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Implementing process innovations in project-based firms: examining the implications on interactive processes with knowledge sources

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New process standards influence interactive processes between projects based firms and knowledge sources. As project based firms interact in a complex and highly competitive systemic innovation environments, they draw from multiple sources of knowledge for delivering design and construction activities. Literature on the management of innovations in the construction industry identifies suppliers, customers, industry groups, specialised organisations and technical standards as important knowledge sources. Research is examining the role of product innovations; little is known of new open process standards embedded in digital design tools even though they facilitate knowledge management activities. Specifically, the research examines how the use of a new process innovation ? the COBie standard, is shaping interactions with established sources of knowledge. This exploratory research is based on a case study in a large multinational design and construction firm. Data is collected through in-depth semi-structured interviews; workshops and secondary publications from the firm. Findings suggest that the firm participates in a collective even with competitors in solving problems emanating from the use of a process innovation. In the process this allows the firm to access multiple sources of knowledge. A COBie trial project involving suppliers, industry groups and clients is one example. Participation in the trial project is found to support a flexible and dynamic interactive process with knowledge sources. As a result, a project-based firm is able to remain efficient, improve quality, reduce risk and increase predictability in its design and construction activities. This is important for the firm to strategically manage its knowledge sourcing activities and remain competitive in the market.

Key words: Process standards, process innovation, project based firms, management of innovation, construction industry

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1. Introduction

New process standards have a role to play in the management of innovations in project based firms. This research investigates the implications of using a new process innovation on a project based firm's interactive processes with its knowledge sources during design and construction activities. The research draws from an ongoing case study in a large multinational design and construction firm. Using the deployment of a new standard process of managing design information as an example; the research examines how this shapes the firm's interactions with its established knowledge sources. While research on the management of innovations examines product standards (Gann, 1996); little is known of the impact of process standards embedded in digital design tools on the project based firm's capacity to manage its interactions with its knowledge sources. The research builds on previous work on the management of process innovations in project-based firms.

Suppliers, customers, industry groups, specialised organisations and technical standards are common sources of knowledge for innovation in project based firms (Reichstein et al., 2005). Knowledge is defined as localised meaningful sets of technical skills that result from repeated interactions between firms embedded in systemic innovation contexts (Antonelli and Quere, 2002). It is socially embedded and context dependant; its management is incredibly complex and requires effective integration capabilities, knowing its sources, creation, codification and transfer mechanisms (Kamara et al., 2002, Dodgson et al., 2008). Research suggests that incremental innovations have some influence on knowledge exchange (Slaughter, 1998). However, the relationship between the use of a new digitally mediated process standard and the effects on a project based firm's interactive processes with its knowledge sources is still to be empirically examined.

The research draws from the literature on the management of innovations in the construction industry. It seeks to understand how the use of new common process standards shapes the project based firm's knowledge sourcing activities. Digitally embedded process standards facilitate design information sharing between inter-organisational teams. The use of COBie as an open process of exchanging design information is examined in detail in the findings section. The next section reviews literature on the management of innovations in project based firms. The remaining sections reviews: research methods, empirical findings and discuss the implications of the findings to the literature. The final section concludes the research and suggests directions for future work.

2. Innovation processes activities in project based firms

The economics of innovation literature is informed by a view that technological change (innovation) is a source of growth, productivity and competition in firms (Freeman, 1985, Schumpeter, 1942). Innovation is viewed as new or changes in products, processes, production technology, combinations of knowledge and its sources, and the successful commercialisation of new ideas (Schumpeter, 1934, Dodgson, 2011). Technology is defined here as "a replicable artefact with practical application, and knowledge that enables it to be developed and used" (Dodgson et al., 2008 p.2). According to economics of innovation school of thought product standards provide a means by which resources can be economically employed in the production of goods and services (Freeman, 1995, Nelson and Nelson, 2002). However, this view is largely informed by and based on research on production in manufacturing industries (Freeman,

1982). Furthermore studies are largely informed by views of production activities in repeatable settings (Nelson and Winter, 1982); project based firms are different (Gann and Salter, 2000). Scholars investigating innovation in the construction industry are observing the need for a different approach to understanding construction innovation processes (Slaughter, 1998).

Research on the management of innovation emphasises the systemic nature of knowledge exchange practices. Project based firms exchange with suppliers, regulators, research and development organisations and clients in systemic innovation contexts (Miozzo and Dewick, 2004, Whyte and Sexton, 2011, Gann and Salter, 2000). Scholars like Gann, Salter, Dodgson, have termed this the “fifth generation innovation process” (Dodgson et al., 2008 p.63). Frameworks for understanding knowledge flows in the industry have been proposed (Blayse and Manley, 2004, Slaughter, 1998, Gann and Salter, 2000), however research is based on projects. Figure 1 below, proposed by Gann and Salter (2000) shows a framework for understanding knowledge flows from the different sources. Despite its wide acceptance among innovation scholars, the systemic focus has been criticised for addressing the national context, yet globalisation has dissipated the nation state (Carlsson, 2006). Moreover systems are dynamic, complex and change so often that developing a coherent framework and establishing a consistent methodological approach for examining innovation activities in such context is almost futile (Carlsson et al., 2002). Little is known on how these systems are mobilised in day to day digital practice (Lundvall, 2007). In spite of the criticisms levelled against this approach, construction innovation scholars are increasingly using it to examine knowledge flows and its sources in design and construction practice (Gann, 2000, Dodgson et al., 2008).

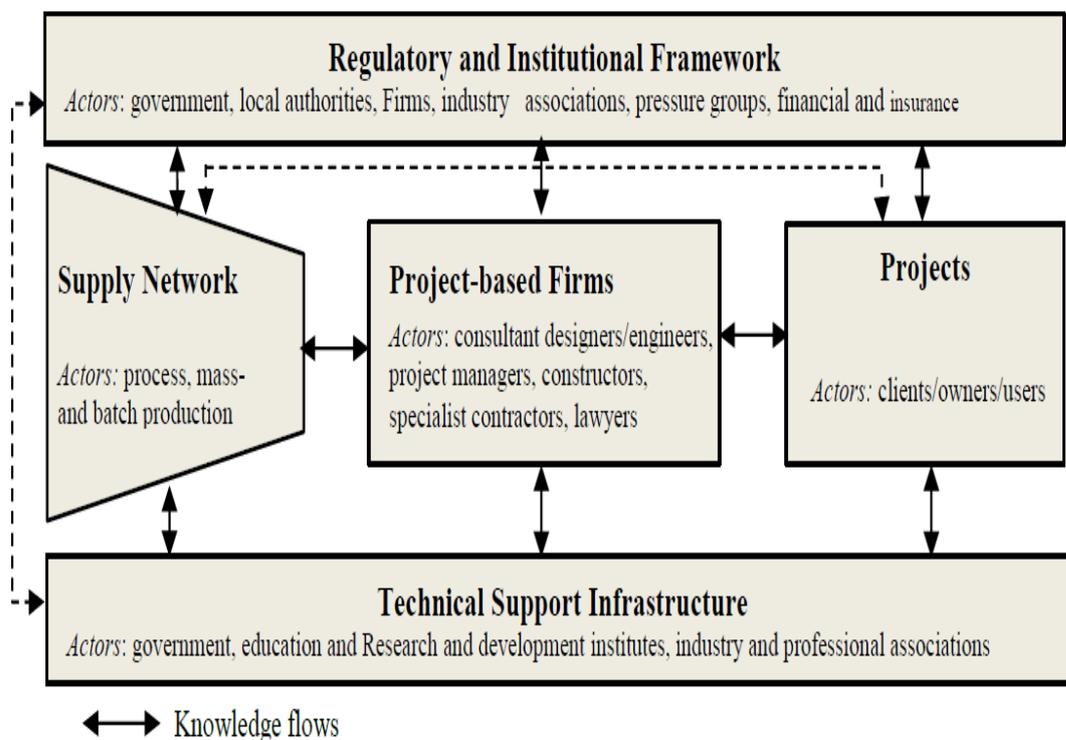


Figure 1- Framework for innovation in construction projects (Source: Gann and Salter, 2000 p.960)

Scholars distinguish between firms and project-based firms. While firms are involved in “... stable production networks in which standard mass-produced products and services are delivered” (Gann and Salter, 2000 p.956), project based firms are involved in the delivery of

complex products and systems in temporary and unique project settings (Brusoni et al., 1998). Design and construction firms are commonly referred as project-based firms because most of their economic activities are executed on projects (Gann and Salter, 2000). The ability to simultaneously integrate and share knowledge between projects and from the firm's institutional environment are observed as crucial requirements (Winch, 2010). Project-based firms face unique challenges in utilising their sources of knowledge due to the nature of their activities and the environment in which they operate (Seaden and Manseau, 2001).

Research distinguishes between codified and tacit knowledge. While codified knowledge is knowledge that can be communicated, tacit knowledge cannot be codified; it is only sharable through observation and imitation (Antonelli and Quere, 2002, Dodgson et al., 2003). Previous studies emphasise that the nature of construction projects and their delivery affects the management of codified and tacit knowledge (Johnson, 2007, Dougherty and Dunne, 2012). Since knowledge resides in humans and projects are predominantly made up of temporary human teams that disband upon completion (Dodgson et al., 2008, Winch, 1998), it is difficult to manage its sources, creation, retention and exchange.

According to Blayse and Manley (2004), project based firms rely on clients, structures of production, relationships between firms, procurement systems, structures of the industry, technical standards and internal resources for sourcing knowledge. Gann and Salter (2000) identify the main sources of knowledge as project based firms, regulatory institutions, technical support infrastructure and supply networks. Research contrasts the systemic flow of knowledge between different sources and the structural features of the industry. Winch observe that the industry's structural features affect learning and knowledge flows between projects, and between projects and firms (Winch, 1998). Others suggest the firm level relationships between project based firms and universities, governments and suppliers are the main drivers of knowledge exchange (Gann, 2001, Salter and Gann, 2003a).

The role of product, process and technical standards has been examined by construction innovation scholars (Gann, 1996, Henderson, 2007). Some innovation researchers define product standards as popular characteristics of a product designed to minimise selection and diversity in production and use (Fagerberg et al., 2005, Blind, 2009). A source of knowledge for innovation is through managing knowledge about the compatibility of the different product component interfaces. Process standards are open, socially and digitally embedded repeatable best practices or voluntary norms which govern human behaviour (Hawkins et al., 1995). Firms use process standards as a means of transporting knowledge and learning between different domains involved production activities (Nelson and Nelson, 2002). Sceptics argue that standardised processes' adverse effects are in constraining humans into established practices thus affecting their search for new alternatives (David, 1985).

Scholars examining innovation processes in design and construction practice identify the use of use of digital tools or products such as building information modelling (BIM) as important for sharing knowledge in project based firms (Whyte and Lobo, 2010). Less attention is being devoted to the effects of such tools to a firm's knowledge sourcing activities. Moreover, the role of embedded processes in digital technologies remains largely unexamined. The literature on digital practices is largely informed by research on construction projects (Neff et al., 2010, Dossick and Neff, 2009), yet such digital tools and embedded protocols are supporting inter-organisational team collaborations (Taylor, 2007). Standards are considered useful for

managing interoperability and interchangeable use of information in design and construction practice (Sacks et al., 2010). Even as research views and explores BIM as a combination of different product standards (Eastman et al., 2010), a view of BIM as a new digitally mediated process of regulating interactions between both humans and digital tools is still to gain traction. While researchers observe that in systemic project based contexts product standards are useful in managing the interface between different digital technologies (Ling, 2003), the impact of standard processes in project based firms remains largely unexplored.

A process view of construction activities has been proposed in studies on business process reviews aimed at quality improvement (Kagioglou et al., 2000). Researchers observe the need for integrating information technologies (IT) with standardised process protocols in design and construction practices (Aouad et al., 1999). Even these studies are based on construction projects. More-so emphasis is placed on the interactive processes between digital tools and yet the practice of digital design involves multiple forms of interaction (Salter and Gann, 2003b).

3. Research method

This main research for this paper is based on an ongoing inductive exploratory study which is examining the implications of mediated process standards (BIM) on digital design and construction activities. This paper examines the implications of a recently developed COBie standard on a project based firm's management of its knowledge sources. A framework proposed by Gann and Salter is used to examine in-depth the impact of this process innovation on the project based firm's knowledge management activities. The research is based on a case study of a large multinational design and construction firm.

Data collection involved 5 semi structured interviews conducted on site, an industry level feedback workshop designed to share best practice from the COBie trial project and secondary documents provided by the firm. The intention of the study was to understand how COBie is used in day to day practice, its benefits and setbacks and how its use is affecting the firm's interactions with its sources of knowledge identified in the construction innovation framework in Fig 1. As a result a decision was taken to only focus on the professionals that are using BIM. Data collection was designed to gather evidence from participants in their natural settings. Although this form of data collection is not uncommon in management of innovation research (Salter and Gann, 2003a), it has its benefits and setbacks. One particular challenge is that it only captures the views of a limited group of set of individuals, in this instance the views of those working in the core BIM team. Most of those interviewed had an engineering background. Despite this challenge, this method enabled rich data to be collected which appreciates the mobilisation of the wider system in day to day practice. In the process the research captures specific issues in localised contexts. Wider generalisations are therefore not the priority here, instead the focus is to understand how the framework in Fig 1, is mobilised in practice.

Studies of this nature often draw from case studies involving the use of multiple sources of data (Salter and Gann, 2003a). The construction innovation framework in Fig 1 was used for identifying the sources of knowledge and guiding the interview discussions. The selected firm is a large multinational construction firm. At one point it was the largest design and construction firm in the whole world by turnover. The construction firm was selected on the basis of its participation in the implementation of BIM standards. Moreover the firm has a

history of championing the use of digital design and construction technologies. Although strategic decisions on BIM use are made at the managerial level or within the core team, it was quickly realised by the research team that practical interaction with the process standards is conducted on projects. The core BIM team provides technical support to projects that are using BIM. Despite the core team's efforts in forcing BIM use across the business, project managers retain autonomy on decisions to use BIM.

In order to capture experiences around COBie use, a decision was taken to only interview the firm's engineering professional pool (Eisenhardt, 1989). Thus far, only the core BIM implementation team has been interviewed. Later, interviews will be conducted among site engineers and project managers to understand the experiences of using COBie. So far the firm has implemented BIM standards on two projects. It is also involved in a virtual COBie trial project. All interviews were recorded for later analysis. Although the interviews are focused at the firm level, they encouraged participants to cite specific examples from their daily experiences. Data is analysed through an iterative process of identifying emergent themes, coding and continuous reviewing of the data to identify aggregate themes and central meanings.

4. Findings

4.1. UK construction industry

The scarcity of innovation in the United Kingdom's (UK) construction industry has been the subject of significant debate over the years (Joint Government and Industry Construction Review, 1994, Ministry of Public Works and Building, 1964). High profile industry reviews have recommended greater collaboration, standardisation and continuous improvement (Construction Task Force, 1998, Department of Trade and Industry, 2002), however other studies have argued that the construction industry different and innovative in its own ways (Slaughter, 1998). The introduction of process standards such as COBie has been considered an attempt by the industry to enhance inefficiencies in information sharing activities (Nisbet, 2012). Attempts to proliferate the process standards across the sector mean various initiatives aimed at championing their use are mushrooming. The UK government recently mandated the use of Building Information Modelling (BIM) on government procured contracts above £5 million from the year 2016 (CabinetOffice, 2011).

4.2. Building Information Modelling process standards

The UK construction industry has recently adopted a new process standard – Building Information modelling and COBie a part of. BIM aims to improve productivity and support collaborative working through integrating digital design and construction technologies/ Computer Aided Design (CAD) technologies, information and communication technologies, technical standards and the industry's best practices (Bimtaskgroup, 2012). BIM provides 3D visualisations of digital construction objects. It is the materialisation of an amalgam of different open standards which serve different functions such as, Industry Foundation Classes (IFC) British Standard (BS) ISO 16739; design management BS 7000; Library objects: BS 854-(1-4); Publicly Available Specification (PAS) 1192; digital building information management BS1192: 2007; COBie; International framework for dictionaries of digital objects BS ISO 12006 -3:2007; Digital information delivery manuals: BS ISO 29481:2010; Object library standards Omni class; and Uniclass2 (UK) to mention but the most popular ones.

These different standards for are used in creating and managing digital design and construction information. The standards are open for use by all and are agreed at national and international levels, and are embedded in digital design tools for use in design and construction activities. Even as these standards have been agreed at the national level, they are still being revised. A construction firm has to customise and change its practices to accommodate them in day to day practice. Reflecting on the complexities of working in such a dynamic environment in which the standards are mobilised an engineer commented:

“...if we went further than that you could see, well, we’ve covered that Uniclass isn’t supported, it’s not finished. It’s been a bit of trouble to change the tables round. We’ll still find we’ll put a Uniclass table in, it will say Omni class in Revit because they’ve hard coded the name. ... So certain things in the vendor’s software will have to change. ... We want you to substitute one classification system for another on the fly, not hard code anything because Uniclass is an emerging standard, it’ll keep changing. It will change monthly and I suppose on a contract you’ll say, well, we’re happy. We will use this version today but it might be a different one later on, which is a bit of a nightmare.”

(Interview01, 2013)

4.3. The COBie process standard

COBie originates from the USA (East, 2012). This new process standard is, “formally described as a subset of the IFC standard” (Nisbet, 2012 p.4). This means that it provides a simplified way of downloading and visualising 3D information contained in an IFC format (Teicholz, 2013). It has been embraced by the UK government for use across its contracts, and has been recommended for use across the industry (interviews, 2013). According to East, the standard aims to reduce construction costs through reducing double handling of built asset information (East et al., 2013). It supports the information exchange between clients, facility managers, building contractors, designers and facility managers throughout the design, construction and maintenance of built assets (Figure 2).

In the case study, findings suggest that COBie is being used to improve efficiency, reduce risks and maximise on the interchangeable use of information (Interviews, 2013). Engineers described how COBie can help to reduce double handling of information and minimise the arduous activities involved in creating and retaining information. Although this open standard is still going through reviews both in the UK and USA, the government has already mandated its use on public building projects and is actively supporting numerous trial projects aimed at solving ‘teething’ problems associated with the standard.

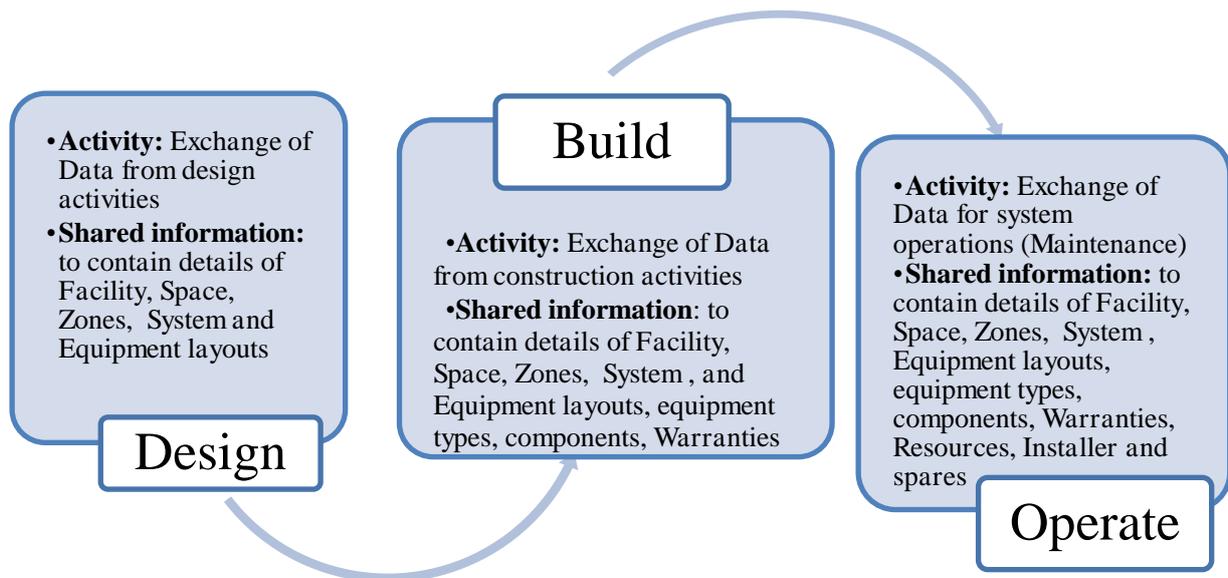


Figure 2- The COBie process adapted from (Source: Nisbet, 2012)

4.3.1. Interactions with knowledge sources

The research examined the relationship between the use of COBie in the design and construction firm and the firm's interactions with established knowledge sources. Findings suggest that COBie use is incredibly complex because of the many linkages with other standards such as the IFC standard. That the standard is still being configured further complicates use. As a result the firm relies significantly on its internal human skills to solve problems. Problems being experienced are mainly to do with unclear clients requirements which affect outputs from the standard and incompatibility with other standards. Engineers often have to develop customised solutions to deliver client's requirements. Other challenges observed are that the standard is in its infancy as a result great deal of time is lost as engineers learn the new forms of working and develop work-arounds to deliver information. In addition projects are unique to the extent that solutions or 'work-arounds' on one project cannot be easily adopted for another project. This means that the firm has to develop a dynamic knowledge management approach. Commenting on the differences on each project and challenges they face an engineer observed:

"Yeah, well, obviously, ideally if you can have a standardised way of sharing information, that would be best because we don't have to worry about anything else, we can just focus on delivering this kind of delivery method. Then is it, well, the question is, is it possible to have one standard way, because when you look at the information at an attributes level, then there is no standard way because it is defined by the employers information requirement. It's defined by that specific project. It will always be like this because one project has different elements and a different facilities management team, they might want different things at the end."

(Interview02, 2013)

The research established that the firm is obtaining knowledge more sources than those identified in the framework for construction innovation in Fig 1 (Interviews, 2013). IT providers and Standards Development Organisations (SDOs) are notably unidentified in the

framework, even though they provide an important source of knowledge for the design and construction firm’s use of COBie (Interviews, 2013). Technical standards and clients did not feature prominently as sources of knowledge in addressing COBie use problems, despite other scholars having alluded to their importance in providing knowledge more generally (Salter and Gann, 2003a, Reichstein et al., 2008). Table 1 shows the firm’s knowledge sources.

Knowledge source	Knowledge provided	Interactive process
Material suppliers	Codified	Contribution to the digital library of objects required to create IFC models. An example is the national BIM library which is proving an important source of knowledge for BIM modellers in the BIM core team and for the COBie trial project.
Government, Professional bodies and local authorities	Codified	Participation through attending conferences and workshops organised by national bodies and professional organisations such as the ICE, RICS and the BIMtask group
Standards Development Organisations	Tacit and Codified	The contractor’s BIM manager is involved in and participates in SDOs such as BuildingSmart. This allows the firm to access information on latest COBie developments.
Universities and other research organisations	Codified	Participation in the COBie trial project. Workshops organised to address COBie implementation issues.
Other project based firms	Tacit and Codified	Collective action in participating in the COBie trial project. Workshops organised to address COBie implementation issues.
IT suppliers	Tacit and Codified	Participation in the COBie trial project and providing feedbacks for solving day to day problems in integrating COBie with other digital design tools. Contributing to the national BIM library of digital objects.
Internal resources	Tacit and Codified	Face to face interactions, internal meetings and simulations. Consultants employed by the firm in design and build contracts
Clients	Tacit and Codified	Participation in the COBie trial project and providing feedbacks at seminars and conferences

Table 1 - Source: Interviews and secondary publications from the firm (reviewed 2013)

The above table 1 shows the interactive processes between the projects based firm and its knowledge sources. Crucially these findings suggests that participating in the COBie trial project allowed the firm to source knowledge directly and indirectly from different actors. However the firm also required a dynamic knowledge integration approach. These findings suggest that the firm strategically mobilised a different knowledge sharing approach depending on the type of knowledge being shared. Tacit knowledge appears to be predominantly exchanged through human interactions in specially organised face to face meetings or workshops and seminars. Codified knowledge is exchanged through IT supplier support, internet search engines and digital objects stored in the national BIM library of digital objects. In addition the firm’s knowledge pool is constantly replenished through the BIM manager and participating in collective action in the COBie trial project.

4.4. The collective knowledge sourcing approach

The COBie trial project

In order to address problems in using COBie, the firm has made a decision to participate in an ongoing COBie trial project. Engineers described the challenges of working with the variously connected process standards and how this drove the firm to participate in the trial project (Interviews, 2013). Moreover the day to day use issues compounded by the different digital tools embedded with process standards meant that the firm needed more knowledge on how to harmonise the use of the tools. The COBie trial project members included representatives from a university, 11 design and construction firms, 17 IT suppliers, 3 standards developers, 1 research and development organisation, and a number of representatives from the government (BuldingSmart-UK, 2013). One of the researchers recently attended a workshop which was organised to provide feedback to the wider construction industry.

Although momentums around a common collective are not new in the industry, studies have often focused on the development of open BIM standards (Maradza et al., 2012). The gathering of a momentum around the use of a process standard was unexpected, particularly competing construction firms. A collective approach in addressing the use of COBie was therefore unexpected, even though its benefits are increasingly being appreciated by the construction firm. Engineers explained that due to a myriad of interconnections between different standards which create a complex web, the firm required knowledge about ‘how and where’ to find knowledge solve problems (Interviews, 2013). Engineers described how this provided best practice which helped to reduce risks. An individualistic approach was considered unhelpful. Participation in the COBie trial project helped the participating firms to not only solve problems but also to gain a much needed voice to push for better knowledge from IT suppliers. An engineer observed that,

“... It’s at the end when we find something, for example we say to the IT supplier; okay this software has an issue. ... It’s a unique voice you (the group) have...”

(Interview02, 2013)

The research shows that individuals within the firm are an important source of knowledge. The BIM manager is technically savvy and involved in various industry bodies. He acts as a knowledge broker for the firm (Blayse and Manley, 2004). As a result the firm is abreast with various industry level COBie implementation initiatives. Almost all the interviewees described how his involvement helps the firm to obtain knowledge, establish new relationships and engage with a diverse source of knowledge (Interviews, 2013). They observed that this allows the firm to maintain a competitive edge against its competitors. This meant that his expertise was very useful in managing knowledge exchange between the firm and other actors especially in the COBie trail project. Moreover findings suggest that the BIM manager facilitated the transfer of good practice from the COBie trial project to other projects in the firm. Referring to the transfer of knowledge from the COBie trial project an engineer noted,

“Yes, but we’re also using the results of that to help with the Wrightington Project, so the best practices of how to export IFC from Revit for example to get the most data out. We’re using the results from the project on the Wrightington Project, so that we can get as much information out of these models as we possibly can.”

(Interview03, 2013)

Clients have been identified as key sources of innovation in previous studies (Blayse and Manley, 2004). While the role of the government as both client and regulator was prevalent throughout the research, findings suggest that less knowledge is flowing from the client especially in the use of COBie. Engineers described how clients lack skills in knowing what the deliverables from COBie. They observed that clients lack an appreciation of COBie and its benefits. As a consequence clients cannot meaningful contribute to and exchange or share knowledge with the firm. This means that the flow of knowledge is a one way process, i.e. from the construction firm to the client. In the end the firm is unable to contribute and obtain essential knowledge required to maximise on best practice to customise and deliver efficiently.

The use of COBie is still marred by complex technical challenges requiring customised solutions from multiple sources of knowledge. Engineers described how the use of COBie requires them to constantly email IT suppliers, discuss with their internal colleagues, perform simulations and search the internet to address the unique problems they face in design and construction practice (Interviews, 2013). They further observed that, the temporary nature of the construction projects, the uniqueness of each project and varying interests means that they have to draw from different sources of knowledge to address COBie use issues. As a result of this approach the firm no longer has a systematic means of managing its relationship with its sources of expertise; instead it uses a dynamic approach. The project based firm finds this useful to address the practical challenges of using a new process innovation. However, this was considered to be resulting from the fact that the technology that is still in its infancy (Interviews, 2013).

5. Discussion and Conclusion

In the context of an evolving and dynamic construction innovation system involving many actors with diverse interests, new process standards have an integral role in the sourcing of knowledge and interactive processes between actors. The advent of cutting edge digital design tools have seen changes in practices as project based firms seek to maximise their competitive advantages (Dodgson et al., 2008). However this is set back by the practice of design and construction which is emergent and contextually driven (Whyte et al., 2008). Even as standardised practices guide expectations, thus reduce change in the production process (Dossick and Neff, 2011), the practice of knowledge management in systemic contexts remains a complex construct. Of necessity is a dynamic and flexible approach which transcends individual interests. The use of a new process innovation required a project based firm to opt for collective action rather than an individualistic approach; even though this meant sharing valuable knowledge with competitors.

The prominence of IT suppliers, standards developers necessitates their inclusion in the innovation framework for understanding construction innovation (Fig 1). The introduction of a new process of managing digital information means that a firm has to interact with different sources of knowledge. Even though project based firms still utilise established practices in interacting with knowledge sources, findings point to the need for a more flexible approach which recognises the uniqueness and complexities of construction projects. Moreover the emergence of new actors could present challenges as well as opportunities for the project based firm. How the firm deals with such management issues could be important for its market performance.

This is an ongoing research into the role of new process standards on design and construction practices. The study focused on the impact of the new process on the firm's management of its knowledge sources. The research has shown that construction process innovations influence a project based firm's interactions with its knowledge sources in different ways depending on the knowledge that is being exchanged. The project based firm uses collaboration through collective participation in the COBie trial project to address problems resulting from a technology that is still in its infancy. This suggests that collective action when a process innovation is in its infancy, even with competitors as an important aspect of the firm's innovation management activities.

Furthermore the firm deploys a dynamic knowledge management approach which allows it to simultaneously obtain knowledge and deploy it elsewhere. Collective action in addressing the use of a new digitally embedded process standard allowed the firm to exploit its knowledge sources. However knowledge exploited in this way might not be readily usable hence it needs to be customised. Participation in the collective is therefore important not only important to address implementation issues but also to reduce risks and costs, and maximise efficiencies in the firm's other ongoing commitments.

While the research participants appreciated the potentiation benefits of the process innovation, almost all of them acknowledged the implications on the firm's knowledge management activities. While the intentions of introducing such a process innovation were clear, findings suggest that a new technology creates significant changes in the ways by which project based firms manage their design and construction work. The integration of socially constructed norms and values in human behaviours with technology makes it easy for actors to invisibly interact. In the context of evolving institutional, government, technical and organisational aspects, these new ways of working will increasingly play an important role. Further research is now examining in-depth the complexities of using BIM process standards on the firm's construction projects. This research has implications on the management of innovation activities in project based firms.

The research has identified the need for a dynamic knowledge sourcing and integration approach. It also observes the complexities of managing knowledge in the design and construction practice. This implies that the role of digitally embedded processes and the implications on knowledge exchange, feedbacks and interactive relationships will continue to be shaped. As design and construction work is executed by interdependent teams, it is important to understand the strategic importance of the new process innovations on productivity and competitiveness. This could be important in addressing innovation concerns raised in numerous industry level reviews.

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