Diffusion of digital innovation in construction: a case study of a UK engineering firm

Routledge
Taylor & Francis Group

Construction Management and Economics

ISSN: 0144-6193 (Print) 1466-433X (Online) Journal homepage: http://www.tandfonline.com/loi/rcme20

Diffusion of digital innovation in construction: a case study of a UK engineering firm

Amna Shibeika & Chris Harty

To cite this article: Amna Shibeika & Chris Harty (2015) Diffusion of digital innovation in construction: a case study of a UK engineering firm, Construction Management and Economics, 33:5-6, 453-466, DOI: 10.1080/01446193.2015.1077982

To link to this article: http://dx.doi.org/10.1080/01446193.2015.1077982

Published online: 15 Sep 2015.

Construction Management and Economics, 2016
Vol. 33, Nos. 5–6, 453–466, http://dx.doi.org/10.1080/01446193.2015.1077982

Routledge
Taylor & Francis Group

Diffusion of digital innovation in construction: a case study of a UK engineering firm

AMNA SHIBEIKA* and CHRIS HARTY

School of Construction Management and Engineering, University of Reading, Reading, UK

Received 29 October 2014; accepted 26 July 2015

The UK government is mandating the use of building information modelling (BIM) in large public projects by 2016. As a result, engineering firms are faced with challenges related to embedding new technologies and associated working practices for the digital delivery of major infrastructure projects. Diffusion of innovations theory is used to investigate how digital innovations diffuse across complex firms. A contextualist approach is employed through an in-depth case study of a large, international engineering project-based firm. The analysis of the empirical data, which was collected over a four-year period of close interaction with the firm, reveals parallel paths of diffusion occurring across the firm, where both the innovation and the firm context were continually changing. The diffusion process is traced over three phases: centralization of technology management, standardization of digital working practices, and globalization of digital resources. The findings describe the diffusion of a digital innovation as multiple and partial within a complex social system during times of change and organizational uncertainty, thereby contributing to diffusion of innovations studies in construction by showing a range of activities and dynamics of a non-linear diffusion process.

Keywords: Building information modelling; case study; diffusion of innovations; digital technologies; project-based firm.

Introduction

The construction sector is witnessing rapid escalation of demands for the exploitation of digital innovation. In the UK, the government strategy is promoting digital innovation in construction with the aim to have a construction industry that is efficient and technologically advanced by 2025 (HM Government, 2013). Furthermore, the government discourse emphasizes the role of digital innovation for the development of the construction industry. As a result, digital innovations such as building information modelling (BIM) technologies and concepts are now attaining the most widespread interest (National Building Specification, 2013).

Construction firms are required to adopt and diffuse digital technologies and practices across their projects in order to meet the industry challenge of 'fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic) as a minimum by 2016' (Office, 2011, p. 14). Technology and innovation management activities in practice are concerned not only with how to implement and make the best use of these digital technologies, but also with embedding digital best practice in projects and spreading that across the different business sectors of the firm to become normal practice and remain competitive. However, in doing so they are faced with important challenges related to both the evolving nature of the technology and the project-based organization of the firm which obstruct uniform diffusion of innovations.

Construction is considered a complex social system for innovation; aspects which can accelerate innovation are also found to stifle the diffusion of new technologies and practices (Dubois and Gadde, 2002). Construction management scholars have identified distinct structural characteristics which differentiate construction project-based firms from other project-based firms. Examples of these characteristics are: the inter-organizational nature of construction projects and firms which involve multiple actors and interfaces (Fellows and Liu, 2012; Winch, 2014) causing the innovation to have ripple effects over multiple spheres of influence

*Author for correspondence. E-mail: a.shibeika@reading.ac.uk

(Slaughter, 1998; Harty, 2005); the tensions between the unique and changing project processes and the relatively stable and standardized firm processes (Gann and Salter, 2000); and the double-edged project-based learning which is found to be problematic and difficult to capture (Davies and Brady, 2000; Scarbrough *et al.*, 2004).

In addition to challenges posed by the organizational and structural characteristics of construction firms, these firms are increasingly faced with numerous changes at environmental and institutional levels (Widén *et al.*, 2009), especially with newly emerging forms of procurement and digital technologies (Jewell *et al.*, 2014). Connaughton and Meikle's (2012) review of the top 20 UK construction firms between 1995 and 2011 highlighted a plethora of significant changes with regard to ownership, firm size, organization and governance, and service diversification over this period. All these are important contextual factors which need to be considered in order to understand diffusion and innovation in construction.

The purpose is to investigate the diffusion of digital innovation in a project-based firm. This is achieved through employing a contextualist approach emphasizing emergent activities (Pettigrew, 1990) to understand the diffusion of digital technologies for project delivery in a global engineering firm, EngCo. This firm's international operations evolved over the four years of fieldwork: the firm is of a significant scale, with more than 10 000 staff and project-based operations on most continents. A significant proportion of the firm's work is on major infrastructure projects. The case presented here was set against the rhetoric around BIM and digital innovation. The first author developed close relations with EngCo through direct and close interaction during the fieldwork when she observed strategic initiatives and conducted the empirical study.

The following section critically reviews the diffusion of innovations literature in construction, arguing that studies of diffusion need to account for unbounded and mutating digital innovation, iterative processes over time, complex and changing contexts and the reciprocal interaction between digital innovation and organization. The research methodology and the methods adopted for data collection and analysis are then presented, positioned against some of the perceived issues with diffusion of innovations approaches. This is followed by the findings of the case study showing diffusion of a digital innovation in multiple paths of organizational change and three phases of diffusion. The findings are discussed in light of relevant literature, suggesting that a simple, linear approach to understanding the practicalities of diffusion, or one based on the assumption that technology alone can bring about successful diffusion, may be likely to fail. Finally, future research is suggested.

Diffusion of innovations theory and concepts

Diffusion of innovations theory examines how new ideas move through a particular social system. Early studies of diffusion investigated a wide range of innovations within varied homogeneous social systems like tribes and communities. The focus of these early studies was on personal innovation adoption behaviour, which includes knowledge, persuasion, decision, implementation and confirmation processes (Rogers, 1962, 1983, 2003; Rogers and Shoemaker, 1971). Later developments extended this work to examine the diffusion of more complex technological innovations like business processes or information systems in heterogeneous social systems such as schools, hospitals and organizations (Rogers, 1995, 2003; Ven *et al.*, 1999). Such studies argued that the innovation adoption process is more complex in organizations than among individuals. Rogers (2003) presents five stages for the innovation process in organizations, categorized into two main processes: initiation which includes agenda setting and matching; and implementation which includes redefining/restructuring, clarifying and routinizing. Despite this process being linear, more emphasis has been given to the reinvention of the innovation to match the organizational context of the firm and to the adaptation by the firm to routinize new working practices for the innovation. Yet less attention is given to organizational structure and multiple adopting units within one firm.

Current research in diffusion, however, is concerned with innovation processes which unfold not just within firms, but also across projects and markets. For example, Garud *et al.* (2013) draw from a process approach for innovation to identify and discuss complexities associated with innovation processes in more complex and heterogeneous social systems. First, there is co-evolutionary complexity which relates to multiple levels of analyses, pertaining to multiple paths for innovation and diffusion, which challenge the classic linear representation of the process. Second, there is relational complexity caused by the interplay between social and material elements of the innovation and diffusion processes. Third, temporal complexity may be induced by the fact that innovation and diffusion processes are characterized by multiple temporal rhythms and experiences. Finally, there is cultural complexity related to innovations being contested within different contexts and hence they do not diffuse without being altered or transformed by these contexts. These complexities resonate with the nature of

the construction industry and call for new extensions to diffusion of innovations theory to understand how construction project-based firms organize around and cope with continuous waves of digital innovations to remain competitive in uncertain times during changing environments.

Digital innovation in construction

Today's pervasive digital technologies and working practices have important characteristics which influence their diffusion. They are unbounded innovations affecting multiple spheres of influences (Harty, 2005); their adoption induces wakes of innovations in a community's tools, technologies, work practices, and organization structures and strategies (Boland *et al.*, 2007); and they are increasingly becoming combinatorial, combining existing modules with embedded digital capabilities (Youngjin *et al.*, 2012). This unbounded, mutating and combinatorial nature of the digital innovation has important implications for diffusion of innovations research, especially when defining the innovation or capturing its attributes before any consideration of diffusion processes.

Current definitions of digital innovation in construction vary depending on how the digital technology and process are considered, whether separately or dependent on each other. These definitions range from the ones focusing on the digital representation of information using different software applications and modelling techniques (Azhar, 2011), to definitions that place more focus on the collaboration and management issues around digital delivery of projects (Davies and Harty, 2013). And while design and engineering technologies are often developed outside the sector, construction firms provide the vision and strategy for the use of such technologies in projects (Whyte, 2003), leading to their consideration as infrastructure for construction work and organizations (Whyte and Lobo, 2010).

The digital innovation in this study is considered as comprised of technology, processes and standards, and is defined as: the technologies and associated digital working practices used for the management and delivery of projects in construction. This includes technologies used for the manipulation of design, whether in the form of 3D or other visualization techniques such as virtual reality for example, and also the coordination of and collaboration around digital data through standards, workflows and processes. This initial conception draws on more technical definitions which emphasize the interrelated components of digital innovation along with considering the more social practices and processes which support the technology. Building information modelling is an example of this digital innovation as it encompasses technologies and processes. However, the investigation of change in firms and how the digital innovation evolves over time is yet to be undertaken through empirical study in order to open avenues for a more comprehensive definition of digital innovation in construction.

Diffusion of innovations in construction

A growing body of research is applying diffusion of innovations theory in construction and drawing on Rogers' (2003) seminal work. However, the original linear model is often found to need modification (Emmitt, 1997) or integration with other social sciences theories such as change management (Peansupap, 2004; Peansupap and Walker, 2005) or social network analysis (Larsen, 2005) to account for the complexity of construction as a social system for diffusion, where multiple actors and interfaces influence diffusion processes over time (Blindenbach-Driessen and Van Den Ende, 2006; Manley, 2008; Widén *et al.*, 2009). In the following sections important constructs from both linear and non-linear models of diffusion of innovations are discussed in order to establish the theoretical foundations for the empirical investigation of this research.

The temporality of diffusion

Departing from the linear approach to diffusion, construction scholars propose more iterative processes with various feedback loops, evident in Slaughter's cycle of innovation in construction which comprises six cyclical stages: identification of potential alternatives to achieve specified objectives; evaluation of a set of alternatives to the project objectives; commitment by the firm to the selected innovation; detailed preparation for the implementation of the innovation; actual use of the innovation; and post-use evaluation (Slaughter, 2000). Moreover, Emmitt accounted for the inter-organizational nature of construction work, and the possibility of product change during the tender or construction stages and extended Rogers' model by adding the new two sub-stages are the tender action as a sub-stage of decision, and the specification substitution as extention to the implementation stage (Emmitt, 1997).

Diffusion studies in construction also differentiate between two levels of diffusion within construction firms. For example, Mitropoulos and Tatum recognize two distinct decision-making processes: a company-level rational process performed by top management which focuses on maximizing the benefits, selecting

the best technology, and maximizing the probability of success; and a project-level behavioural process which is performed by project managers and focuses on minimizing the costs and exposure, and followed by an opportunity-based experimentation approach to innovation (Mitropoulos and Tatum, 1999). Likewise, Peansupap and Walker (2006) propose a two-stage model for diffusion based on the initial adoption by the firm, and the actual implementation by individual users or groups within the firm. Whilst retaining linear orientation, these studies demonstrate the uneven and heterogeneous paths through which innovations in construction contexts diffuse. They do not go as far as arguing for co-evolutionary complexity, but do point towards something other than a stable and unitary landscape within which diffusion occurs over time.

Non-linear approaches started to emerge in construction. One example of these is proposed by Manley (2008) based on a three-construct model which accounts for the innovation and diffusion process as the result of the interaction between the environment surrounding the firm and the diffusion process; the firm capabilities and the processes employed to build it over time; and the characteristics of the construction innovation, which Manley recognizes as multidimensional. Despite the focus being on small construction firms, this development improves the understanding of the relational and cultural complexities of diffusion processes in the construction context.

Communication channels and network development

Classic diffusion research places great attention on how adopters gain knowledge about the innovation; hence the focus was on external sources of information such as media channels and interpersonal communication (Rogers, 2003). However, while considering the relational and cultural complexities of diffusion in the construction context, the concept of communication channels is approached differently by construction researchers. Issues such as communication dynamics and networks (Harkola, 1994; Larsen and Ballal, 2005), and information management and awareness processes (Emmitt, 2001c; Lees and Sexton, 2014) can be key factors in attempts to address how construction innovations travel within and across the complex landscape of construction firms.

Interactions among different actors within construction firms and their influence on diffusion have been found to vary through the diffusion process over time. The network activity and channels change over time and are perhaps different in early stages to later diffusion processes, and activities of network and channel building are important, especially in early diffusion (Harkola, 1994; Larsen and Ballal, 2005). Awareness and how construction firms come into contact with innovations are also argued to influence diffusion patterns; this depends on whether construction professionals are actively seeking new information or passively busy with other tasks (Emmitt, 1997, 2001b). Adoption of innovations is often motivated by how those innovations provide technical efficiency, cost-benefit, and minimum disruption to the standard range of products for the firm (Lees and Sexton, 2014).

This focus on awareness and knowledge processes for diffusion is useful for bounded innovations such as building products and technologies; however, this does assume an existing and unproblematic and relatively distinct innovation is present to discover. The relational complexity (Garud *et al.*, 2013) and the combinatorial nature (Youngjin *et al.*, 2012) of digital innovations might suggest different dynamics to communication and network building, as well as challenging the notion of minimum disruption.

Diffusion across social systems

Early work in innovation in construction firms advocated that the organization for innovation in construction firms requires attention to inter- and intra-firm coordination and the structure of the firm as well as working practices and routines (Tatum, 1989). Important factors related to the organization of construction firms as the social system where diffusion takes place are found to be conducive to innovation and diffusion (Blindenbach-Driessen and Van Den Ende, 2006). Within the firm, these are concerned with engaging all possible groups in the early evaluation of alternatives, developing broad and deep technical capabilities, and encouraging and providing the resources and time for early experimentation with new ideas (Tatum, 1989). This also has been extended to consider the influence of the wider construction industry on a firm's innovation (Widén *et al.*, 2009). More recent work in diffusion of innovations in construction has built on these inter- and intra-firm dynamics and turned the attention to managing the firm's different organizational, regulative and work interfaces and aligning the innovations with the firm's current working practices and routines (Taylor, 2007).

This demonstrates that diffusion in construction contexts can move across different social systems: firms, projects, sectors and so on. This leads to both temporal complexities, where innovations diffuse according to different rhythms, and cultural complexities, as they are moving across a range of institutional and organizational contexts.

Champions and early adopters

One important concept associated with innovation and diffusion is that of the innovation champion. Research in diffusion of innovations in construction extended classic diffusion research with regard to innovation champions to address different forms of championship in construction which are mainly motivated by the project-based nature of construction work. Construction firms are found to require a different and earlier concept of the champion, including the visionary who sees change as opportunity and welcomes all forms of competition because they improve the firm technologically and the iconoclast who discovers disguised opportunities (Tatum, 1989). Furthermore, as construction is knowledge intensive and based on a wide range of technological innovations, technological gatekeepers play an important role in filtering information about new technologies and products into construction firms such as architects' offices (Emmitt, 2001c).

Construction innovation champions are not just different from other innovation champions, but also their role varies across the innovation process over time. For example, Slaughter (2000) mapped five innovation champion roles to the five implementation stages: where the *idea generator* and *gatekeeper* are needed for the identification and evaluation of the innovation, a *champion* is critical for the commitment stage, and a *project leader* and *coach* are important for the preparation and use of the innovation. Also, while drawing on Rogers' work, Harkola (1994) identified formal and informal types of opinion leaders who can be seen as repositories of organizational know-how and are able to influence decision-making only during the early, cohesive phases of diffusion.

This shows that the concept of championship in construction contains multiple roles and players at different stages of the implementation of the innovation and within different parts of the firm or project.

Together, these studies on diffusion point to a series of contextual challenges that diffusion of digital innovations in construction faces. For example, whether the different sets of existing practices and interests across multiple organizational, institutional and professional consistencies, the malleability of digital technologies or the different temporal cadences of projects, firms and sectors, the classic notion of diffusing existing innovations through established communication channels is not the focus of these studies. Previous research in diffusion of innovations in construction is largely based on the assumption that construction innovation is bounded and the construction firm is not changing; however, in reality there are many complexities which complicate this view.

Research method

Diffusion is a context-specific and time-sensitive phenomenon. Diffusion research has been (often unfairly) criticized as having several methodological weaknesses: the assumption that innovations diffuse rapidly to all members of the social system and without any changes; a focus on the individual as responsible for his or her decisions rather than the context within which the individual exists and interacts; and the inaccurate representation of the element of time through retrospective reconstruction of staged diffusion stories (Rogers, 2003). Construction with its project-based nature provides a complex context for diffusion. To understand the process with its challenges and overcome the above weaknesses 'One has to take a multilevel, longitudinal perspective, and follow events implicating actors, artefacts, and institutions over time' (Garud *et al.*, 2013, p. 803). The methodology to understand diffusion should assume that digital innovation is most likely to be affected by the diffusion process, that more than individual choice must be accounted for and that within the chronology of a diffusion process, non-linearity and iteration may be present.

To enable both contextual and processual interpretations of diffusion, the methodology adopted in this research is underpinned by two theories of methods used to understand organizational change. First, there is a longitudinal approach to fieldwork to develop *historical and developmental* (Van De Ven, 2007, p. 197) perspectives of diffusion over time. Second, there is a contextual inquiry to link the *content, context and processes* (Pettigrew, 1990, p. 268) of diffusion of digital technology together with their interconnections through time. This is achieved through an in-depth single case study (Yin, 2009) of the project-based firm EngCo. Within this contextualist approach time is emphasized to initially provide a chronology of important events, and then the analysis moves to develop a conceptual explanation of the diffusion process.

The research process comprised four fieldwork phases conducted by the first author through close interaction with EngCo between 2009 and 2013. The four phases of data collection started with an exploratory study to understand the firm and technology status quo in the summer of 2010. Further understanding of digital innovation was achieved through an interpretative investigation of the use and management of the digital innovation for project work during the summer of 2011. Then in 2012, four project case studies were conducted to investigate the diffusion of technology in projects. And finally, a strategic initiative for the diffusion of BIM was observed and analysed in the

period between November 2012 and March 2013. The research iterated between the literature, the data and the analysis to test and further extend the diffusion of innovations theory through the case of diffusion of digital innovation (Eisenhardt, 1989). Each data collection phase was informed by the analysis of the data collected for the phase before, and also by the literature.

The data is drawn from multiple sources of evidence. This included: 28 formal interviews with 30 professionals across the different organizational levels of the firm (with more than one interviewee for some interviews); observation and attendance of 20 meetings, of which 7 meetings were focused on research development and feedback; reviews of 1109 pages and 128 slides and 8 Excel sheets which were downloaded from the firm intranet or circulated by e-mail; and 40 pages of detailed field notes recorded from the meetings and informal interaction with EngCo's employees in the main office in London, through various discussions over lunch and tea and coffee breaks. Background information about the firm was also gathered from the internet.

To address the many complexities associated with diffusion of innovations in construction contexts, this research drew upon Rogers' (2003) definition of diffusion as 'the process in which an innovation is communicated through certain channels over time among the members of a social system' (Rogers, 2003, p. 5) instead of following the classic linear approach for diffusion. Therefore, the data collection and analysis was based on the four elements of diffusion originally defined by Rogers and adapted to this case as follows;

- The innovation: the digital technologies used for the delivery of infrastructure projects, the perceived attributes and associated outcomes;
- Communication channels: the means and mechanisms through which knowledge and learning about the digital innovation spread in the firm;
- Time: the process as it unfolds over time across the firm; and
- The complexity of the social system: EngCo as a project-based firm which is characterized by inter-organizational professional work, different levels of analysis, and multiple internal and external interfaces.

The collected data was qualitative and processual in nature as it concerned multiple units and levels of analysis with ambiguous boundaries (Langley, 1999). Hence, the data analysis followed a qualitative approach using data reduction techniques in the form of data tables and other forms of data visualization such as drawings and diagrams (Miles and Huberman, 1994). Constructing detailed stories from raw data is an analytical strategy well known for process studies, especially those in innovation, organizational change and strategic management (Pettigrew, 1990; Van De Ven and Huber, 1990; Van De Ven and Poole, 2005; Langley *et al.*, 2013). It is a primary tool for contextualist investigations (Pettigrew, 1990). In this research narrative was used as a primary analytical tool to capture important events related to the diffusion of digital innovation in EngCo, and to reveal the underlying logics that give events meaning and significance (Pettigrew, 1990). Moreover, Rogers' four elements presented above informed the thematic coding of the interview data. Each theme code included multiple sub-codes. The coding was conducted through several iterations of coding, collecting new data, and recoding.

Diffusion of the digital innovation in EngCo

The findings of this research reveal two parallel paths of organizational change and diffusion within EngCo. The first path represents the change in the organizational structure of the firm between 2009 and 2013. First, EngCo reorganized to consolidate the dispersed technology management efforts, then it restructured to balance supply with demand for projects and finally, it merged with a US company to develop global capabilities for project delivery. The second path captures the evolving diffusion process which unfolded across the firm following three distinct and interrelated phases over the four-year period: centralization of technology management, standardization of digital working practices, and globalization of digital resources. The diffusion of the digital innovation at the intersection between these two processes is presented in Figure 1 and discussed in the following section.

Organizational restructuring

EngCo went through processes of organizational change which transformed it from a UK headquartered planning, design and management consulting firm in 2009/10, to a major international arm of a US headquartered global full-service consulting, design, construction and operations firm by 2013. This change was in response to unprecedented uncertainties in its operating environment, caused by the global recession and political instabilities as discussed in the following sections.

Reorganization to consolidate and centralize technology management

EngCo was comprised of five business groups in 2009 and through 2010. These groups were: Consulting, Property, Water and power, Transport and Maritime.

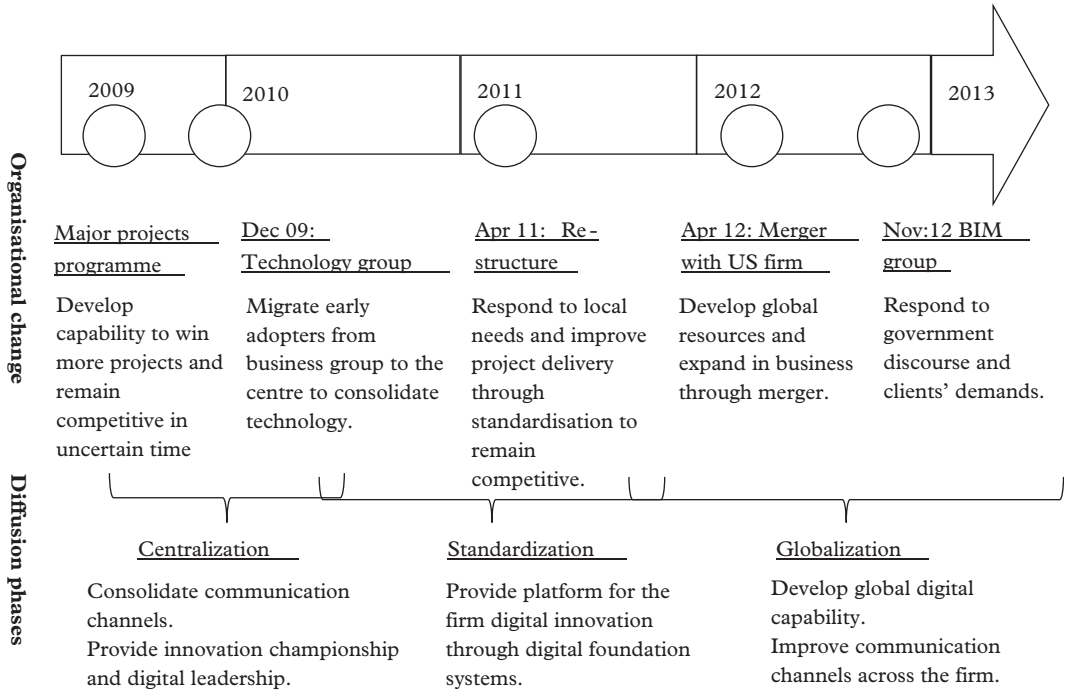

Figure 1 Organizational change and diffusion phases over the four-year period

There were various professional skill groups such as tunnelling, rail engineering, geotechnique and CAD within the five business groups. During that time EngCo's work was delivered from 90 offices in eight regions across the world. Centralized corporate services such as human resources (HR) and finance provided support to the five business groups. The Management Information Systems group was one of these centralized corporate services; it provided information and communication infrastructure across the firm.

At this time, as the data shows there was no firm-wide technology strategy; the digital technologies for project delivery were enacted and managed partially within each business group and in isolation from the other business groups. Clients' requirements, complexity of the engineering work, available skills and knowledge, and awareness about the technology and its benefits were some aspects highlighted by the interviewees which influenced the uptake of technology for projects across EngCo. The data also showed that some groups were heavily reliant on simple and widely available tools and applications such as Excel sheets, which for example were found sufficient for modelling and simulation of economic and financial information for the work of the Consulting group. While others, such as the Transportation group were using sophisticated and highly specialized software packages for the production of engineering designs as well as for the management of data and collaboration, this advanced use of technology has been attributed to the strict compliance and systems requirements of the clients of the Transportation group.

During this period of dispersed technologies and isolated digital strategies, two important events influenced the diffusion of digital innovation in EngCo. First, the Major Projects Programme, a strategic initiative put in place to enable the firm to win more major projects to remain sustainable, was initiated in early 2008 and mobilized in 2009. This firm-centric projects initiative was considered as a catalyst for the diffusion of digital innovation across the firm because it was based on adopting effective management processes for projects' bidding and delivery which required sophisticated digital tools and systems to enable collaboration and coordination between groups of professionals in EngCo's offices around the world.

The second event was the formation of a centralized technology group to manage technologies and digital strategies for projects across the firm. The Project Delivery Technology group was formed at the end of 2009 as the result of EngCo's realization of early adopters of technology in the Transportation group who were emerging across the firm as technology champions, and in response to the firm's efforts to win more major projects. By April 2010, a digital systems architect was appointed and five technology managers were migrated from the Transportation group to the newly formed group. The group Director had extensive

experience in designing and implementing tools and systems for the rail sector and had a background in civil engineering and CAD; moreover he had been with the firm for around 20 years. Three team members were responsible for the licensing, installation and technical support of the major software packages used for project delivery across EngCo's business groups, while two team members were assigned to the Major Projects Programme. This new centralized group became part of the Information Management Systems group.

Restructuring and balancing supply with demand

By 2010/11 the global recession had its effects on the construction industry, posing numerous challenges for firms such as EngCo. Examples of challenges facing EngCo were

> Shrinking and uncertain core markets; ever more demanding and cost-conscious clients; fewer, larger more complex projects; more competition and significant industry consolidation; growth opportunities in markets where we lack scale and which are distant from the centre; increasing cultural and linguistic diversity in our workforce; changing employee expectations; and scarce talent in emerging markets. (Source: EngCo's Group Board Director, PowerPoint presentation, September 2011)

Some of these challenges already existed, for example the industry competitiveness and the more demanding clients, while others were manifested by the growing globalization of the business and the emerging digital technologies like new ways of work, new markets and a more diverse workforce. To overcome these challenges, EngCo ought to strengthen its core capabilities in engineering and design, and make these available at the point of need, and at the same time understand the needs of the diverse new markets. This tension between the firm and specific needs of the local markets has been found to be difficult to resolve through EngCo's organizational structure which was set up in 2001, and as a result EngCo went through restructure.

A new organizational model took effect from April 2011 to balance supply with demand, to achieve more regional management for the business, and to ensure better quality of project delivery. The new organizational structure is based around four geographical regions; three global practice areas in tunnels and earth sciences, planning and development, and business and asset management; and several global markets such rail, power and energy, water and environment, and buildings among others; and central corporate and support services which include group business development, human resources, security, finance, health and safety, management information systems (including the Project Delivery Technology group) and corporate communications, amongst others.

EngCo's new structure emphasized the role of clients and local markets as it:

> [c]reates what is in effect a series of local businesses – managing sales, clients and projects locally but with unrestricted access to our global skills and expertise. This is a very powerful combination and is at the heart of what we mean when we say we are 'moving the whole business closer to clients'. (Source: Operating model booklet, March 2011)

It also ensured high quality and efficiency in project delivery, leading to the realization of projects' technology as an enabler for improved engineering and design capabilities to win new projects and enter new markets, and also as a global resource to enhance project delivery as discussed by an IT manager in 2011:

> it's really important that EngCo begins to recognize strategically the importance of adopting and applying these technologies and that again is something that we are looking to help the business to achieve because we don't want to be in the position where our clients are saying 'We need you to do this and we need you to do that using these particular technologies' and we say 'Actually we might struggle with doing that' because if the competitors can do that and we can't we are losing competitive advantage as well as the business efficiencies that come with applying the software that way. (IT Manager, 2011)

Technology for project work for the first time was seen as an autonomous entity different from other groups within the Management Information Systems group, which was a major shift towards the investment in and the development of the firm's digital capabilities to win strategic and major infrastructure projects and remain competitive during the global recession period. While technology was just a part of the change process for better competitiveness, the data shows that diffusion issues during this period were concerned with the push for better mobilization of technology across the restructured firm, and addressing the tensions with the local markets' opportunities and needs. Moreover, the technology itself started to emerge as means for diffusion through standardization of digital working practices.

The development of global capabilities and the merger with the American company

Six months after the implementation of the new organizational structure, EngCo was acquired by an

American global firm on 10 November 2011. The American firm specializes in full-service consulting, design, construction and operations. From April 2012 EngCo became one of the Ch2mHill companies. Following the merger the organizational structure of EngCo remained the same with three practice areas; however, reorganization took place to remove duplications of roles and responsibilities, and to achieve full integration between the two firms. At that time the Project Delivery Technology team comprised only three members, as one team member had left the firm, and the two team members assigned to support major projects moved to design and manage the digital systems for a large UK rail project. And as a result of the merger the rest of the Project Delivery Technology team were migrated into the Project Excellence team, which is a similar but bigger group within the American company.

The Project Excellence team provides a platform for common standards, processes and tools for winning and delivering work. The Project Excellence team supports the different business groups by tailoring the platform to their specific needs. Moreover, it provides a forum for sharing ideas and lessons learned to achieve excellence in project delivery. The Project Delivery Technology group fitted well within this arrangement because it put the group in place to provide centralized technology support through standardized processes based on the different needs of the various business groups globally. During this time BIM started to emerge within EngCo, and a BIM technology group was formed in response to the government initiatives, and to aid the diffusion of BIM across the different market sectors of EngCo.

Three phases of diffusion

During the organizational change, and as described above, strategic objectives and imperatives associated with the digital innovation and the technology for project delivery have evolved in response to changes in the organizational context. The previous section provided the narrative for this change, and the next subsections will describe three main phases of diffusion across the firm while dealing with uncertainties and environmental changes. These phases are shown in Figure 1.

Centralization of technology management

As shown above, challenges posed by changes in the organizational environment coupled with increasing demands by clients and advanced developments in technologies required the firm to better manage and develop its capabilities for digital project delivery. And while the digital innovation in the form of digital technologies and practices for project delivery has been enacted differently and partially within the different parts of the firm, it emerged as imperative for EngCo to gather the disparate management efforts into one central resource to technologically support all the business groups in the same way the Management Information Systems group centrally maintained the firm's IT and communication infrastructure.

The formation of the Project Delivery Technology group shows that the diffusion of digital technologies across the firm has started with synthesizing existing efforts rather than replacing it with new approaches; this is achieved through providing a platform to bring the different parts of the firm together within a central part. As discussed by the group's director and members, the role of the new group was to: coordinate and manage digital technologies for project delivery across the firm; join the fragmented systems into one central resource; champion the use of technology; and raise the firm's awareness of digital technologies for project delivery in order to maintain sustainable business. In doing so it was seen as 'a group that's almost pioneering or pushing the boundaries' (Director Project Delivery Technology, 2010). It needed to maintain the communication channels for diffusion using its new central position.

The group provided innovation championship and leadership in an uncertain context while the firm was experiencing organizational change. Examples of these processes are meetings they held with technology users to engage them in the identification of appropriate technologies for projects, and also a technology report prepared by the systems architect describing the current status of technology in the firm. The group was UK centric but then their global role started to emerge as discussed by their director in 2010:

> Our particular group isn't a global group at the moment, it's very UK centric but I think as we see our role and the technologies involved in that have an increased relevance globally, the group itself will take on a global remit and will use the same approach. (Director, Project Delivery Technology, 2010)

The data shows that the group members helped various parts of EngCo in the UK, but also they interacted with various international offices giving support and advice. For example they gave presentations to the Middle East office in late 2009 about digital data management technologies, and advised on the set-up of a local delivery office in India for the water business in 2010.

Parallel to this shift towards the consideration of digital technologies for project work and its management, BIM started to receive increased attention from EngCo; a draft BIM strategy was developed by the Project Delivery Technology and the Innovation and

Technology directors in collaboration with a few interested managers in January 2011. This was considered the starting point to build the business case for BIM adoption within EngCo. Coupled with the new direction towards standardized working practices and a more globalized firm this raised the profile of digital technologies within EngCo's agenda for improvement. However, all these efforts were still very UK centric and the changing organizational context was challenging.

The centralization of technology management within EngCo involved coordinating and synthesizing activities which were performed by the Project Delivery Technology group. In terms of diffusion this group consolidated communication channels that already existed between the firm and its different parts, especially within the UK. It started with local diffusion and then aimed to extend this globally. It also created new communication channels in response to external pressures such as the BIM agenda, and extended these channels to diffuse technology to global parts of the firm such as in India. In performing those activities and maintaining the communication channels for diffusion, the Project Delivery Technology members acted as champions relying on their experience and their new centralized position within the firm.

Standardization of digital practices

The data shows that the newly formed and centralized Project Delivery Technology group inherited a legacy of digital systems, which it found confusing, disconnected, out of date, not validated, uncontrollable and slow. This is explained by the systems architect interviewed in July 2010:

> There was a lot of tactical development, rather than strategic development, so these things – these systems just spurted out of the ground for a particular person or initiative and that initiative might have fallen away. The system's still there and it's just disconnected and people don't know whether they should be using it or not, so there's a bit of confusion. (Systems Architect, 2010)

This shows parallel diffusion processes with duplicated communication channels which can be attributed to the nature of the business as organized around projects and different market sectors and lacking a central or firm-wide digital strategy. To overcome this fragmentation, the group started to develop what they call digital foundation systems as described by the group director:

> and therefore, we're very much into putting in what we term the foundation systems that support elevated working methodologies and also will support BIM in terms of electronic document management systems, standard file naming, the ability to search and retrieve data. (Director, Project Delivery Technology, 2010)

These foundation systems were proposed to provide standardized ways of working across the different parts of the firm. They are intended to support the implementation of BIM, which was rapidly diffusing across the construction sector at that time. As such the digital innovation within this phase of diffusion started to emerge as the means for diffusion rather than laying communication channels first and then diffusing the technology. However, this development didn't come without problems and challenges which were due to the project-based nature of the firm.

While technology managers within EngCo argued that some degree of standardization of project processes is necessary to enable the firm to learn from its experience in previous projects and apply this to new projects, the proposed digital foundation systems were required to be flexible and scalable to meet the specific needs of the various market sectors, projects and clients within EngCo. This is explained by the systems architect in the following quote:

> So it's like you've got your list of deliverables, but what does that deliverable mean, put a weighting on that to record your percentage complete and stuff like that, so it's making sure that the tools that we're offering are flexible enough for the projects to be able to work within them. (Systems Architect, 2010)

Following the centralization of technology management, the standardization processes within EngCo aimed to enforce the role of the digital foundation systems as the platform for project delivery. However, this platform faced challenges and tensions between standardization across the firm and the need for customization for projects and market sectors.

Globalization of project work

The change in organizational structure in 2011 and the merger with the American firm in 2012 both strengthened EngCo's efforts in diffusing the digital innovation through building global communication channels for the diffusion of the digital innovation, and supporting the proposed digital foundation systems. However, important factors influenced this phase of diffusion through globalization. For example, the new organizational structure in 2011 reduced EngCo's regions from eight to four. Within each region there were specific teams for a number of local markets. These local teams are responsible for identifying and managing the demands of the local clients and systems of that area.

Moreover, it combined the five different business groups into three more integrated global practice areas; these, in addition to global technology teams, stand as a pool of global resources for skills and technical expertise to support the needs of the local markets.

The same tensions of standardization and customization between the local and the central exist here, with further complexity added by the shifting organizational context.

Analysis and discussion

The findings of this in-depth case study provide a narrative for the diffusion of digital innovation at times of change in a complex social system where tensions between the local and central, the unique and routine, the ad hoc and standard were dominant. The diffusion process within the firm was comprised of three main distinct and interrelated phases of: centralization of technology management, standardization of working practices across the firm, and globalization and digital capability development. The analysis suggests five insights into the diffusion process.

The innovation: incomplete digital infrastructure

The innovation observed in this research was emerging within the firm. It cannot be considered as a black box. The analysis showed that this innovation is incomplete and evolving, constituting different parts and with different effects on different organizational units. It also changes over time and has the ability to be scaled up or down depending on the need of the social system into which it diffuses, whether it is a project or a market sector. While the digital foundation systems proposed by technology managers support the conceptualization of such digital innovation as digital infrastructure for delivery (Whyte and Lobo, 2010) or platform for the firm (Youngjin *et al.*, 2012), the findings also revealed that this infrastructure is incomplete. It needs to meet the standardization agenda proposed by the technology managers while responding to the different needs of the different projects and clients. This resonates with previous studies considering the modularity (Youngjin *et al.*, 2012) or boundedness (Harty, 2005) of the innovation. However, the question that arises is how to keep some kind of control or management over these tensions between standardization and customization.

The multiple temporalities of diffusion

The findings of this research revealed three phases for diffusion of innovation in EngCo over the course of the research. Within each phase there were different diffusion processes and decisions. These processes and decisions were influenced by changes in the organizational structure and the technological choices made by the firm over time. First, when the firm's business groups were dispersed and fragmented (Dubois and Gadde, 2002), technology managers from the transportation group received the required buy-in from the business because of their technology championship to gain a central position within the firm. They immediately started on persuasion activities (Rogers, 2003) to spread knowledge about, and set the agenda for, the digital technologies for project delivery across the firm.

Then the diffusion processes moved to account for reinvention of the innovation and adaptation by the firm (Rogers, 2003) during the standardization phase when the same technology managers started to reconcile technology systems and take decisions about versions and licences for the technology. Also, the shift towards client-focused markets and understanding of local needs while being able to deliver projects from around the globe led to a technology management approach that is focused on globalization of resources. Diffusion processes at this phase were more focused on routinizing (Rogers, 2003) the digital practices and the sustainability of the technology across the different parts of the firm.

The point to be made here is that the three phases observed in this study unfolded differently within the different parts of the firm. Within these overlapping and interrelated phases of diffusion there are multiple processes of the stages identified by Rogers such as persuasion, or reinvention and adaptation by the firm. All this is happening at different rates across the various parts of the firm and involves several forms of championship. It departs from the diffusion of innovations in construction studies which followed the stage model approach to describe the diffusion of relatively bounded innovations in stable and unchanging environments (Emmitt, 1997; Peansupap, 2004). Thus, this finding responds to the debate on whether diffusion unfolds over time through specific stages or follows parallel paths (Boland *et al.*, 2007; Garud *et al.*, 2013) by showing an evolving process with multiple processes in response to changes in its environment. Whilst this is not necessarily unique, it is certainly a function of big construction firms and innovation.

Communication channels and network development

While the above discussed phases did not respond directly to a more linear account (Rogers, 2003) of stages of the diffusion process, the communication

channels for diffusion also did not appear in the classic form of mass media or interpersonal channels. Furthermore, they were influenced by the change in the organization and the phase of diffusion. First there were parallel and duplicated diffusion and communication channels across the different parts of the firm. During the centralization phase the technology managers were focused on synthesizing these communication channels. Then with the standardization and globalization efforts, the technology itself started to be the means of diffusing digital technologies and practices in the firm. This was evident in how BIM was key for spreading digital practices across the firm from 2011 onwards.

Communication channels in this case were not fixed. Instead, they were continuously configured and reconfigured depending on the diffusion processes and decisions. While scholars like Harkola (1994) and Larsen (2005) were concerned with patterns for social interaction across the diffusion stages, this research explains how technology managers within EngCo were busy removing duplicate and parallel communication channels, building new ones, and enforcing those that already existed.

Social systems

In this case, the social system and context into which the digital innovation was introduced was neither stable nor static. But the construction project-based nature of EngCo had a great effect on diffusion as well. The findings of this study revealed that the matters which were discussed as drivers for the digital innovation were also highlighted as challenges for diffusion. The digital innovation was motivated by the need for:

(1) Centralized technology management to integrate the diverse market sectors of the firm. *But*, the results of the case showed that achieving this was challenging because of the nature of EngCo's business which is organized around different market sectors and projects;
(2) Standardized working practices to overcome learning and knowledge transfer problems. *Yet*, this was also identified as challenging for diffusion because of the diversity of projects and the view by engineers that these standard systems were a kind of technology managers' 'utopia'; and
(3) Global digital resources and capabilities for global delivery of projects which can lead to improved competitive advantage. *However*, differences between regions and local norms were identified as major challenges associated with diffusion.

This finding not only confirms that construction is a complex social system for diffusion (Gann and Salter, 2000; Dubois and Gadde, 2002), but it goes further to show that there are multiple social systems within large firms such as EngCo. It also highlights important tensions in the social system between the central and local, and between the routine and the ad hoc within the firm and its projects, which have great effects on the diffusion process.

The role of champions

The evidence from this case supports the role of technology managers as innovation champions who are instrumental in supporting new digital technologies and working practices (Peansupap and Walker, 2006), or act as gatekeepers to promote innovations into the firm (Emmitt, 2001a). The case also goes further to describe the role of the firm in formalizing the efforts of these champions to enhance the diffusion process through centralization of technology management and globalization of digital resources. However, this form of championship is happening within a set of constraints such as the incompleteness of the digital innovation and the changing contexts, and where the leader or the champion is not able to make changes on their own.

Conclusion and future research

The aim was to follow and analyse the diffusion of a digital innovation in a project-based firm. This aim was founded on a practical need from engineering firms to address the government discourse for an industry that is largely based on technological promise. Building on and extending the literature in diffusion of innovations in construction, this research investigated the diffusion of digital technologies for project delivery and its associated practices in the different parts of the UK engineering project-based firm EngCo. This is achieved through the analysis of the reciprocal interaction between two distinct and parallel processes of: (1) organizational change which the firm witnessed in response to uncertainty in its operating environment, and (2) the diffusion of the digital innovation during the same period of time.

The study has important practical implications because it describes rather than prescribes the process through which the firm managed and diffused the digital innovation. This type of study is needed in construction to capture diffusion processes within one firm. This comprised a range of activities and dynamics;

the roles of changing strategies, efforts of champions, shifting social systems, new communication channels.

The developments achieved in the research can be used for the investigation of the diffusion of different types of innovations in construction project-based contexts. For example, these innovations could be: construction business innovations in the form of new procurement methods or innovative and sustainable technologies for the built environment such as the emerging energy efficiency and low carbon technologies and practices.

The findings of this case considered the firm as a whole and showed that diffusion is both time sensitive and context specific. As such, these findings should enable further investigation of diffusion dynamics for digital innovations for project delivery at the firm interface with the industry, clients and technology providers. First, there is a need to understand the diffusion of the digital innovation at the interface between the firm and the industry by understanding the dynamics and challenges of the diffusion of the digital innovation in relation to technology standards and best practice. Second, the diffusion of the digital innovation at the interface between the firm and its clients and how this influences technology choice for projects needs to be understood. Third, it is important to understand the diffusion of the digital innovation at the interface between the firm and technology providers to capture the innovation development process over time.

Acknowledgements

This work is based on a PhD research funded by an EPSRC CASE award (F3264104/14).

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Azhar, S. (2011) Building Information Modeling (BIM): trends, benefits, risks, and challenges for the AEC industry. *Leadership and Management in Engineering*, **11**(3), 241–52.

Blindenbach-Driessen, F. and van den Ende, J. (2006) Innovation in project-based firms: the context dependency of success factors. *Research Policy*, **35**(4), 545–61.

Boland, J.R.J., Lyytinen, K. and Youngjin, Y. (2007) Wakes of innovation in project networks: the case of digital 3-D representations in architecture, engineering, and construction. *Organization Science*, **18**(4), 631–47.

Cabinet Office. (2011) *Government Construction Strategy. Cabinet Office*, available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/61152/Government-Construction-Strategy_0.pdf (accessed 26 August 2015).

Connaughton, J. and Meikle, J. (2012) The changing nature of UK construction professional service firms. *Building Research & Information*, **41**(1), 95–109.

Davies, A. and Brady, T. (2000) Organisational capabilities and learning in complex product systems: towards repeatable solutions. *Research Policy*, **29**(7–8), 931.

Davies, R. and Harty, C. (2013) Measurement and exploration of individual beliefs about the consequences of building information modelling use. *Construction Management and Economics*, **31**(11), 1110–27.

Dubois, A. and Gadde, L.-E. (2002) The construction industry as a loosely coupled system: implications for productivity and innovation. *Construction Management & Economics*, **20**(7), 621.

Eisenhardt, K.M. (1989) Building theories from case study research. *Academy of Management Review*, **14**(4), 532–50.

Emmitt, S. (1997) *The diffusion of innovations in the building industry*, Unpublished PhD thesis, School of Architecture, University of Manchester.

Emmitt, S. (2001a) Technological gatekeepers: the management of trade literature by design offices. *Engineering Construction and Architectural Management*, **8**(1), 2–8.

Emmitt, S. (2001b) Observing the act of specification. *Design Studies*, **22**(5), 397–408.

Emmitt, S. (2001c) Technological gatekeepers: the management of trade literature by design offices. *Engineering Construction & Architectural Management*, **8**(1), 2–8.

Fellows, R. and Liu, A.M.M. (2012) Managing organizational interfaces in engineering construction projects: addressing fragmentation and boundary issues across multiple interfaces. *Construction Management & Economics*, **30**(8), 653–71.

Gann, D.M. and Salter, A.J. (2000) Innovation in project-based, service-enhanced firms: the construction of complex products and systems. *Research Policy*, **29**(7–8), 955.

Garud, R., Tuertscher, P. and Van de Ven, A.H. (2013) Perspectives on innovation processes. *Academy of Management Annals*, 7(1), 775–819.

HM Government. (2013) Construction 2025. In: *Partnership*, I S G a I I, Ed.

Harkola, J. (1994) *Diffusion of construction technology: in a Japanese firm*, Unpublished PhD thesis, Department of Civil Engineering, Stanford University.

Harty, C. (2005) Innovation in construction: a sociology of technology approach. *Building Research & Information*, **33**(6), 512–22.

Jewell, C., Flanagan, R. and Lu, W. (2014) The dilemma of scope and scale for construction professional service firms. *Construction Management and Economics*, **32**(5), 473–86.

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

Langley, A., Smallman, C., Tsoukas, H. and Van de Ven, A.H. (2013) Process studies of change in organization

and management: unveiling temporality, activity, and flow. *Academy of Management Journal*, **56**(1), 1–13.

Larsen, G.D. (2005) *A polymorphic framework for understadning the diffusion of innovations*, Unpublished PhD thesis, School of Construction Managment and Engineering, University of Reading.

Larsen, G.D. and Ballal, T.M.A. (2005) The diffusion of innovations within a ukci context: an explanatory framework. *Construction Management and Economics*, **23**(1), 81–91.

Lees, T. and Sexton, M. (2014) An evolutionary innovation perspective on the selection of low and zero-carbon technologies in new housing. *Building Research and Information*, **42**(3), 276–87.

Manley, K. (2008) Against the odds: small firms in Australia successfully introducing new technology on construction projects. *Research Policy*, **37**(10), 1751–64.

Miles, M. B. and Huberman, A. M. (1994) *An Expanded Sourcebook: Qualitative Data Analysis*, 2nd edn, Sage publications, Inc, Thousand Oaks, CA.

Mitropoulos, P. and Tatum, C. (1999) Technology adoption decisions in construction organizations. *Journal of Construction Engineering and Management*, **125**(5), 330–8.

NBS. (2013) *NBS International BIM Report*, RIBA Enterprises Ltd, available at http://www.thenbs.com/pdfs/NBS-International-BIM-Report_2013.pdf (accessed 26 August 2015).

Peansupap, V. (2004) *An exploratory approach to the diffusion of ICT in a project environment*, Unpublished PhD thesis, School of property, construction and project managment, RMIT University.

Peansupap, V. and Walker, D. (2005) Exploratory factors influencing information and communication technology diffusion and adoption within Australian construction organizations: a micro analysis. *Construction Innovation*, **5**(3), 135–57.

Peansupap, V. and Walker, D.H.T. (2006) Innovation diffusion at the implementation stage of a construction project: a case study of information communication technology. *Construction Management & Economics*, **24**(3), 321–32.

Pettigrew, A.M. (1990) Longitudinal field research on change: theory and practice. *Organization Science*, **1**(3), 267–92.

Rogers, E.M. (1962) *Diffusion of Innovations*, 1st edn, The Free Press og Glencoe, New York, NY.

Rogers, E.M. (1983) *Diffusion of Innovations*, 3rd edn, The Free Press, New York, NY.

Rogers, E.M. (1995) *Diffusion of Innovations*, 4th edn, Free Press, New York, NY.

Rogers, E.M. (2003) *Diffusion of Innovations*, 5th edn, Free Press, New York, NY.

Rogers, E.M. and Shoemaker, F.F. (1971) *Communication of Innovations: A Cross-Cultural Approach*, 2nd edn, The Free Press, New York, NY.

Scarbrough, H., Swan, J., Laurent, S., Bresnen, M., Edelman, L. and Newell, S. (2004) Project-based learning and the role of learning boundaries. *Organization Studies*, **25**(9), 1579–600.

Slaughter, E.S. (1998) Models of construction innovation. *Journal of Construction Engineering and Management*, **124**(3), 226.

Slaughter, E.S. (2000) Implementation of construction innovations. *Building Research & Information*, **28**(1), 2–17.

Tatum, C. (1989) Organizing to increase innovation in construction firms. *Journal of Construction Engineering and Management*, **115**(4), 602–17.

Taylor, J.E. (2007) Antecedents of successful three-dimensional computer-aided design implementation in design and construction networks. *Journal of Construction Engineering and Management*, **133**(12), 993–1002.

Van de Ven, A.H. and Poole, M.S. (2005) Alternative approaches for studying organizational change. *Organization Studies (01708406)*, **26**(9), 1377–404.

Van de Ven, A.H (2007) *Engaged Scholarship: A Guide for Organizational and Social Research*. Oxford University Press, New York, NY.

van de Ven, A.H. and Huber, G.P. (1990) Longitudinal field research methods for studying processes of organisational change. *Organization Science*, **1**(3), 213–9.

Ven, A. H. V. d., Polley, D. E., Garud, R. and Venkataraman, S. (1999) *The innovation journey*. Oxford University Press.

Whyte, J. (2003) Innovation and users: virtual reality in the construction sector. *Construction Management & Economics*, **21**(6), 565–72.

Whyte, J. and Lobo, S. (2010) Coordination and control in project-based work: digital objects and infrastructures for delivery. *Construction Management and Economics*, **28**(6), 557–67.

Widén, K., Atkin, B. and Hommen, L. (2009) Setting the game plan: the role of clients in construction innovation and diffusion, *Clients Driving Innovation*, Wiley-Blackwell, pp. 78–87.

Winch, G.M. (2014) Three domains of project organising. *International Journal of Project Management*, **32**(5), 721–31.

Yin, R.K. (2009) *Case study research design and methods*. 4th edn, Sage publications, Inc.

Youngjin, Y., Boland, R.J. Jr, Lyytinen, K. and Majchrzak, A. (2012) Organizing for innovation in the digitized world. *Organization Science*, **23**(5), 1398–408.