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DIFFUSION OF DIGITAL INNOVATION IN A PROJECT-BASED FIRM: CASE STUDY OF A UK ENGINEERING FIRM

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Digital innovations are rapidly diffusing within the construction sector. With the UK government policy mandating building information modelling (BIM) by 2016, engineering firms are faced with challenges related to embedding new technologies and associated working practices for the digital delivery of major infrastructure projects. Drawing from diffusion of innovations theory, this research attempts to answer the question of: how digital innovation diffuses in the firm? It adopts a contextualist approach through in-depth case study of a large and international engineering project-based firm. The analysis of the empirical data, which was collected over four years of close interaction with the firm, provides a narrative for the diffusion of the digital innovation across the firm where both the innovation and the firm were in flux. The diffusion process has evolved through three main mechanisms: centralisation of technology management, standardisation of digital working practices, and globalisation of digital resources. This case has both theoretical and practical implications; it describes the diffusion of a digital innovation in a complex social system. This extends diffusion of innovations studies in construction, and guide engineering firms in their efforts to adopt and implement new innovations.

Keywords: digital technology, diffusion of innovation, case study, project-based firm.

INTRODUCTION

The UK government is promoting digital innovation in the construction industry by driving digital engineering and design, it aspires to have a construction industry that is efficient and technologically advanced by 2025 (Government 2013). Moreover, the recent policy calls for “*fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic) as a minimum by 2016*” (Office 2011:14). In order for the Industry to meet the challenge, engineering firms working on infrastructure projects are required to embrace digital innovations such as building information modelling (BIM), including new technologies and associated working practices.

Construction is considered complex social system for innovation; aspects which accelerate innovation 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, and influence diffusion and innovation. Examples of these characteristics are: the inter-organisational nature of construction

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projects and firms which involves multiple actors and interfaces (Winch , Harty 2005, Fellows and Liu 2012) causing the innovation to have rippled effects over multiple spheres of influences (Harty 2005), the tensions between the unique and changing project processes and the relatively stable and standardised firm processes (Gann and Salter 2000), and the double-edged project-based learning which found to be problematic and difficult to capture (Davies and Brady 2000, Scarbrough *et al.* 2004). It is, therefore, important to understand the diffusion process within the different organisational levels of the firm over time, and capture the mechanisms through which the firm facilitate the transfer of knowledge and learning about digital technologies and practices.

Understanding the innovation attributes is critical for investigating the diffusion of that innovation (Wolfe 1994). Hence, the digital innovation under study in this paper 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 visualisation techniques, and also the coordination of and collaboration around digital data through standards, workflows and processes. Building information modelling is an example of this digital innovation as it encompasses technologies and processes.

The purpose of this paper is to investigate the diffusion of digital innovation in a project-based firm. This is achieved through a contextualist approach (Pettigrew 1990) to understand the diffusion of digital technologies for project delivery in a global engineering firm which is named EngCo in this paper for confidentiality reasons. This firm's international operations evolved over the three years of field work: it 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.

DIFFUSION OF INNOVATIONS IN CONSTRUCTION

Diffusion of innovations theory examines how new ideas move through a particular social system. While early studies of diffusion started with the analysis of the diffusion of new technologies across homogeneous population of a society (Rogers 1962, Rogers and Shoemaker 1971, Rogers 1983), more recent work examines innovation in relation to the heterogeneous organizational structures associated with firms, projects and markets (Rogers 1995, Ven *et al.* 1999, Rogers 2003, Garud, Tuertscher and Van De Ven 2013). This paradigm shift towards more complex social systems opens new doors for research, yet pose challenges to understand innovation and diffusion processes that are: "*co-evolutionary, relational, inter-temporal, and cultural*" (Garud, Tuertscher and Van De Ven 2013: 776).

Growing body of research is embracing diffusion of innovations theory in construction. Emmitt (1997) provided one of the early studies of diffusion of innovations in construction. He investigated the diffusion of new building products into architect offices, and concluded that Rogers' (1983) model of diffusion requires modifications in order to be applied in a construction context. Following the same line, Larsen and Ballal (2005) studied the social interaction across the UK construction industry through mapping three classic diffusion concepts: cohesion, structural equivalence and threshold, to Rogers' (1995) stages of the innovation diffusion process. They found that adopters of new innovations experience the three concepts in different ways at different times during the innovation diffusion process. Both Emmitt (1997) and Larsen and Ballal (2005) highlighted the importance of the

relationship between the adopters and their social system as a context for diffusion, and provided an epistemological shift that is desired to overcome the positivist view of classic diffusion research when applied into construction.

Another stream in construction management literature is concerned with the diffusion of digital innovations. For example Peansupap and Walker investigated the diffusion of intranet technology in three Australian contractors (Peansupap and Walker 2005, Peansupap and Walker 2006); they integrated diffusion of innovations model by Rogers (1995 with change management theory, and proposed a two stage model for diffusion which is based on: the initial adoption by the firm, and the actual implementation by individual users or groups within the firm. In addition to identifying six- stages process for diffusion, the authors suggested that management, individual, technology and environment considerations are critical for the diffusion of technology within the firm. Also, Taylor (2007 investigated antecedents and consequences for the diffusion of 3-D technologies in 26 design and construction firms, and proposed a framework to understand these issues at the organisation, work, technology and regulative interfaces. These Studies of the diffusion of technologies in construction found: training and technical support provided by the firm, the role of senior business managers and IT managers in driving the vision for the implementation of the innovation, technology experimentation, work distribution and standards as important factors which influence the diffusion of digital innovations in project-based firms (Peansupap and Walker 2006, Taylor 2007).

Building upon and extending this work, the research reported in this paper investigated how digital innovation diffuses in a project-based firm. It considered the reciprocal interaction between the digital innovation, the innovation champions and the project-based firm over time.

RESEARCH METHOD

The investigation of the diffusion of digital innovation in EngCo through this research followed the principles of a contextualist approach as suggested by Pettigrew (1990, by doing so, it explores the "*context, content, and process*" of diffusion together with their interconnections through time in a single case study of a project-based firm (Yin 2009). Within this contextualist approach time is emphasised to initially provide chronology of important events, and then through the analysis, it moves to more conceptual explanation of the diffusion process. Thus, the research seeks to build theory on diffusion of digital innovation from the case (Eisenhardt 1989).

The research process comprised four field work phases conducted between 2009-2013. The four phases of data collection started with exploratory study to understand the firm and technology status quo in the summer of 2010. Further understanding of the digital innovation was achieved through interpretative investigation of the use and management of the digital innovation for project work during the summer of 2011. Then in 2012 four projects 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 in a fashion that is similar to iterative grounded theory as proposed by (Orton 1997). 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 organisational 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 downloaded from the firm intranet or circulated by email; 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.

The collected data was qualitative and processual in nature as it concerned with multiple units and levels of analysis with ambiguous boundaries (Langley 1999). Hence, the data analysis followed qualitative approach using data reduction techniques in the form of data tables and other forms of data visualisation such as drawings and diagrams (Miles and Huberman 1994). Thematic coding was adopted, with four main themes derived from Rogers model (Rogers 2003), these were:

1. The innovation: digital innovation as defined above;
2. Communication channels: learning and diffusion of ideas and technology across the firm and its projects;
3. Time which indicates a process; and
4. The project-based firm as the social system where diffusion takes place.

Each theme code included multiple sub-codes. The coding was conducted through several iterations of coding, collecting new data, and recoding.

THE CASE STUDY FIRM; A JOURNY OF CHANGE

The data shows that, between 2009 and 2013 EngCo has gone through processes of reorganization, restructure and merger in response to unprecedented uncertainties in its operating environment, which caused by global recession and political instabilities. This has transformed EngCo from being a UK headquartered planning, design and management consulting firm in 2009/10, to a major international arm of a USA headquartered global full-service firm by 2013. This journey of organisational change is represented by a time line provided in figure 1.

EngCo was comprised of five business groups in 2009 and through 2010, these groups were: consulting, property, water and power, transport, and maritime. This is in addition to centralised corporate services such as human resources (HR) and finance among others. The Management Information Systems group was one of these centralised corporate services; it provided information and communication infrastructure across the firm. Furthermore, the firm's work was delivered from 90 offices on 8 regions across the world.

Global recession had its effects on the construction industry; as a result firms like EngCo faced numerous challenges such as:

“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 for the Middle East and Africa- power point presentation -September 2011)

Within the context of the firm work in infrastructure projects and the challenges posed by environmental uncertainties, engineering and design remained as the core capability for the firm to stay sustainable and gain competitive advantage. Consequently, EngCo ought to strengthen this core capability in light of new needs by the diverse new markets. This was found to be difficult to achieve through EngCo's organizational structure which was set in 2001.

With the objective to balance supply with demand, to achieve more regional management for the business, and to ensure better quality of project delivery, a new organizational model took effect from April 2011, this was based around: 4 regions (Asia and Australia, Americas, Europe, and the Middle East and Africa), and 3 global practice areas (tunnels and earth sciences, planning and development, and business and asset management), in addition to central corporate and support services.

Then, in 10 November 2011 EngCo was acquired by an American global firm which specialises on full-service consulting, design, construction, and operations. From April 2012 EngCo became one of that firm's companies. Following this merger the organizational structure of EngCo remained the same with three practice areas, however reorganization took place to remove duplications on roles and responsibilities, and achieve full integration between the two firms.

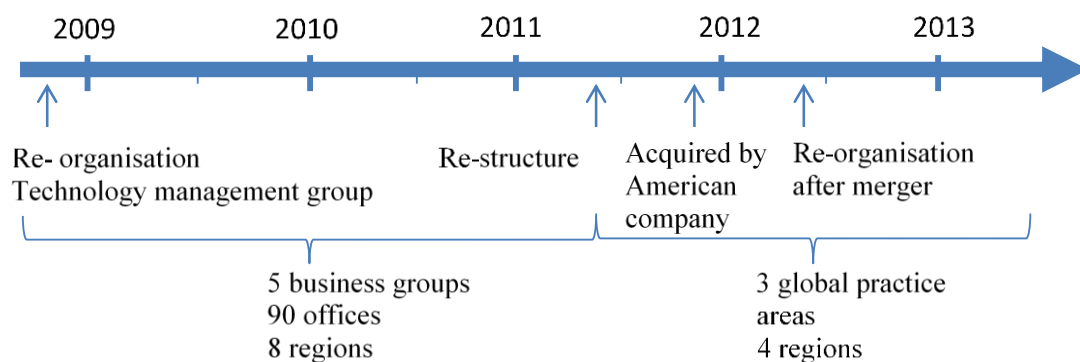


Figure 1: Timeline for EngCo's organisational change

THE DIFFUSION OF DIGITAL INNOVATION IN THE FIRM

During the firm's journey of change described above, strategic objectives and imperatives associated with the technology for project delivery have evolved in response to changes on the organizational context. The previous section provided the narrative for this change, and the next sub-sections will describe three main mechanisms which the firm adopted to diffuse the innovation while dealing with uncertainties and environmental changes. These mechanisms are: centralisation of technology management, standardisation of digital working practices, and globalisation of digital resources.

Centralisation of technology management

Increasing demands by clients and advanced developments in technologies required the firm to better develop its capabilities for digital project delivery. And while the digital innovation in the form of digital technologies and associated digital 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.

As a result, early adopters of technology in the Transportation Business group started to attract interest from senior management, and by the end of 2009 this group of technology managers was migrated from the business group to the centre of the firm to be part of the Information Management System group. Enhanced with a newly appointed systems architect and another technology manager, by April 2010 the recently centralised Technology Management group was comprised of 6 team members. The group Director has extensive experience on designing and implementing tools and systems for the rail sector and have background in civil engineering and CAD, moreover he has 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 support global delivery of major infrastructure projects.

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 technology use, and raises 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"*.

Standardisation of digital working practices

The newly formed and centralised Technology Management group has 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)

To better manage the technology and overcome this fragmentation, the group started to develop what they call Digital Foundation Systems as described by the group director when interviewed in 2010:

"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"

(Technology Management Director 2010)

These foundation systems are proposed to provide standardized ways of working across the different parts of the firm. It will also support Building Information Modelling (BIM) implementation.

While, technology managers within EngCo argued that some degree of standardisation of project processes is necessary to enable the firm to learn from its experience in previous projects and applying this to new projects, the proposed digital foundation systems are also designed 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)

Globalisation of digital resources

The change on organisational structure in 2011 and the merger with the American firm in 2012 both strengthened the firm efforts on diffusing the digital innovation through the building of global resources for digital delivery of projects, and to support the proposed digital foundation systems. For example, the new organizational structure in 2011 reduced EngCo's regions from 8 to 4. 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, and 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 new structure which put in place in April 2011 is described by EngCo as:

"Creates 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- EngCo intranet)

Within this new organizational structure, technology was realised as enabler for improved engineering and design capabilities to win new projects and enter new markets, and also as a global resource to enhance projects delivery. Moreover, technologies for project work for the first time was seen as independent form the Management Information Systems, which was a major shift towards the investment on and the development of the firm digital capabilities for strategic projects and developments.

DISCUSSION AND CONCLUSIONS

The aim was to understand the diffusion of digital innovation in a project-based firm. This aim was founded on a practical need from engineering firms to meet the government discourse for an industry that is technologically driven. 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 in-depth case study revealed how the diffusion process takes place in not only complex but also changing organisational context, an aspect which has been underexplored in previous diffusion research.

The findings of this in-depth case study provides 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 empirical study also highlights important mechanisms through which the firm diffuses the innovation.

Evidence from this case supports the role of technology managers as innovation champions who motivate new digital technologies and working practices (Peansupap and Walker 2006), or act as gate keepers to promote new innovations into the firm (Emmitt 2001), it goes even further to describe the role of the firm on formalising the efforts of these champions to enhance the diffusion process through centralisation of technology management and globalisation of digital resources.

Moreover, as project-based literature highlights the need for integration of processes across projects and with the firm (Davies and Brady 2000, Gann and Salter 2000), the use of diffusion of innovations theory to understand digital innovation in the inter-organisational context of construction in this research revealed how standardised working practices provide the required integration through the flexible infrastructure prescribed the experienced, networked and knowledgeable technology managers.

Furthermore, this study has important practical implication because it describes rather than prescribes the process through which the firm managed and diffused the digital innovation. Future avenues for research are to continue to investigate the diffusion process after the merger with the American company and better understand the effect of change on the leadership and strategy of the firm on diffusion.

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