm |
| AEC institutions | Limited to collaborative research projects supported by government and industry | | The wider institutions in the AEC community follow the UK approach |

...
Table 4. The evolution of factors influencing the adoption of BIM: standards and policies.

| Phase 1                          | Phase 2                          | Phase 3                          |
|---------------------------------|----------------------------------|----------------------------------|
| Users of BIM                    | The lack of standards and training limited practitioners in their use of BIM particularly in inter organizational work where standards and policies were important | The standards and policies available at institutional and organizational level were central in enabling practitioners to work innovative and collaboratively across boundaries. The important role of standards in projects become evident |
| Design partnership              | Some attempts were made to gather best practice guidance from across the firm, but this did not lead to the envisaged guidance | Organization specific and centralized policies were published on the company’s intranet site. These required and published guidance and standard forms for stages and routines in using BIM to be present. Other policies were brought into line to support BIM enabled working – e.g. HR policies Following the mandate several bodies changed their processes to support BIM enabled working. Standards were also published that supported the use of BIM, for example by the British Standards Institute. Information was made readily available |
| AEC institutions                | The UK government produces its BIM mandate which catalysed change and raises the profile of BIM | |

professional institutions and educators offered specialist BIM qualifications in a range of dimensions. The greatest change occurred in the firm, from no standard training being offered internally during Phase 1, to the realization of the variable and complex training needs of personnel in the firm that occurred during Phase 2, to the large variety of training courses relating to BIM available to staff during Phase 3. These training experiences were tailed to fit a range of experience levels, disciplinary backgrounds and levels of seniority. They were delivered through a range of channels, both online and face to face and varied in length from short internal seminars to a Master’s courses provided in partnership with a leading university. They offered training in both the technological and organizational challenges of using BIM. The development of skills levels amongst users is apparent over the time period, during Phase 1 a limited number of enthusiasts have the skills needed to use BIM. In Phase 2, a growing number of users develop the necessary expertise but often through their own initiative. During Phase 3, all staffs are offered and required to participate in the range of training and skills development opportunities offered.

While this analysis shows how the diffusion of BIM in Design Partnership was effected by the evolution of these three broad areas at multiple levels, the question remained of what was different across the temporal phases about the relationship between them. Therefore, further analysis focusing on events at multiple levels in Phase 3 when BIM adoption accelerated substantially at Design Partnership was carried out. Illustrative examples of change are described, as presented in Table 6. These examples illustrate how instances of organizational change co-evolved across user, firm and institutional level. For example, in 2013

Table 5. The evolution of factors influencing the adoption of BIM: training and skills development.

| Users                        | Firm                          | Institutions                        |
|------------------------------|-------------------------------|-------------------------------------|
| Investment and leadership support | A group of users initiates and drive the development of a highly experimental, innovative BIM project in 2013 | Developed Demonstration projects to provide industry wide best practice examples and develop the business case for BIM |
| Standards and routines       | Drove and demonstrated the business benefits of measuring BIM use across the firm by using a survey developed by Pennsylvania State University | BIM Project Execution Planning Guide developed by Pennsylvania State University’s which measures various dimensions of BIM use on projects |
| Learning and skills development | Capturing lessons learnt; Instigated informal BIM “lessons learnt” debriefings at close of projects | Inscribed the need for project debriefings and learnings to be used in institutional frameworks (e.g. Stages 0 and 1 of RIBA Plan of Works) |
Table 6. Alignment between Users (of BIM), Design Partnership and AEC institutions during phase 3.

| Users of BIM                  | Phase 1                                      | Phase 2                                      | Phase 3                                      |
|-------------------------------|----------------------------------------------|----------------------------------------------|----------------------------------------------|
|                               | Advanced users can use BIM expertly, but widespread skill levels across the firm are very low | Individuals acquire skills in using BIM on an ad hoc basis, however, the skills acquired are reliant on individual interests, rather than being offered by the firm | All staff are offered training opportunities, tailored to their individual requirements |
| Design partnership            | No standard training is offered to the firm’s employees. The firm does not consider ‘BIM skills’ as being an important capability to develop | A series of internal initiatives emphasizes the complex training requirements in the firm. Leadership begins establishing strategic relationships with higher education institutes to offer advanced, bespoke training packages | Staff is offered a large variety of training courses related to BIM, suiting a range of experience and disciplinary needs. Internal training seminars, experimental projects and external networks all provide additional opportunities to develop relevant skills. Professional institutions and educators offer specialist BIM/modelling qualifications to suit a range of requirements. The UK BIM Task Force offers extensive guidance |
| AEC institutions              | BIM is not part of most professional education or CPD training courses | –                                            | –                                            |

(at the beginning of Phase 3) a group of users initiated and drove the development of a highly experimental, innovative project involving the creation of 3D BIM model based on a human body. They were inspired to do this, in part, by the Demonstration Projects developed by the UK BIM Task Force which provided best practice case studies. The leadership of the firm officially sanctioned and invested in this project with the purpose of developing the firm’s capabilities in BIM modelling. On completion of this project, the designers working on it recorded their experience in an article for an influential institutional body and it became enshrined as a case study of institutional bodies to promote this initiative and to provide an ad hoc basis, however, the skills acquired are reliant on individual interests, rather than being offered by the firm.

**Discussion**

This article presents a detailed view of the process followed by an established firm in the AEC industry in responding to technological change. By attending to how technology is used, it draws attention to the often neglected but increasingly critical relationship between organizations and technology (Orlikowski and Scott 2008). It shows how one firm adopts novel and radical technologies in its everyday work, studying this process at multiple levels of analysis. The main findings of the study are discussed here, with reference to their contributions to literature.

**Digitalization as embedded**

Design Partnership follows three distinct phases in the process of adopting BIM, each of which is defined by major institutional and firm level events and each of which possesses a markedly different approach. The three phases identified in this process illustrate the attempts made by the firm to adopt BIM across its business. This ranged from an initial “hands-off” approach where an evolutionary style was taken to adopting BIM as had been successful with past incremental technological change, through to the increasing awareness of the potential benefits of but the complexity involved in adopting BIM. In the most recent phase, strategic investment and leadership were used to create the “infrastructure of support” needed to adopt radical and potentially disruptive technologies. This general shift across the phases reflects the perception that firm was adopting an incremental technology to the realization that BIM is a potentially disruptive technology, whose widespread use requires both bottom-up, problem-solving activities and top-down strategic actions. Subsequent comparative analysis between the phases draws on three
main themes of intervention that evolve in multiple levels across the adoption process, namely 1) investment and leadership support, 2) standards and policies and 3) training and skills development. This supports existing literature on BIM implementation and the diffusion of digital innovations that draws attention to aspects of these factors theme. Literature shows that investment and leadership support is critical in technological adoption, created by uncertainty and change (Shibeika and Harty 2015). Standards and policies create influential national frameworks for adopting digital innovations (Papadonikolaki 2017). Training and skills development is critical to develop the competencies needed to adopt BIM (Murphy 2014). The study reflects Poirier et al.’s assertion that four embedded contexts – namely industry, institutional, organizational and project – influence the adoption process and finds support for studies exploring the multiplicity of factors affecting technological adoption (Loosemore 2015, Jacobsson et al. 2017, Linderoth 2017). It extends these studies by identifying the significance of these themes at multiple contexts.

Mutual constitution in adoption

A major contribution of this study comes from the subsequent analysis which explores the relationship between the multiple levels studied in Phase 3, during which time BIM was diffused successfully in the firm. The findings suggest that not only do the actions taken in the three levels of analysis enable the adoption of BIM, but that it is also enabled by their alignment and constrained by their misalignment. The enabling effects of the alignment occur at multiple levels: at user, firm and institutional level. In drawing on Gidden’s structuration theory and its theorization that the relationship between structure and actor is mutually constitutive (1984), events at the levels of analysis studied here show that they shape and are shaped by each other. Examples of this iterative process, including measurement and the development of best practice, occur during Phase 3 of adoption, as illustrated in Table 6 and discussed in detail in the accompanying text. It is also apparent in the limited diffusion of BIM that occurred in Phases 1 and 2 of this study, that without institutional frameworks the innovative practices of users at Design Partnership remained isolated incidents.

The view of organizational change and innovation diffusion as involving both top down and bottom up initiatives (Winch 1998) is borne out in this research: however, the process of organizational change studied here – that is the diffusion of digital innovations in firms – is also facilitated by the alignment between them. This draws on and develops the findings of recent research, which suggests that adoption of ICTs is influenced by alignment between the technology and contextual factors (Jacobsson et al. 2017).

Firm centrality

Significantly, this article suggests that the firm can play a central role in organizing for digitalization. Design Partnership successfully adopts BIM across its business by creating alignment between user and institutional change. In order to gain competitive advantage and use BIM to serve its clients better, during Phase 3 Design Partnership mediates between users and institutional bodies, ensuring its employees are supported in their innovative practices through industry rules and standards. The firm does this by encouraging and attending to users and by seeking to influence the institutional environment.

While a substantial body of research focuses on the increasing interdependence of technologies and growing boundary work necessitated by digitalization (Boland et al. 2007, Yoo et al. 2010), extant research is less clear about the role of the firm in digitalization. Although much attention has been paid to BIM adoption in projects in the AEC industry, if firms can play a central role in enabling the diffusion of new technologies, incumbent organizations in the AEC industry can adopt a proactive role in organizing their firm for digitalization. This is particularly significant given the widely predicted accelerating rate of digitization. In this view, rather than being a passive recipient of digital transformation, with the associated risks of being disrupted (Christensen 1997). However, the degree of disruption generated by novel technologies is variable and can be determined, to an extent, by firm responses. Radical technologies can either disrupt or sustain organizations.

Innovation in a design firm

In viewing digitalization as an embedded process, the nature of the firm is clearly significant. This article generates insights into the process of digitalization in a design firm. Concurring with Loosemore’s view that digital innovations occur through organic processes during design stages (2015), this article suggests that the problem-solving or bottom-up actions of users in the firm catalyse digital innovations. By viewing
organizing for BIM implementation in a large design firm such as Design Partnership, where innovation is vital to the success of its business yet industry regulation and standardization is increasing, the significance of the relationship between users, firm and institutions is apparent. In such complex organizational settings, high-trained practitioners draw skilfully on firm and institutional frameworks to provide a stable structure within which they can innovate freely and effectively. The two approaches to change: top down and bottom up are aligned and occurring apparently simultaneously.

This provides insights into the digitalization occurring in a significant but little understood setting. Extant research identifies that the early design stages of projects are highly influential in the subsequent uses of digital technologies (Sebastian 2011). The design firm is the starting point of the “wakes of innovation” that can spread across the supply chain catalysed by novel digital technologies (Boland et al. 2007). Scholars show how digital technologies can add substantial value to design processes, for example through design thinking (Comi and Whyte 2018) and visualization (Whyte et al. 2008, Ewenstein and Whyte 2009). Yet our understanding of how design firms can affect widespread adoption of novel technologies is scant. Although extant research studies BIM diffusion in contracting firms (Gledson 2016), SMEs (Poirier et al. 2015) and engineering companies (Shibeika and Harty 2015), BIM adoption in design firms remains little understood.

Limitations and future research
This study does have several limitations. While the single case used here is suitable for the longitudinal and detailed study presented which was necessary to respond to this study’s research question, single cases have limited generalizability (Yin 2009). Although this is minimized here by generating thick descriptions which increase the case’s transferability (Lincoln and Guba 1985), this limitation does raise several possibilities for future research. Developing our understanding of the nature of digitalization across firms in the AEC supply chain is important. Following Loosemore’s account that innovation occurs more systematically in construction processes, suggests that firms need to adopt different approaches in organizing for digitalization. A comparative study between firms operating across the AEC supply chain would be one method of exploring this issue further. Similarly, how does a smaller, less influential firm organize for digitization?

On one hand, research shows that they are disadvantaged in the adoption process. For example, Whyte (2013) argues that the peripheral position of SMEs minimizes their ability to influence the field. Similarly, Dainty et al. (2017) argue in their recent paper that existing SMEs have been disadvantaged in the recent adoption of BIM as they do not have the necessary resources to invest in the software and training required to adopt new technologies. This article adds weight to this argument, implying that to develop digital capabilities, firms need to be able to affect external change while supporting internal practices. Large, often incumbent, firms have the resources and often the influence to do so, and can devote considerable management resources to internal implementation efforts. On the other hand, however, SMEs are often faster to adapt and better placed to respond to future technological change. The role of power in firms and individuals in the digital transformation of the AEC industry remains a under explored area that would benefit from future research. Finally, the study’s finding that the relationship between contextual elements is significant in affecting digitalization offers a promising avenue for future researchers.

Conclusion
This article develops our understanding in an increasingly important area, in showing how firms in the AEC sector can organize for digital technologies. In viewing digitalization as an embedded process, it builds upon recent research that finds that the diffusion of innovation in firms is influenced by changes in the institutional, firm and user context (Poirier et al. 2015, Shibeika and Harty 2015, Jacobsson et al. 2017, Linderoth 2017). It contributes to this research by unpacking the relationship between these multiple levels, thus demonstrating that the mutually constitutive relationship existing between institutions, firms and users can influence the adoption of digital technologies. The findings from this article suggest that firms play a central role in organizing for digitalization. This article generates insights into how processes of digital innovation occur in design firms, an important but little understood setting for the industry. However, in acknowledging that processes of innovation are contextually embedded, further research is needed in understanding how different firms in the AEC industry can organize for digitization. In order to develop our understanding of how work in firms, of all types, can adopt this firm-centric position, and generate detailed, rich descriptions researchers and industry practitioners
are called upon to work collaboratively. The Engaged Scholarship approach used here, and by previous research, holds much promise for developing the detailed accounts needed. of how an established design-led firm in the AEC industry responds to technological change and adopts novel and radical technologies in its everyday work.

The findings suggested in this article are significant for the future performance and structure of the industry. As digitization levels in the AEC industry increase in the next decade and increasingly radical technologies are introduced, the organizational capability needed to adopt technologies effectively will become a key competitive differentiator between firms and will determine whether technologies disrupt or sustain organizations and industry architectures (Christensen and Overdor 2000). This is particularly pertinent for incumbent organizations as experience from other more highly digitized industries shows that established high-performing firms often fail in the face of radical technologies, such as those being adopted in the AEC industry (Christensen 1997).

This research has several implications for practitioners working in the AEC industry. In proposing that organizing for digitalization is firm-centric, this study suggests that managers of design firms can take a proactive stance in preparing their firms for this accelerating process. As firms in the AEC industry experience increasing rates of digitalization and associated threats of disruption through existing and new entrants to the market, so this is an increasingly important skill for managers. To do so, leaders and managers of firms in the construction industry should acknowledge the mutually constitutive relationships that exist between users, the firm and institutions operating in the AEC industry. This study finds that managers use both formal and informal mechanisms to enable organizing for digitalization, falling into three main categories of investment and leadership support, standards and policies and training and skills development. These mechanisms can be used at firm and institutional levels to create alignment between them.

The findings from this research are also pertinent to policy makers dealing with digital change in the built environment. This study describes a potentially positive role for policy makers, apparent in viewing the BIM implementation process described here. The leadership displayed by the UK Government in mandating use of BIM on its projects has had a significant impact in catalysing adoption of BIM in Design Partnership and arguably across the AEC industry. It has driven change in the professional institutions, amongst technology developers and generally raised the profile of BIM. The policies, standards and guidance that have been issued in the UK since 2010 have supported BIM-enabling practices. Far from restricting digital innovations, standards are seen here to create a common framework within which practitioners can innovate and improvise. However, this study also finds support for recent calls for policy makers to pay greater attention to heterogeneous practices in the construction industry (Whyte and Sexton 2011). The resistance to change demonstrated in the industry to policy interventions from the Latham and Egan reports in the 1990s stems, in part, from homogeneous policies that fail to reflect the heterogeneous practices prevalent in the AEC industry (Whyte and Sexton 2011).

Acknowledgements

Thank you to my colleagues for their helpful comments that contributed to the development of this article. Particular thanks go to Dr Eleni Papadonikolaki and Professor Andrew Davies at The Bartlett for their valuable input. Thanks also to the three anonymous reviewers and editors of CME for their insightful guidance. I am grateful to the EPSRC for their ongoing support of my work and to Design Partnership for collaborating in this study.

Disclosure statement

No potential conflict of interest was reported by the author.

Funding

This work was supported by Engineering and Physical Sciences Research Council (Grant: EP/N509577/1).

References

Afuaah, A.N. and Bahram, N., 1995. The hypercube of innovation. Research policy, 24 (1), 55–76.
Agarwal, R., Chandrasekaran, S., and Sridhar, M., 2015. Imagining construction’s digital future. New York, NY: McKinsey.
Barley, S., 1986. Technology as an occasion for structuring: evidence from observations of CT scanners and the social order of radiology departments. Administrative science quarterly, 31 (1), 78–108.
Bernard, H.R., et al., 1984. The problem of informant accuracy: the validity of retrospective data. Annual review of anthropology, 13 (1), 495–517.
Bew, M. and Richards, M., 2008. The BIM maturity model. Construct IT Autumn 2008 Members’ Meeting, Brighton.
Bew, M. and Underwood, J., 2009. Delivering BIM to the UK Market. Handbook of research on building information modeling and construction informatics: concepts and technologies. Hershey, PA: IGI Global, 30–64.
Boland, R.J., Lyytinen, K., and Yoo, Y., 2007. Wakes of innovation in project networks: the case of digital 3-D representations in architecture, engineering, and construction. Organization science, 18, 631–647.

Brener, S. and Kreiss, D., 2014. Digitalization and digitization. Available from: http://culturedigitally.org/2014/09/digitalization-and-digitization [Accessed 8 March 2018].

Christensen, C., 1997. The innovator’s dilemma: when new technologies cause great firms to fail. Brighton, MA: Harvard Business Review Press.

Christensen, C.M. and Overdorf, M., 2000. Meeting the challenge of disruptive change. Harvard business review, 78 (2), 66–76.

Comi, A. and Whyte, J., 2018. Future making and visual artefacts: an ethnographic study of a design project. Organization studies, 39, 1055–1083.

Criscuolo, P., Salter, A., and Sheehan, T., 2007. Making knowledge visible: using expert yellow pages to map capabilities in professional services firms. Research policy, 36 (10), 1603–1619.

Cusumano, M.A. and Gawer, A., 2002. The elements of platform leadership. IEEE engineering management review, 43 (3), 51–58.

Dainty, A. et al., 2017. BIM and the small construction firm: a critical perspective. Building research & information, 45 (6), 696–709.

Davies, R. and Harty, C., 2012. Control, surveillance and the “dark side” of BIM. In: S.D. Smith, ed. Proceedings of the 28th annual ARCOM conference. Edinburgh, UK. London, UK: Association of Researchers in Construction Management.

Dodgson, M., Gann, D.M., and Salter, A., 2007. In case of fire, please use the elevator*: simulation technology and organization in fire engineering. Organization science, 18 (5), 849–864. https://doi.org/10.1287/orsc.1070.0287

Dossick, C.S. and Neff, G., 2010. Messy talk and clean technology: communication, problem-solving and collaboration using building information modelling. The engineering project organization journal, 1 (2), 83–93.

Edmondson, A.C., 2012. Teaming: how organizations learn, innovate, and compete in the knowledge economy. San Francisco: John Wiley & Sons.

Ewenstein, B. and Whyte, J., 2009. Knowledge practices in design: the role of visual representations in epistemic objects. Organization studies, 30 (1), 07–30.

Ferlie, E., et al., 2005. The nonspread of innovations: the mediating role of professionals. Academy of management journal, 48 (1), 117–134.

Gann, D., 2000. Building innovation: complex constructs in a changing world. Westminster, London: Thomas Telford.

Giddens, A., 1984. The constitution of society: outline of the theory of structuration. Berkeley, CA: University of California Press.

Gledson, B.J., 2016. Hybrid project delivery processes observed in construction BIM innovation adoption. Construction innovation, 16 (2), 229–246.

Gledson, B.J. and Greenwood, D., 2016. Surveying the extent and use of 4D BIM in the UK. Journal of information technology in construction, 21, 57–71.

Grilo, A. and Jardim-Goncalves, R., 2010. Value proposition on interoperability of BIM and collaborative working environments. Building information modeling and collaborative working environments, 19 (5), 522–530. https://doi.org/10.1016/j.autcon.2009.11.003

Harty, C., 2005. Innovation in construction: a sociology of technology approach. Building research & information, 33 (6), 512–522.

Harty, C. and Whyte, J., 2010. Emerging hybrid practices in construction design work: role of mixed media. Journal of construction engineering management, 136, 468–476.

Henderson, R.M. and Clark, K.B., 1990. Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms. Administrative science quarterly, 35 (1), 9–30. https://doi.org/10.2307/2393549

HMG. 2015. “Digital built Britain, level 3 BIM strategic plan.” ICE. 2017. Digital transformation: state of the national report. London.

Jacobsson, M. and Linderoth, H.C.J., 2010. The influence of contextual elements, actors’ frames of reference, and technology on the adoption and use of ICT in construction projects: a Swedish case study. Construction management & economics, 28 (1), 13–23.

Jacobsson, M., Linderoth, H.C.J., and Rowlinson, S., 2017. The role of industry: an analytical framework to understand ICT transformation within the AEC industry. Construction management & economics, 35, 611–626. https://doi.org/10.1080/01446193.2017.1315148

Langley, A., 1999. Strategies for theorizing from process data. Academy of management review, 24 (4), 691–710.

Lincoln, Y.S. and Guba, E.G., 1985. Naturalistic inquiry (Vol. 75). Thousand Oaks, CA: Sage.

Linderoth, H.C.J., 2017. From visions to practice – the role of sensemaking, institutional logic and pragmatic practice. Construction management & economics, 35 (6), 324–337.

Loosmore, M., 2015. Construction innovation: fifth generation perspective. Journal of management in engineering, 31 (6), 04015012.

Mazmanian, M., Orlikowski, W.J., and Yates, J., 2013. The autonomy paradox: the implications of mobile email devices for knowledge professionals. Organization science, 24, 1337–1357.

Merriam, S. B., 2002. Introduction to qualitative research. Qualitative research in practice. San Francisco, CA: Jossey-Bass.

Morgan, B. and Papadonikolaki, E., 2017. Organizing for digitization: a balancing act. Academy of management specialist conference on big data. Stag Hill, Guildford, UK: University of Surrey.

Murphy, M.E., 2014. Implementing innovation: a stakeholder competency-based approach for BIM. Construction innovation, 14 (4), 433–452.

Orlikowski, W.J. and Scott, S.V., 2008. Chapter 10: sociomateriality: challenging the separation of technology, work and organization. Academy of management annals, 2 (1), 433–474.

Orlikowski, W.J., 1992. The duality of technology: rethinking the concept of technology in organizations. Organization science, 3, 398–427.

Orlikowski, W.J., 1993. Learning from notes: organizational issues in groupware implementation. Information society, 9, 237–250.

Orlikowski, W.J., 1996. Improvising organizational transformation over time: a situated change perspective. Information system research, 7, 63–92.
Orlikowski, W.J., 2000. Using technology and constituting structures: a practice lens for studying technology in organizations. *Organization science*, 11, 404–428.

Papadonikolaki, E., 2017. Grasping brutal and incremental BIM innovation through institutional logics. *Proceedings of the 31st annual association of researchers in construction management conference (ARCOM 2017).* Leeds, UK: Association of Researchers in Construction Management.

Peansupap, V. and Walker, D.H.T., 2007. Innovation diffusion at the implementation stage of a construction project: a case study of information communication technology. *Construction management and economics*, 24 (3), 321–332.

Pettigrew, A.M., 1990. Longitudinal field research on change: theory and practice. *Organization science*, 1 (3), 267–292.

Poirier, E., Staub-French, S., and Forgues, D., 2015. Embedded contexts of innovation: BIM adoption and implementation for a speciality contracting SME. *Construction innovation*, 15 (1), 42–65.

Salter, A. and Gann, D., 2003. Sources of ideas for innovation in engineering design. *Research policy*, 32, 1309–1324.

Sebastian, R., 2011. Changing roles of the clients, architects and contractors through BIM. *Engineering, construction and architecture management*, 18, 176–187.

Shaw, J.D., Bansal, P., and Gruber, M., 2017. New ways of seeing: elaboration on a theme. *Academy of management journal*, 60 (2), 397–401.

Shibeika, A. and Harty, C., 2015. Diffusion of digital innovation in construction: a case study of a UK engineering firm. *Construction management and economics*, 33 (5–6), 453–466.

Slaughter, E.S., 1998. Models of construction innovation. *Journal of construction engineering and management*, 124 (3), 226–231.

Succar, B., Sher, W., and Williams, A., 2013. An integrated approach to BIM competency assessment, acquisition and application. *Automation in construction*, 35, 174–189.

Tatum, C., B., 1989. Organizing to increase innovation in construction firms. *Journal of construction engineering and management*, 115 (4), 602–617.

Van de Ven, A. H., 2007. *Engaged scholarship: a guide for organizational and social research.* Oxford, England: Oxford University Press on Demand.

Van De Ven, A.H. and Poole, M.S., 1995. Explaining development and change in organizations. *Academy of management review*, 20 (3), 510–540.

Whyte, J., *et al.*, 2008. Visualizing knowledge in project-based work. *Long range planning*, 41, 74–92.

Whyte, J. and Sexton, M., 2011. Motivations for innovation in the built environment: new directions for research. *Building research information*, 39, 473–482.

Whyte, J., 2013. Beyond the computer: changing medium from digital to physical. *Information and organization*, 23 (1), 41–57. https://doi.org/10.1016/j.infoandorg.2013.01.002

Winch, G., 1998. Zephyrs of creative destruction: understanding the management of innovation in construction. *Building research and information*, 26 (5), 268–279.

World Economic Forum. 2017. Shaping the future of construction: a breakthrough in mindset and technology. Switzerland: World Economic Forum.

Yin, R. K., 2009. *Case study research, design & methods.* 4th ed. Thousand Oaks, CA: Sage.

Yoo, Y., Henfridsson, O., and Lyytinen, K., 2010. The new organizing logic of digital innovation: an agenda for information systems research. *Information systems research*, 21 (4), 724–735.