Boundary-spanning for managing digital innovation in the AEC sector

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Managing projects in Architecture, Engineering, Construction (AEC) undergoes digital transformation as novel technologies emerge. Digital technologies, such as Building Information Modelling (BIM), push this transformation. Innovation happens in firms and project-based organisations where agents shape how digital technologies are adopted and implemented. This study offers insights into agents of digital innovation, by conducting engaged scholarship within the case study of one large international multi-disciplinary consultancy. The study first builds upon qualitative data collected by interviewing digital agents. Additional data, for triangulation and research validation, were collected from an internal online platform. The analysis revealed a disconnect between digital agents' technical background, skills and their managerial routines. These individuals crossed professional, hierarchical and organisational boundaries, showed multi-membership and held fluid identities. This has implications for the interfaces between organisational behaviour and projects. The study concludes with suggestions for AEC organisations to reap the benefits of digitalisation.

Keywords: digital technologies; innovation; boundary spanner; boundary theory; project manager.

Introduction

Projects and innovation are mutually inter-dependent as innovations are observed in projects and successful innovation relies on a sound project (Shenhar and Dvir, 2007). Digitisation and digitalisation increasingly monopolise the interest of management practitioners and scholars. Whereas digitisation is an operational function, digitalisation is a 'customer-driver proposition' (Ross, 2017) to make company processes digital. In the Architecture, Engineering, Construction (AEC) industry, digitalisation affects both firms and projects. For example, Building Information Modelling (BIM) transforms how projects are set up, executed (Liu et al., 2016) and delivered (Whyte et al., 2016). Projects are typically delivered through temporary Project-Based Organisations (PBO) involving multiple disciplines from AEC firms (Hobday, 2000), collocated or

geographically dispersed.

Innovation equals introducing novel artefacts or processes (Abernathy and Clark, 1985). The AEC undergoes a digital transformation where digital innovations affect organisations. BIM is touted as an important digital innovation, due to its project benefits, such as time reduction, coordination improvement, lower costs and fewer returns for information (Bryde *et al.*, 2013). This study investigates the relation between organisations and innovation focusing on how agents promote knowledge sharing about digital innovation.

The main contribution of the paper is revealing the roles of boundary agents in digital innovation in the AEC firms and PBOs. Boundary theory is used as a theoretical lens, being compatible with both temporary organisations (Engwall, 2012) and knowledge transfer (Alin *et al.*, 2013). As digital innovations change actors' roles interdependently, better understanding of roles and behaviours in digitally-enabled projects is needed. This study focuses on the soft aspects of BIM (Liu *et al.*, 2016) and aims to understand the importance of agents such as innovation brokers, by exploring boundaries they cross in their boundary-spanning capacity (Koskinen, 2008) to increase a shared understanding of innovation. Looking beyond traditional hierarchical powers that include top-down mandates, policies and strategies for change, agents act as boundary spanners to increase knowledge transfer around innovation and lead digitalisation in AEC firms and projects. The main research question (RQ) is:

> *How do agents of digital innovation mobilise boundary-spanning competences to manage innovation?*

First, the relation among projects, digital innovation agents and boundary theory is discussed. Then, the methodological rationale and methods are explained. After data analysis, findings are discussed against literature. The paper concludes with

implications and suggestions for organisations to overcome challenges of innovation adoption by deploying boundary spanners.

Theoretical basis

Relation among projects, organisations and agency

The AEC industry is project-based, and AEC projects are constrained by localised activities on-site, high degree of embeddedness (Blomquist and Packendorff, 1998) and involvement of internal and external agents. PBOs are firms set up around projects (Gann and Salter, 2000). PBOs are intrinsically innovative, formed by juxtaposing various inter-disciplinary teams to create a functional whole (Hobday, 2000) in a bespoke, temporary nature. This temporal nature of projects, brings challenges for innovation, e.g. when introducing new technologies, for lack of standard, formalised control mechanisms, described as the "*lonely project perspective*" (Engwall, 2003). Despite being seemingly temporal, projects have similar learning mechanisms as firms (Brookes *et al.*, 2017) led by project actors/agents.

The information processing approach of projects emphasises agency – as Giddens (1984) defined it – and implies that Project Management (PM) is governed by imperfect or incomplete information exchanged among actors (Winch, 2002). Galbraith (1974, p. 28), presented the information approach and a non-deterministic view of projects designed "*to create mechanisms that permit coordinated action across large numbers of interdependent roles*". Pryke and Smyth (2006, p. 23) proposed the relationship approach where "*projects are initiated, designed, managed, constructed, maintained and serviced by networks of people*", a less deterministic view of PM that focuses on agents and networks that exchange information, trust and knowledge.

Digital innovation in AEC

Innovation is the introduction of novel artefacts or processes (Abernathy and Clark, 1985). Understanding and nurturing innovations in projects is essential, as it increases productivity in project execution (Peansupap and Walker, 2006). AEC innovation is divided into two categories of product or process innovation (Winch, 2003). AEC is slow in technology take-off and adopting technological innovations (Davies and Harty, 2013).

As innovations are necessary for supporting and managing projects, an organisational view of how agents share knowledge is needed. Harty (2005) distinguished 'bounded' innovation, which does not require engagement with other disciplines, from 'unbounded' innovation, whose implications spilled across disciplines. Harty (2005) contested that understanding unbounded innovations such as three-dimensional (3D) Computer-Aided Design (CAD) within the embeddedness of construction work requires an approach that accounts for interactions among agents and technological artefacts. BIM, a successor of 3D CAD, provides various technological artefacts and digital processes that promise to revolutionise construction work. In BIM-using projects, complex socio-technical processes emerge to align agents with information artefacts (Sackey *et al.*, 2014). Consistent with business and management discourse (Ross, 2017) 'digital innovation' is heretofore referred to as 'digital'.

Building information Modelling (BIM) as digital innovation

This study chooses BIM as an instance of digital innovation to discuss how to manage digital innovations in AEC. BIM is an ubiquitous and highly pervasive digital technology that works as a 'digital platform' together with other innovations (Morgan and Papadonikolaki, 2018). BIM entails digital technologies and hybrid workflows for

sharing information among actors (Harty and Whyte, 2010). BIM offers a 'multifunctional set of instrumentalities' (Miettinen and Paavola, 2014) and 'ready packed' commercial solutions that show immediate benefits (Jacobsson and Linderoth, 2010). As its implementation implications extend across disciplines (Harty, 2005), BIM is an 'unbounded innovation'.

The impact of BIM does not only pertain to *hard* and technological aspects, e.g. processual/operational improvements but also implicate agential aspects, e.g. knowledge, commitment, trust (Liu *et al.*, 2016). BIM also delivers various *soft* gains related to better information sharing, coordination (Bryde *et al.*, 2013) and collaboration improvement (Barlish and Sullivan, 2012). The continuously evolving digital innovations and their increasing connectedness influence how organisations assess and develop their digital capabilities. This carries implications for AEC professionals who engage in roles beyond disciplines they were originally trained in (Jaradat *et al.*, 2013). Davies *et al.* (2015) stressed that personality, experience and training/education are necessary to develop social competences for collaboration, communication and negotiation using digital technologies. *Soft* competences for digital innovation are skills that do not require domain expertise or BIM-related technical skills, unlike *hard* skills that do.

Technology implementation largely depends on change management within the organisations adopting it (Thong *et al.*, 1994). Morgan (2019) suggested that organisational issues, such as leadership, human resources management, strategy, impact digital innovation adoption rate and success by firms. Because AEC is fragmented into numerous firms, to understand and deploy digital in projects, managing organisational behaviour and agency is paramount. This study focuses on agents that manage knowledge of digital innovation.

Managing boundaries to support digital innovation

Boundary objects and spanners

Boundary theory originates from sociology. Boundary objects are physical or virtual entities attributed multiple meanings (Star and Griesemer, 1989). Boundary objects are theoretical lenses to understand innovation, information systems and new technologies (Kimble *et al.*, 2010). Boundary theory relates to both management and innovation scholarship. Through shared understanding, boundary objects facilitate communication, information exchange, knowledge sharing, collaboration and innovation adoption. For Levina (2005, p. 127) only focusing on boundary objects lacks "*insight into whether an object would be effectively used in practice*" and a structurational view, from Giddens' (1984) duality of structure and agency, is needed.

Successful innovation adoption depends on communication among actors developing new competences and producing synergistic solutions to complex projects (Carlile, 2004). Managing knowledge is crucial for innovation. Agents may cross their role and knowledge boundaries as boundary-spanners (Levina and Vaast, 2005), boundary brokers (Koskinen, 2008), or mediators (Holzer, 2012). They also function as 'facilitators of design negotiations' using 'digital boundary objects' (Alin *et al.*, 2013). Boundary spanners belong and enjoy trust from different communities of practice and support knowledge transfer (Brown and Duguid, 1998) by translating and negotiating meaning across communities. Project managers typically broker across boundaries, for having 'multi-membership' of communities (Koskinen, 2008).

Scholars have problematised with positioning these cross-boundary agents inside organisations. Levina and Vaast (2005, p. 354) argued that only agents centrally positioned with "*a significant amount of symbolic capital*" are boundary-spanners-in-practice. Swan *et al.* (2016) distinguish boundary roles through five role

interpretations/enactments: *knowledge broker* (nurturers and facilitators of knowledge-sharing, not leaders), *internal consultant* (accountable to senior management and leading their communities), *avant-garde* (self-starters who push the boundary in their organisations to create new knowledge), *service provider* (coordinators providing services to customers and creating back-stage practices for their community) and *orphaned child* (experiencing abandonment and lacking support from management resulting in disempowerment). Knowledge brokers, avant-garde and orphaned child broker types dominate the back-stage, whereas internal consultants and service providers the front-stage (Swan *et al.*, 2016). Digital innovation agents facilitate knowledge-sharing and act as conduits for new relationships and knowledge.

Boundary-spanning in digital innovation

As an unbounded innovation, 3D CAD had inconsistent and less unified 'distributions of influence and expectation' across actors (Harty, 2005). Similarly, as BIM can be described as an unbounded innovation, for necessitating an approach to facilitate various interactions across multi-disciplinary actors. Project managers are centrally-positioned in project teams, however, they might not have all necessary digital and BIM-related knowledge to support digital innovation. Existing roles are adjusted, or new functions emerge, such as BIM managers and BIM coordinators (Badi and Diamantidou, 2017) to manage digital innovations. These roles carry similarities to knowledge spanners and BIM artefacts as boundary objects are highly efficient in structuring communication and negotiation. The boundary spanners do a 'balancing act', being trusted by different communities, and gradually developing a "*repertoire of shared resources such as rules, procedures and boundary objects*" in each community (Kimble *et al.*, 2010, p. 438).

Organisations leverage knowledge of innovation agents – or brokers – to support innovation adoption. Rogers (2003) recognised an innovation champion or agent as an organisational role driving innovation. For Nam and Tatum (1997) innovation agents implement innovations with authority and power. BIM displays both project-based and organisational definitions of innovation agents. A plethora of new terminologies describes BIM roles (Akintola *et al.*, 2017), project-based or organisational (Davies *et al.*, 2017, Papadonikolaki and Azzouz, 2018). Hosseini *et al.* (2018) claim that this role is same as project managers' apart from digital skills. This study focuses on *digital innovation agents* as organisational roles, drawing upon Rogers (2003). A *digital innovation agent* or 'digital agent' (as this paper refers to *digital innovation* as *digital*) is an individual who guides teams to improve processes by ensuring implementation of digital and manages resistance to change.

The theoretical lens of boundaries is used to explore how boundary spanners facilitate knowledge of digital innovations. Drawing upon emphasis on agency, the study views digital agents as knowledge spanners that facilitate and nurture knowledge-sharing and act as central points (Swan *et al.*, 2016). Whereas the terms boundary broker and boundary spanner are used interchangeably, this study uses 'boundary spanner' throughout, for its high leadership potential (Fleming and Waguespack, 2007). To form the theoretical framework and guide the research, it is synthesised that boundary spanners in digital innovation display the following features:

- Multi-membership;
- Mediation in negotiations;
- Translation of meaning;
- Facilitation of knowledge transfer.

Methodology and Methods

Methodological rationale and research strategy

The study accepts constructivist epistemology to understand how boundary spanners facilitate knowledge of digital innovation. The study follows constructivism by acknowledging that boundary-spanning and role-taking in BIM-using projects, is constructed in the minds of the agents. Because this study poses a 'how' RQ, mixed methods and data types were deployed. Creswell (1994) claimed that combining and triangulating different data sources enhances research accuracy. Gorard and Taylor (2004) challenged the dominance of monothematic research methods and supported synthesis of findings from triangulation. The RQ was addressed by two qualitative datasets and analyses, based on interviews and validation through online group discussion. These mixed methods induced communicative validity (Sarantakos, 2005) by involving participants to check data accuracy and enrich interpretations.

The empirical setting was key for data access, validity and research generalisation. The research strategy of a single-case study provided rich "*real-life context*" and inductive character (Yin, 1984). Single case studies offer 'thick descriptions' of complex and distinct phenomena unravelling in unique, bounded systems (Stake, 2008). Single cases relate to interpretivist epistemological traditions, as opposed to multiple case studies that relate to positivist traditions and used for comparison (Stake, 2008). Being consistent with the theoretical framework of boundaries and constructivism, the single case was applied to collect various qualitative data (Merriam, 1998) and work inductively to reach generalisation within the case context.

This study focuses on one international multi-disciplinary firm, offering empirical depth. This organisation – hereafter referred to as the Firm – was selected for

their well-defined digital strategy. The Firm has a dedicated world-leading Research and Development (R&D) centre which prototypes solutions and develops research agendas. It provides services that cover the AEC spectrum including planning and project management. The Firm was established in the 1950s and has over 15,000 staff from diverse disciplines located in offices in 35 countries across five continents. Previous studies researched how the Firm used simulations to facilitate communication and collaboration across disciplines (Dodgson *et al.*, 2007). The Firm uses online knowledge management systems to capture and share knowledge (Criscuolo *et al.*, 2007) that are also used in this study to increase communicative and internal validity as explained later in this section.

The study focused in the UK, where digital delivery through BIM is mandated in governmentally-regulated projects. UK government requires a fully collaborative BIM-based delivery process as a minimum for all government projects since 2016. Selecting UK as a case increases findings transferability across other countries trialling similar mandates, such as Germany and France. Kassem and Succar (2017) stated the UK digital delivery mandates show a 'top-down' innovation diffusion strategy.

Qualitative data collection and analysis

To present a pragmatic view of the digital innovation and understand the role of digital agents, qualitative data were collected and analysed by both authors. The data are derived from the Firm's UK offices. Digital innovation agents were interview informants. To increase data richness (Creswell, 1994) interviews were considered the most appropriate means to capture their input. The first author was embedded researcher (Angen, 2000) in the Firm, ensured access and collated information about digital innovation from study informants. In total, 8 digital agents were interviewed (out of 24 approached) and the sample provided saturation, when no new information was added

(Bazeley, 2013). Table 1 presents their profile, background information and roles.

<<INSERT TABLE 1 HERE>>

The 8 interviews were conducted in London and via teleconference for interviewees outside London. The questions were designed to reflect the research aim and question. Ten semi-structured open-ended questions allowed for additional follow-up questions for elaboration during the interview. The initial questions were descriptive and addressed the background of interviewees, their routine and roles as boundary spanners, e.g. soft competences and hard skills needed. Afterwards, the questions were reflective, about their daily routine, how they transfer knowledge across projects and how to accelerate digital innovation.

The transcripts were analysed through 'coding' (Miles and Huberman, 1994). The study used both deductive and inductive coding, consistent with qualitative content analysis. As there is not a definitive manner to rigorously analyse qualitative data (Robson and McCartan, 2016) the theoretical framework was used as sensitising concept for data analysis (Blumer, 1954). Constructs of the theoretical framework were used as deductive (theory-based) codes that directed the analysis of the dataset. Next, inductive codes (data-based) from repetitive concepts emerged during the interviews.

This is consistent with boundary theories, which "*lack precise reference and have no benchmarks which allow a clean-cut identification*" (Blumer, 1954). The deductive codes were terms such as 'knowledge transfer', 'teams', 'training' and so forth. The inductive codes were mainly in vivo codes, based on words or phrases directly from data (Saldanā, 2009) that presented personal and unique quotations of interviewees on their competences. Descriptive codes described their routines and innovations that they implemented in projects. All transcripts from the interviews were

combined in one database, structured and indexed to identify conceptual linkages and themes.

Triangulation and validation through online platform

Engaging in more than one data collection process can increase the credibility of findings and interpretations (Miles and Huberman, 1994). Secondary data from an internal online forum was used to triangulate and validate the findings offering empirical richness and increasing the validity of case study method (Merriam, 1998). Mixing various datasets by involving study participants to check data accuracy, improves communicative validity of research and adds depth to data (Sarantakos, 2005, p. 86). Validation is an opportunity for the informants to reflect on their input and comment on preliminary findings. In social sciences and information systems research, internal validity that takes place from post-hoc analysis and is crucial for research validation (Boudreau *et al.*, 2001).

After data collection and preliminary data analysis, the research team used the internal online forum, a knowledge management system, or expert 'yellow pages' described in Criscuolo *et al.* (2007). The following question was formulated:

> *"How do you think we can better share knowledge we create? And if knowledge has been shared, what is the best way to apply it and make the most of new initiatives we get introduced to?"*

This online forum is the Firm's knowledge forum where data and preliminary findings were presented as direct quotations. The data validation prompted participants' input, over the period of one week, after posting the question above. In total 8 employees of the Firm engaged in the online validation session, totalling 16 study informants.

Data presentation and findings

Interview data and analysis

Contribution of digital agents to innovation

When interviewed about how to master digital innovation, the interviewees offered rich perspectives and advocated a hands-on approach. As Interviewee 3 said:

> *"It is important that digital champions spend the majority of their time doing and leading real projects while taking the strategic aims of the firm as their cue for going beyond the usual."*

Through leadership, digital agents create needs, bring tools and support change management when staff is sceptical about new initiatives. One of the common themes across answers was about continuous learning in AEC, education and training. Interviewee 1 noted: "*Our role is to help focus training aspects, develop the best way to do this, and concentrate on the needs."* This was also emphasised by Interviewee 2 who explained how sharing knowledge and upgrading the digital skills of staff leads to process improvement savings by questioning existing processes: "*We need to share the skills, so they could do it themselves."*

Routines and competences

The digital agents discussed their roles and daily routines. To strengthen qualitative data reliability and avoid 'impression management' (Eisenhardt and Graebner, 2007), the interviewees were asked to give specific examples of their routines. These examples confirmed and complemented descriptions about their roles and helped summarise them. Table 2 tabulates interviewees' routines. The first column from the left contains the interviewee identifier and the second their role. The subsequent three columns present skills and competences (in vivo codes), daily routine (descriptive codes) and

role summary.

<<INSERT TABLE 2 HERE>>

The interviewees discussed various skills and competences needed to perform their role. First, technical skills were mentioned, such as knowledge of digital tools, BIM software and standards (Table 1). Interviewee 1 summarised the hard skills:

> *"Understanding of how the different collaborators are delivering their work. If they are working on different software, you have to know about the model sharing issues, IFC [Industry Foundation Classes] and where are risks of information loss."*

Similarly, Interviewee 3, added that digital agents also need understanding of the contractual context of projects:

> *"Hard skills required include a thorough knowledge of the supporting BIM standards and contractual vehicles, the common data environment approach, and hands-on knowledge of the different digital tools."*

Second, digital agents stressed the importance of soft skills to support digital innovation. Interviewee 2 stated that *"soft skills are absolutely crucial; the digital champion should have a mind-set of sharing".* Similarly, Interviewee 7 stressed that later in their role as digital agents they *"don't deal with technical stuff anymore"*. The soft competences of digital agents were also compared to *"of a salesman's or politician's way of doing things to engage people to become involved and follow"* (Interviewee 6). There was a mix of soft and hard skills and transition between the two in their roles.

The daily routines revealed either technical or organisational roles of digital agents (see Table 2). Interviewee 1 had technical role as it was mentioned that their routine involved "*reviewing the model content and (…) reviewing almost with*

Navisworks [digital planning software], (…) on the daily basis". Interviewee 8 had technical role for stating that the daily routine was a *"normal day-to-day work routine (…) A lot of it has to do with CDE [Common Data Environment] and steering people in the right direction".* Other digital agents had more flexible organisational routine. Namely, "*difficult to say, I never had a standard daily routine"* (Interviewee 2), "*daily routine is unpredictable"* (Interviewee 5) and *"routine is varying from day-to-day"* (Interviewee 6).

Delving further into roles, the digital agents explained that they belonged to various intra-organisational teams and PBOs. They engaged beyond Firm and PBOs and connected with senior management and external stakeholders. All interviewees confirmed that they became involved as digital agents informally, as the Firm "*does not formally identify a digital champion role"* (Interviewee 1). Being involved in projects as digital agent was a combination of proactivity and networking. Interviewee 1 stated: *"I put myself forward to be involved with BIM; I volunteered as I saw it as a key part of how the industry was going".* According to Interviewee 5 involvement in projects comes "*via relationships not through formal structure".* Similarly, Interviewee 7 noted being *"pulled into projects. I am the go-to person when someone wants to do BIM or digital work".*

Boundaries spanners primarily facilitate communication across groups. Similarly, the digital agents crossed various boundaries and norms as an integral part of their role. Interviewee 7 supported an open structure for leading innovations and stated that *"with lots of rules we lose innovation. (…) BIM and innovation do not go hand in hand".* Table 3 presents data on multi-membership of digital agents, regarding projects (second and third columns), internal engagement with senior management (fourth column) and external engagement with PBOs and stakeholders (fifth column).

<<INSERT TABLE 3 HERE>>

Naturally, all interviewees belonged to different PBOs. Some were involved only at the front-end, or working as technicians in projects. Others engaged with senior management of the Firm, for *"mediating with the top managers" (*Interviewee 7) and raising awareness of digital agents *"to acknowledge them"* (Interviewee 6). Most agents engaged beyond internal teams to *"lead relationships with clients"* (Interviewee 4) and *"deal with resistance from collaborators, suppliers and client teams*" at the PBOS (Interviewee 7).

Drawing upon the theoretical framework, communication was deemed key part of boundary brokers' role. Table 4 presents data on how digital agents communicated. From a summative content analysis (Hsieh and Shannon, 2005) of codes pertinent to communication, it was extracted that there were three main categories of communication in the digital agents' interviews: (1) 'conflict management', (2) 'translation of meaning' and (3) 'knowledge sharing'. Among those, conflict management was the least (n=5) occurring concept, relating with bridging boundaries among actors (Table 3). Translating meaning across domains (n=28) was a project-based function related to day-to-day communication with internal or external people (Table 3). Knowledge transfer was the most frequently (n=46) occurring construct pertinent to digital agents and it involved crossing various boundaries within PBOs and the Firm.

<<INSERT TABLE 4 HERE>>

An unexpected emerging (inductive coding) theme of the data was digital agents' identity. Upon reflection on the interviewees' involvement in projects and daily routine, fluidity and plasticity of roles emerged. Interviewee 2 shared: "*I did not know we had BIM champions. (...) we need to look at how to get more people with BIM champions*

status", which relates to their informal involvement and unclear nomination process, governed by personal relations and networks. Interviewee 8 stated: *"the acronym BIM changes how people react. They are scared of it. People seem to be happier if you just talk about a 3D model."*

This fluidity and plasticity of roles relates to digital agents' role perception. Interviewee 5 stated that *"the job title 'BIM manager' is not recognised. We have to internally come up with a new title"*. In a similar spirit, Interviewee 7 explained: *"everyone has a different idea. (…) The term BIM champion could be called instead: 'leadership in digital construction' or 'leadership and innovation in construction"*. As digital is continuously evolving, using the term 'BIM' seemed to have negative connotations. Interviewee 7 stated:

> *"We should lose the BIM terminology, talk about digital initiative and discuss new things, otherwise, it will be just a 'closed shop' for a few people."*

Validation session through online platform

To validate the previous findings, representative quotations from Interviewees 2-4 and preliminary findings from Tables 2-4 were posted online. The quotations selected were purposefully provocative to trigger discussions in the forum. Interviewee 2 posted: *"The majority of Firm is very good in sharing. But I think there are some people who think that knowledge is power. And to protect themselves they hold into their skills"*. Interviewee 4 posted: *"I think there are pockets of great things being done. But at the moment it is pockets, rather than across the board"*. By accessing the Firm's online knowledge platform, the research team had access to a broader pool of informants (in total 8 new informants), beyond the network of digital agents, to validate data and also enrich them.

The feedback included suggestions to reward digital agents for knowledge transfer, increase their happiness and reputation: *"it would be great if we could identify MVP's ("Most Valuable Players") and then reward them for their efforts"* (User-A). Others highlighted that the Firm uses 9 different web platforms to share information and stated "*dissemination where telling a story to get the information across would definitely be an improvement on an information dump"* (User-B).

Discussion

Roles of digital agents: Competences, boundary-spanning and identity

This study explored how boundary spanners facilitate knowledge sharing of digital innovations to support digitalisation in AEC. The study adopted a structurational view of communication (Levina, 2005, p. 128), drawing upon Giddens' (1984) duality of structure and agency, where boundary spanners as agents shape and are shaped by digital innovation. The empirical dataset established that digital agents crossed various boundaries to communicate knowledge of innovation.

The main theoretical contribution is revealing the roles of innovation champions in digital innovation in AEC. Previous studies, identified that construction innovation champions differ from other innovation champions (Nam and Tatum, 1997, Shibeika and Harty, 2015) and in this study, the specifics of how 'digital agents' evolve together with evolving digital innovations were presented. The analysis of digital agents' roles, routines, boundary-spanning, communication and identity, showed that they present a disconnect between their background and competences, cross professional, hierarchical and organisational boundaries and hold fluid identities (answer to RQ).

Disconnect between skills and routines

Various scholars discussed how digital innovation impact actors' roles in the AEC (Jaradat *et al.*, 2013, Davies *et al.*, 2015, Akintola *et al.*, 2017). This impact is categorised into two categories: changes in existing roles (Sebastian, 2011, Jaradat *et al.*, 2013, Davies *et al.*, 2015) and emergence of new roles (Liu *et al.*, 2016, Akintola *et al.*, 2017). As digital agents in this study were informal existing and not emerging roles (Table 1), the discussion focuses on changing roles due to digitalisation and less on role emergence. The roles are discussed through the relation between competences and enacted routines (Table 2).

Sebastian (2011) previously discussed changing roles in clients, architects and contractors due to digital delivery and associated changes in procurement, policy and project complexity. Whereas these changes are project-focused, they have intra-organisational implications (Sebastian, 2011). Interviewees discussed how their routines primarily involved meetings (Table 2, IDs-3,8) and emphasis on the front-end of projects (Table 2, ID-3). This confirms that the advent of digitalisation activates actors in undertaking new roles, beyond their disciplines (Jaradat *et al.*, 2013). Table 1 shows that interviewees with a background in engineering were called to undertake organisational roles. Others presented a disconnect between their organisational roles and their routine as digital agents that included technical tasks (Table 2, IDs-4,7). This confirms findings from Papadonikolaki and Oel (2016) regarding consultants perceiving their role as more *soft* than *hard* due to digital technologies involved.

Scholars who reported emerging new roles (Liu *et al.*, 2016, Akintola *et al.*, 2017, Davies *et al.*, 2017), initially showed ambiguity in naming and categorising them. Whereas interviewees touched upon modelling and coordination tasks (Table 2), such technical tasks and skills were not central in their routines. This study confirms

arguments by Liu *et al.* (2016) about 'soft factors' and particularly the need to show leadership to bring teams together and collaborate. Akintola *et al.* (2017) also supported that 'BIM champions' with technical roles have opportunities to show leadership comparable to managers' and architects'. Not only both soft/organisational competences and hard/technical skills are crucial for digital innovation but also there exists a dialectic and evolutionary relation between perceived skills and actualised routines. Digital agents as boundary spanners, casually cross boundaries between soft and hard routines and between perceived and required competences for those routines.

Boundary-spanning across projects and hierarchies

Project managers broker across domains, being 'multi-membership' individuals (Koskinen, 2008). The data revealed that also digital agents being knowledge brokers of digital innovation had influence at four network levels within and outside their organisation (Levina and Vaast, 2005). The data showed an extended network of internal and external relations (Table 3). They casually crossed hierarchical (internally) and organisational (externally) boundaries and frequently engaged with:

- internal project teams;
- external project stakeholders and PBOs;
- senior management within their firm;
- intra-firm network of digital agents.

The digital agents presented boundary-spanning competences at three levels: professional, hierarchical and organisational. First, these individuals display personal and professional brokering. The interviewees' profiles (Table 1) show that some had a background in social science (IDs-5,7) or outside AEC (ID-6) yet they were digital agents. More than half of them were engineers who undertook organisational roles. This

indicates that these individuals have already crossed personal and professional boundaries, being comfortable in different knowledge domains (Brown and Duguid, 1998) and inclined to become innovation agents. Davies *et al.* (2017) described that BIM specialists are expected to move beyond technical roles and show leadership mastering oral and written communication.

Second, digital agents crossed intra-organisational hierarchical boundaries. Interviewees 6 and 7 engaged with senior management (Table 3). The fact that only two out of the eight digital agents were directly engaging with senior managers, indicates that there is probably additional room to increase the diffusion of digital innovations across hierarchical levels, from top management to work-floor. Table 3 shows that digital agents exercised more external than internal boundary-spanning and were outward-looking.

Third, digital agents' boundary-spanning at an inter-organisational project level, facilitated PM functions and directly shaped the PBOs. The digital agents with technical roles were not engaging beyond the boundaries of their projects (Tables 4-5). However, the organisational-oriented digital agents were keen to move beyond firm boundaries. Whereas this study approached digital agents as organisational roles, from Rogers (2003) definition, it found evidence of both project-based and organisational routines (Davies *et al.*, 2017). The digital agents had more impact on PBOs rather than intra-organisationally (Table 3). As boundary spanners facilitate negotiations through boundary objects (Alin *et al.*, 2013), crossing boundaries to communicate, negotiate and transfer knowledge was integral. After all, the inter-disciplinary nature of digital/BIM domain (Sackey *et al.*, 2014) necessitates frequent communication among actors from different disciplines. The data revealed higher utilisation on communication for translating meaning and knowledge transfer rather than mediation (Table 4).

The facets of these three boundary-spanning competences are intertwined and should not be looked at in isolation. Digital agents who exercise personal and professional brokering, cross boundaries and implement change in open environments that enable boundary-spanning. This freedom and openness might vary across different cultural and socials contexts where hierarchies are influenced by power, seniority and gender.

Fluid identity

Rogers (2003) defined innovation agents as dynamic organisational roles responsible for developing the organisation for innovation or adjusting the innovation to fit the organisation. Whereas all interviewees concurred that the digital agent is an informal existing and not an emerging role (Table 2), there was ambiguity in role definition. The data showed that digital agents had incongruent perceptions about their skills and routines (Papadonikolaki and Oel, 2016).

Whereas this study did not initially focus on identity, this theme emerged from data. Sveningsson and Alvesson (2003) defined identity as a process where individuals continuously form, repair, maintain, strengthen or revise their roles within a discursive context. As digital innovation is volatile, it is continuously informed by its context through policies, markets, institutions and the advent of new technologies. The identities of digital agents change and adjust to fit this context. Akintola *et al.* (2017) discussed the transitory nature of newly-created BIM-related roles and argued that digital agents will only stay relevant as long as industry is learning. Digital agents are key organisational roles to drive innovation and support their organisations until it reaches an industry-wide digital maturity and project managers develop these digital capabilities instead (Hosseini *et al.*, 2018).

Swan *et al.* (2016) categorised boundary roles into five roles: knowledge broker, internal consultant, avant-garde, service provider and orphaned child. These boundary spanners facilitated knowledge in digital innovation, operated primarily at the back-stage but were neither self-motivated and ad-hoc (avant-garde), nor isolated (orphaned child) as these types do not support communication in teams (Swan *et al.*, 2016). All digital agents were knowledge brokers, positioned at project front-end and client-facing. Most digital agents acted as internal consultants, centrally positioned in the PBOs. This resonates with findings by Shibeika and Harty (2015) about construction innovation champions assuming new centralised position within firms. Accordingly, these digital agents were both central organisationally and closer to clients depending on project stage and their role (technical/organisational, Table 2). Based on their competences (Table 2), Interviewees 2 and 4-7 were hands-on service providers. Drawing upon the above, Table 5 summarises the digital agents' boundary-spanning.

<<INSERT TABLE 5 HERE>>

Reflection

Research contribution and implications

This study set out to understand the role of innovation agents in AEC digitalisation. Boundary theory was deemed compatible with both innovation, which is based on communication (Kimble *et al.*, 2010) and projects, which are made up by fluid and temporary boundaries of firms (Engwall, 2012). Consistent with constructivist epistemology, this study discussed divergences in findings compared to extant literature and facilitated theoretical dialogue.

This study contributed to theory at two levels. First, it revisited boundary theory and reaffirmed its relevance to management (Alin *et al.*, 2013) and innovation (Kimble

et al., 2010). It contributed to boundary spanners scholarship by providing rich data and evidence from AEC digitalisation (Tables 2,4). It presented how digital agents with organisational roles are keener to cross hierarchical and project-based boundaries, as opposed to technical-oriented digital agents (Table 5). Consistent with Swan *et al.* (2016) knowledge broker types, knowledge transfer was the most prominent quality of digital agents (Table 4).

Second, the theoretical contribution also lies on digital innovation and its organisational implications. The study contributed to digital innovation agents literature from an organisational perspective, as opposed to mainly technical views of BIM champions (Akintola *et al.*, 2017) and defined their socio-technical nature. Adding to previous studies on how construction innovation champions differ from other innovation champions (Nam and Tatum, 1997, Shibeika and Harty, 2015) this study explained two types of digital agents, organisational or technical (Table 5). The 'internal consultants' and 'service providers' digital agents were centrally positioned, closer to PBOs, than knowledge brokers, who are positioned at the client-facing part. Finally, the study explained how digital agents mobilise their qualities to sync in the evolving digital innovation and transfer knowledge within their firms (Tables 2,4).

Implications for practice and policy

The study widens the knowledge base of how digital innovation is applied in UK and how firms benefit from individuals with boundary-spanning competences. As digital agents are ephemeral roles relevant to project managers (Akintola *et al.*, 2017, Hosseini *et al.*, 2018), the identified boundary-spanning competences show the future of digitally-enhanced project managers. This study showed a promising way forward for leveraging the social capital of firms to develop both centrally-positioned and client-facing digital agents (Table 5). Whereas this study focused on a large-scale inter-

disciplinary firm, the following propositions extracted from the empirical data are relevant to other organisations in AEC and beyond:

- Acknowledging innovation agents come from diverse backgrounds;
- Increasing organisational awareness of innovation agents;
- Leadership training is essential to further develop innovation agents;
- Creating channels and networks for formal and informal engagement of agents;
- Incentivisation culture of knowledge sharing to avoid knowledge hoarding.

To achieve these propositions digital agents should become more visible and enhance knowledge sharing across organisational hierarchies. This could be achieved through different means such as creating learning and educational events (e.g. lunch and learn sessions, debates, panel discussions) open not only locally level, but also across regions of international firms. Global and regional BIM and digital networks could be established where grassroot efforts of individuals are supported by leadership encouragement (Morgan, 2019). Current digital agents as in this study, have shown high levels of engagement within and outside their groups (Tables 2-4) but there is a need for such digital agents to develop more networks.

Additionally, companies could create assessment tools and mechanisms focused both on projects and individuals (Succar *et al.*, 2013). By assessing digital innovations, companies will be able to identify best practices and exemplary projects. On individuals' level, assessments could be directed towards self-assessment and self-improvement. Mapping these competences should make it easier for firms to identify digital agents to support new projects. This study initiated a discussion about digital agents and their key role in crossing boundaries, creating knowledge and sharing it

within PBOs. Policy- and decision-makers should incentivise and strengthen networks of digital agents to drive innovation and spread knowledge across the industry.

Methodological contribution and research limitations

The methodological contribution included the deployment of a mixed methodology by combining different qualitative datasets for research validation, triangulation and credibility (Creswell, 1994), including novel online sources. Using triangulation from multiple data sources achieves reliability and confirms data authenticity (Sarantakos, 2005). The interviews dataset reached saturation due to repetitive information provided and is representative of this single embedded case study (Bazeley, 2013).

Research limitations relate to studying the perspective of a large inter-disciplinary design consultancy. Although findings are generalisable only in design and engineering consultancies, practical implications are also relevant to contractors and clients. Whereas the study focused on a large-scale firm where specialised infrastructures are available to enable digital agents promote innovation, the described knowledge transfer and communication mechanisms are applicable to Small Medium Enterprises (SMEs) and micro-sized firms, such as educational events, knowledge platforms and networks of digital agents. As the AEC mainly consists of SMEs, research findings are partially reflective of the sector. Because the findings relate to PBOs where numerous SMEs work, the study is representative of the industry context where SMEs can learn and benefit from digital agents of larger organisations that cross boundary to engage with external stakeholders in PBOs (Tables 3,5). Future research could investigate SMEs and perhaps shed light on innovation implementation across varying scale firms.

Whereas the study focused on only one firm, it presented a rich empirical description and replication to other large-scale international firms would reveal new

knowledge sharing patterns. The fact that the study context was undertaken in six cities in the UK, where digital delivery in governmentally-sponsored projects was mandated since 2016, makes the findings transferrable only to countries with top-down innovation diffusion strategy (Kassem and Succar, 2017). As the Firm has offices in 35 countries across all continents, potential future research could focus on issues of organisational differences across geographies. Different power, social and cultural lenses help understand how digital innovations are managed across regions.

Conclusion

The relation between projects and innovation is exemplified by agents who cross boundaries and share knowledge. This study shed new light on agents of digital innovation. The data and analysis revealed qualities of digital agents, around boundary-spanning and revealed a disconnect between role expectation and reality, multi-membership and fluid identities (answer to RQ). Namely, it first revealed a disconnect between digital agents' background, skills and routines, who engage in routines not supported by their professional skills and competences (Tables 3-4). Simultaneously, digital agents crossed project, organisational, hierarchical and professional boundaries (Table 3) to communicate for conflict resolution, meaning translation and knowledge transfer (Table 4). Their fluid identities were an unexpected knowledge contribution that implies their need to align with the continuously evolving nature of digitalisation.

The practical implications are that digital agents should be nurtured and supported within firms by breaking intra-organisational silos and providing training opportunities to allow for organic development of digital innovation in AEC. Whereas the research focused on one international multi-disciplinary design and engineering firm, the findings can be transferred to other AEC firms, such as contractors, by recognising that the digital agents can be both centrally-positioned but also client-facing

in PBOs that consult with external partners at the front-end of projects. Additionally, SMEs that work with digital agents in PBOs can benefit by engaging with large firms' digital agents and solidify their knowledge economy. Focusing on developing the social capital of firms is a promising way towards the digital transformation of AEC to increase diffusion of digital innovations across the ecosystem.

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Table 1. Profile of the Firm's *digital agents* interviewed with their identifiers (ID).

ID	Background	Years in industry	Position in Firm	Location	Group	Present title	Years in Firm
1	Building Services Engineering	15	Associate	London	Building Engineering	Mechanical Engineer	16
2	Building Services Engineering	28	Associate	Birmingham	Buildings	BIM manager	28
3	Structural Engineering	16	Associate	Edinburgh	Buildings	Structural engineer	16
4	Civil Engineering	22	Director	London	Infrastructure	Civil Engineer	22
5	English Literature	12	Senior technician	Bristol	Infrastructure	Building Information Manager	13
6	Mechanical Manufacturing	23	Senior technician	Manchester	Buildings	CAD technician	11
7	Psychology	15	Associate	London	Building Engineering	BIM & CAD Lead	5
8	Mechanical and Manufacturing Engineering	19	Senior technician	Belfast	Infrastructure	CAD / BIM Co-ordinator	2

Table 2. Role-related characteristics of *digital agents*.

	Role-related characteristics			
ID	**Present role**	**Skills and competences (in vivo codes)**	**Daily routine (descriptive codes)**	**Role summary**
1	Mechanical Engineer	*Awareness of how disciplines work and model sharing issues, contractual understanding, change management*	• BIM models review • Documentation (schedules and BIM) • Data integration	Technical
2	BIM Manager	*Open-mind, mind-set of sharing, soft skills, knowledge is power, questioning ability*	• Model sharing • Project control • Training and development • Model management	Technical
3	Structural Engineer	*Knowledge of BIM standards, process planning and mapping, meetings, soft skills, change management*	• Leadership at the front-end • Stakeholder engagement • Knowledge transfer	Technical
4	Civil Engineer	*Use of technology, understanding and selecting software packages, communication, meetings, negotiation, influence, persuasion*	• Stakeholder engagement • Team leadership • Project management • Training and development	Organisational
5	Building Information Manager	*Knowledge dissemination, understanding technology, Knowledge of BIM standards, understanding of the interfaces between people and processes*	• Training and development • Stakeholder engagement • Mentoring apprentices • Coding macro-instructions • Knowledge transfer	Technical
6	CAD Technician	*Deliverables management, time management, project management, salesman's pitch, knowledge spreading, meetings with team*	• BIM modelling • Team leadership • Working on digital software • Promoting BIM	Technical
7	BIM & CAD Lead	*Hard skills, work with different people and tools, mediation, team meetings, engagement with people, delegation, soft skills, 'selling' BIM*	• Stakeholder engagement • Team leadership • Knowledge transfer • Mediation • Promoting BIM	Organisational
8	CAD/BIM Co-coordinator	*Changing people and their ethics, knowledge of developments in the firm, meetings with team, communication*	• Model management • Training and development • Team leadership • Documentation (BIM)	Technical

Table 3. Boundary-spanning of the *digital agents*.

	Multi-membership			
ID	**Intra-firm engagement with project teams (all)**		**Intra-firm engagement with senior management**	**Project-related engagement with PBOs and external stakeholders**
	No. of projects	**Comments**		
1	6	Not all as digital agent	-	-
2	8	Involved primarily at the front-end	-	-
3	4	1-2 of which as a digital agent	-	Yes
4	10	Involved primarily at the front-end	-	Yes
5	7	And many more informally	-	Yes
6	6	At varying stages	Yes	Yes
7	5	2 of which are project bids	Yes	Yes
8	2	-	-	-

Table 4. Analysis of *digital agents'* communication.

	Communication (descriptive codes)		
	Mediation in negotiations/conflicts	**Translation of meaning across domains**	**Facilitation of knowledge transfer**
1	Mediating between architect and senior technicians	Bringing the project team together to discuss the plan	Extensively testing new solutions before sharing them in the firm
2	-	Delegating work among project team and pushing people outside comfort zone	Centrally sharing knowledge across digital champions through repositories, meetings and social media
3	Connecting experienced people and recent graduates (reverse mentoring)	Continuously engaging with external stakeholders	Bringing knowledge by selecting appropriate people for digital teams
4	-	Continuously engaging with external stakeholders and then the internal team	Sharing knowledge of good practices across the board
5	-	Bringing the project team up to speed regarding client requirements and mandates	Upskilling people; Capturing knowledge across projects
6	-	Facilitating team's understanding of various datasets and file formats; Continuously engaging with external stakeholders	Transferring knowledge from experienced people to the whole project team
7	Dealing with resistance from external stakeholders	Pointing the project team to the right direction, giving them answers	Capturing knowledge across projects; Making digital business-as-usual
8	Facilitating and supporting the transition of senior designers and engineers; Dealing with model accountability issues	Answering questions of project team about BIM models	Transferring knowledge across projects; Promoting knowledge sharing among individuals
In vivo codes	• Mediation • Connection • Resistance • Transition • Accountability	• Communicat* (n=13) • Meeting (n=8) • Question (n=3) • Answer (n=4)	• Knowledge (n=26) • Train* (n=8) • Information shar* (n=12)
Total	N=5	N=28	N=46

Table 5. Summary of the *digital agents'* boundary-spanning qualities.

			Boundary-spanning competences			**Swan et al. (2016) boundary roles enactment**				
ID	**Role summary**	**Role position**	**Professional boundaries**	**Hierarchical boundaries**	**Project-based boundaries**	**Knowledge broker**	**Internal consultant**	**Avant-garde**	**Service provider**	**Orphaned child**
1	Technical	Centrally-positioned	Yes	-	-	Yes	-	-	-	-
2	Technical	Centrally-positioned	Yes	-	-	Yes	Yes	-	Yes	-
3	Technical	Centrally-positioned	Yes	-	Yes	Yes	-	-	-	-
4	Organisational	Client-facing	Yes	-	Yes	Yes	Yes	-	Yes	-
5	Technical	Centrally-positioned	Yes	-	Yes	Yes	Yes	-	Yes	-
6	Technical	Centrally-positioned	Yes	Yes	Yes	Yes	Yes	-	Yes	-
7	Organisational	Client-facing	Yes	Yes	Yes	Yes	Yes	-	Yes	-
8	Technical	Centrally-positioned	Yes	-	-	Yes	Yes	-	-	-