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BOUNDARY SPANNING AND KNOWLEDGE BROKERING FOR DIGITAL INNOVATION

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ABSTRACT

The adoption of digital innovations in construction is a topic with growing importance, as organisations restructure to adopt and sustain innovations. Building Information Modelling (BIM) is currently at the forefront of this digital shift in Architecture, Engineering, and Construction (AEC) industry. The relation between knowledge sharing and sustained innovation adoption in organisations has been previously acknowledged by management scholars. There is further room to adopt a structurational view of knowledge and focus on how agency contributes to knowledge sharing for increasing digital innovation adoption in firms. This paper uses the theoretical lens of boundaries and boundary brokers to guide the data selection and interpret a rich dataset about boundary brokers of digital innovation. The research aim is to explore how these boundary brokers, referred to as digital innovation champions, facilitate knowledge of digital innovations and BIM to support digital transformation in firms. A single case study of a large international multi-disciplinary consultancy was used as a research setting. Data were collected through interviews with the digital champions as well as with additional data collected from the internal online platform for data triangulation and research validation. Key findings include the multi-faceted levels of boundaries crossed by the digital champions to share knowledge about digital innovation: hierarchical, professional and organisational boundaries. Namely, the digital champions were found to hold multiple memberships in groups, holding both technical and inter-personal competences as well as engaging in conflict resolution. The study concludes with implications for practice and suggests courses of actions to increase knowledge sharing in firms for innovation adoption by developing and incentivising individuals.

KEYWORDS

Boundary spanning, Building Information Modelling (BIM) adoption, digital innovation, knowledge brokers.

INTRODUCTION

Digitalisation in construction recently gains traction in Architecture, Engineering, and Construction (AEC) industry. Building Information Modelling (BIM) is at the forefront of digitalisation in the Built Environment and is being widely endorsed as an approach that will drastically transform the industry. The uptake of BIM technology is of strategic national importance in many countries. BIM radically affects technology, team structure, business processes, organisational culture and the way participants in

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construction perform their work (Gu and London 2010). With the emergence of BIM, which is currently the most popular instance of construction digitalisation, various actors are called to undertake new roles, beyond the disciplines that they were initially trained (Jaradat et al. 2013).

At an organisational level, BIM has been considered an innovative digital platform that changes how services are delivered in the Built Environment. The adoption of information technology is affected by motivation, leadership, technology-readiness and lack of skills across firms and the way large and small firms adopt BIM could induce a "digital divide" (Dainty et al. 2017). This study focuses on how organizations capture and transfer knowledge about digital technologies within their boundaries through individual roles to support the journey towards digitalization and digital transformation.

According to Carlile (2004), the understanding and successful adoption of innovations lies at the boundaries of communication among actors. Managing meaning and knowledge through communication across disciplinary boundaries is crucial for understanding innovation. According to Maaninen-Olsson et al. (2008) knowledge boundaries among different disciplines during communication are more pragmatic and complex than actors perceive them to be. Thus, reaching a 'common understanding' among actors is a crucial function of knowledge transfer. The organisational agents that may or may not cross their role boundaries in order to further facilitate knowledge transfer are defined as boundary spanners (Levina and Vaast 2005), boundary brokers (Koskinen 2008), or mediators (Holzer 2012).

With the advent of digital innovations and BIM, the increasing complexity creates pressure for firms to uptake the new digital technologies. Therefore, there is a need to not only manage knowledge but also key relevant roles for knowledge transfer that are emerging in firms. These roles are typified as transient (Akintola et al. 2017) and whereas their contribution to innovation change management is acknowledged, studies have focused more on the technical rather than organisational qualities. This study sets up to explore organisation approaches to sharing knowledge in BIM innovation, drawing upon empirical data and exploratory research through the lens of knowledge brokers. The research question is:

"How do boundary brokers facilitate knowledge of digital innovations and BIM to support digital transformation in firms?"

After this introductory section the paper is organised as follows. The ensuing section presents the theoretical framework of boundaries and boundary brokers as well as conceptualises digital innovation in construction to present how the paper studied digital innovation through the lens of boundaries. Afterwards the methodology and methods are presented. Next, the data and key findings are analysed. The paper concludes with a discussion and a conclusion section offering implications and propositions for practice.

MANAGING BOUNDARIES TO SUPPORT DIGITAL INNOVATION

BOUNDARY OBJECTS AND BROKERS

The concept of boundary objects originates from sociology, where boundary objects are physical or virtual entities that can be attributed multiple nuances of meaning (Star 2010; Star and Griesemer 1989). Boundary objects are good theoretical lenses to

understand innovation (Kimble et al. 2010), Information Systems (IS) (Barrett and Oborn 2010) and new technologies: (Fox 2011) and for different collaborative processes, such as scheduling (Chang et al. 2013; Engwall 2012) or training evaluation (Lee-Kelley and Blackman 2012). By enabling and shaping shared understanding (Star 2010), boundary objects can facilitate communication, information and knowledge exchange, collaboration and innovation adoption. Levina (2005) showed that only focusing on boundary objects provides "insufficient insight into whether an object would be effectively used in practice". A structurational view of collaboration (Levina 2005), drawing upon Giddens' (1984) duality of structure and agency, according to which an agent 'shapes' the situation and 'is shaped' by the situation is thus desired.

Agents are thus very important in joint understanding boundary objects and situations (Star 2010). Agents called boundary spanners may also cross their role boundaries (Levina and Vaast 2005). These agents are also called boundary brokers (Koskinen 2008), or mediators (Holzer 2012) with boundary spanning competences. They also function as "facilitators of design negotiations" using "digital boundary objects" (Alin et al. 2013). In communities of practice field, boundary brokers belong and have trust from different communities and support knowledge transfer among them (Brown and Duguid 1998) by translating and negotiating meaning across knowledge domains. Project managers typically broker across role boundaries and domains, as they are 'multi-membership' team members (Koskinen 2008).

Scholars have problematised with the position of these agents and knowledge brokers inside the organisation or the team. Levina and Vaast (2005) argued that only agents centrally positioned in relations and who, possess "a significant amount of symbolic capital" are boundary-spanners-in-practice. According to Swan et al. (2016), boundary roles include five distinct role interpretations: knowledge broker, internal consultant, avant-garde, service provider and orphaned child. For Swan et al. (2016), knowledge brokers, avant-garde and orphaned child broker types are dominant at the back-stage, whereas internal consultants and service providers are at the front-stage. As this paper focuses on the role of brokers for facilitating knowledge in innovation, they might operate primarily at the back-stage, due to the implementation focus of their role and be closer to the definition of knowledge brokers, because neither self-motivated (avant-garde type), not isolated (orphaned child) types (Swan et al. 2016) can support innovation as they do not support communication in teams.

BIM AS A DIGITAL INNOVATION

Innovation refers to a new product, service or process (Abernathy and Clark 1985). The close relation between innovation and projects is acknowledged due to the former being usually observed in projects (Shenhar and Dvir 2007). BIM has evolved through decades of push and pull strategies and efforts to standardise the representation of building information in AEC (Papadonikolaki 2016). Thus, it is not entirely novel as it has evolved from efforts for structuring and representing information about buildings, a predominant line of thought in the 1970s (Eastman 1999). These advancements in *building product modelling* shaped a long-standing debate on the computerisation and construction digitalisation (Eastman 1999). Nevertheless, BIM could still be seen as an innovation because apart from the technology associated to it, the associated processes and methods to implement it are novel and challenging and require change at both organisational and institutional levels (Papadonikolaki 2017).

BIM is currently at the forefront of construction digitalisation. Apart from digital representation of buildings, BIM relates to artefacts that affect the processes that technologies are adopted and implemented through. BIM is a *"multifunctional set of instrumentalities for specific purposes"* (Miettinen and Paavola 2014) and affects various actors across the AEC, while policies, processes, and technologies interact to generate a digital building (Succar et al. 2012). BIM is a set of existing and new digital technologies for generating, controlling, and managing building information. Various digital artefacts such as the Common Data Environment (CDE), an online platform to exchange files, BIM-specific contracts, BIM Execution Plans (BEP), a plan that defines BIM-related roles and team interactions, and so forth, affect how digital innovation is used and increase the complexity of innovation adoption and implementation.

Apart from knowledge and innovation adoption intra-organisationally, BIM and digital innovation affect projects because various multi-disciplinary organisations engage in BIM-based collaborative work (Grilo et al. 2013). The ability to enhance collaboration of these organisations in projects is a priority for increasing BIM adoption (Cao et al. 2017). Nevertheless, due to being highly heterogeneous, firms deploy different strategies towards BIM innovation in a closely-knit network of formal and informal inter-organisational relations (Papadonikolaki et al. 2017; Papadonikolaki and Wamelink 2017). Effective collaboration among multi-disciplinary teams enables organisations to draw on diverse forms of expertise and create new competences and produce synergistic solutions to complex projects (Carlile 2004). As BIM innovation is closely linked to collaboration (Oraee et al. 2017), understanding how individuals enable collaboration is important for innovation adoption. To this end, approaching BIM as a digital innovation influences apart from innovation also knowledge sharing intra-organisationally and collaboration inter-organisationally.

THE ROLE OF BOUNDARIES IN DIGITAL INNOVATION

Typically, project managers, are centrally based in projects and teams, however, in the context of digital innovation, they might not have all necessary BIM knowledge to support innovation adoption. Thus, new functions have emerged or existing ones have been adjusted that attempt to manage BIM innovation adoption in firms and BIM innovation implementation in projects. These roles carry similarities to knowledge brokers and boundary objects as described in the previous sub-section have been found highly efficient in structuring communication, negotiating and overcoming conflict (Ruuska and Teigland 2009). The role of brokers is that of a "balancing act" (Kimble et al. 2010), as they have authority and trust from various groups.

Organisations leverage the knowledge of innovation agents – or brokers – to support innovation adoption. In the context of innovation, Rogers (2003) recognised an innovation champion as an organisational function responsible for driving innovation adoption. Nam and Tatum (1997) stated that innovation champions in construction are perceived as individuals responsible for implementing innovations in and enjoying authority and power. Similarly, in digital innovations in construction and specifically BIM, there are both project-based and organisational definitions of BIM specialist roles. There exists a plethora of new terminologies to describe BIM specialist roles (Akintola et al. 2017) and typically these are either project-based or organisational (Davies et al. 2017). From the above, this study focuses on *Digital Champions* as an organisational role, in keeping with the organisational definition by Rogers (2003).

Digital innovation and BIM Champions guide project teams to improve their processes by contributing to the development of BIM execution plans (BEPs), managing the quality of BIM model(s) and facility information, timely sharing of model(s) and chairing and facilitating meetings. This study defines a *Digital Champion* as an individual who guides teams to improve their processes by ensuring implementation of digital innovation and BIM, and managing resistance to change. This individual might be working on multiple projects simultaneously and be available for advice and input at key project stages. These Champions would help ensure pitfalls are avoided, and would present to clients as appropriate, to show what BIM can deliver.

Because of the affinity between boundaries and communication function, the theoretical lens of boundaries is used in this paper to explore how the afore-described brokers facilitate knowledge of digital innovations and BIM to support digital transformation in firms. In keeping with the emphasis on the agency of communication, the study views digital champions as knowledge brokers that facilitate and nurture knowledge-sharing and act as central conduits for forging new relationships and connections (Swan et al. 2016). Therefore, the role of a boundary broker in the BIM domain might display the following boundary and communication features: (1) multi-membership, (2) facilitation of knowledge transfer and (3) facilitation of collaboration.

RESEARCH METHODOLOGY AND APPROACH

RESEARCH RATIONALE

The study follows an interpretative approach and a case study methodology. The study draws upon a single case study to provide a rich, "real-life context" and inductive character to the research (Yin 1984). The research methods and data used were qualitative and the epistemological paradigm followed interpretative (Merriam 1998). As knowledge brokers in the context of innovation are typically firm-based roles, the study used a single firm as a 'point-of-entry' to access a wealth of data by studying various teams and projects. To this end, selecting this single case is of major importance.

This study focuses on one international multi-disciplinary firm that offers rich empirical data for further analysis and research. This company was selected – hereafter referred to as the Firm – for their strong digital and BIM strategy, and directed significant efforts towards assessment of digital innovation. They also have dedicated Research and Development (R&D) which is strong in researching, prototyping solutions and developing research agendas. It provides different services that cover different aspects of the built environment including architecture, engineering, consulting, planning and project management. The firm was established in the 1950s and has currently over 15,000 staff from diverse backgrounds and disciplines located in offices in 35 countries across Africa, the Americas, East Asia, Europe and the Middle East. For this study, the data will be derived from their branches in the United Kingdom (UK), 15 offices, to present a deep contextual description.

The context of the study is also crucial for research analysis and interpretation. The data were collected in the UK branches of the Firm, where BIM is required in governmentally-sponsored projects from 2016. The UK government has required a fully collaborative 3-dimensional BIM as a minimum for all government projects by 2016 (GCCG 2011). Currently, BIM use has been mandated or strongly recommended for governmental buildings from policy-makers in various European countries, such as

the UK, Germany, France, the Netherlands, and the Nordic countries. For this reason, the study focused on the UK branch of a large international firm, that could increase transferability of the findings across other countries starting their digital journey.

As deduced from the case, the Firm, does not simply try to raise the minimum bar to meet new government requirements, but has a long tradition of R&D and efforts to lead in digital innovation in construction. Previous studies have researched the Firm's development and use of an online knowledge management system, or an expert 'yellow pages' (Criscuolo et al. 2007) to capture and manage knowledge. Dodgson et al. (2007) studied how digital innovation such as simulation technologies used in the Firm facilitate communication and collaboration across disciplines.

DATA COLLECTION AND ANALYSIS

The single case study was studied over a period of 10 months. Two sets of data were collected from (1) interviews and (2) validation through an online forum. Through embedded research (Angen 2000), the research team had access to the Firm's online platforms, used for validation. More than one source of data supports data triangulation and adds to research validation (Creswell 1994). The first data was from interviews with knowledge brokers of digital innovation, also referred to as *Digital Champions*. The interview questions were on digital innovation, their contribution to sharing relevant knowledge across their firm, as well as other intra-firm channels for knowledge sharing and the interviews lasted 30-45 minutes.

The Digital Champions, who direct work on BIM implementation in projects, were ideal informants for the qualitative dataset. Given that the aim was to increase the wealth of data and not generalisability (Creswell 1994), interviews were considered the most appropriate means to capture their input. As the focus of the study was the UK branches, all 24 Digital Champions based in the UK were contacted initially. From these, 8 were available due to time restrictions and agreed to participate in the study. This sample size is considered representative of the UK context of the Firm. The profile of the interviewees including key characteristics of their background and roles is presented in Table 1. For anonymity their identifiers are assigned pseudonyms.

Table 1: Profile of the Firms' BIM Champions interviewees.

Pseudo-nym	Background	Position in the Firm	Location	Present job title
Adam	Building Services Engineering	Associate	London	Mechanical Engineer
Barb	Building Services Engineering	Associate	Midlands	BIM Manager
Colin	Structural Engineering	Associate	Edinburgh	Structural Engineer
Debra	Civil Engineering	Director	London	Civil Engineer
Ewan	English	Senior Technician	Bristol	Building Information Manager
Filip	Mechanical Manufacturing	Senior Technician	Manchester	CAD Technician
Gina	Psychology	Associate	London	BIM & CAD Lead
Hans	Manufacturer Engineering	Senior Technician	Belfast	CAD / BIM Co-coordinator

The interviews were conducted in London for the 3 participants who were based in the Greater Area and via video teleconference, for interviewees based outside London, between July and August 2017. The list of questions was designed to reflect the aim and objectives of this research project. It included ten semi-structured open-ended questions, which allowed for additional follow-up questions, if needed. The first set of questions was descriptive and addressed the background of interviewees, their routine and involvement in projects, the soft competences and hard skills a BIM Champion might need. The second set of questions was reflective, as to how their daily routine unfolds, how they transfer knowledge across projects, what specific innovations and contributions they add to projects as Digital Champions, and how digital innovation could accelerate project improvement through BIM and digital innovation.

The interview data were transcribed and the transcripts were analysed through coding (Miles and Huberman 1994). As there is not a definitive manner to rigorously analyse qualitative data (Robson and McCartan 2016) the theoretical framework from the second section of the paper was used as an indication of concepts for first-level coding to analyse the data according to (1) multi-membership, (2) facilitation of knowledge transfer and (3) facilitation of collaboration. Descriptive and in vivo codes were used (Saldanā 2009). In vivo codes, drawn upon words or phrases directly from the data (Saldanā 2009), were used to present quotations, for being more personal.

DATA VALIDATION

Secondary data form the internal online forum was used to triangulate the findings and validate the findings offer a rich representation of the phenomenon. Validation is an opportunity for the informants to reflect on their feedback and comment on the preliminary research findings. Mixed methods increase the communicative validity of research (Sarantakos 2005) by allowing the participants to check the accuracy of data and add depth and richness to the data. Merriam (1998) also stressed the need to increase the validity of case study methods. To this end, after the data collection and the preliminary data analysis, the research team used the internal online forum, similar to the online knowledge management system, or an expert 'yellow pages' analysed by Criscuolo et al. (2007). It namely addressed the question:

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

This online forum that functions as a knowledge platform of the Firm was used to both share some of the preliminary findings and also seek validation and additional feedback from the Firm employees. The preliminary findings and data were presented as direct quotations. This process aimed to validate the existing findings and collect new insights not visited before. The data validation part prompted participant's input, which took place over a period of one week, after posting the question in the thread. Apart from validation, this approach also provided new data.

DATA PRESENTATION

DIGITAL CHAMPIONS' AREAS OF ACTIVITY

Consistent with the characteristics of boundary spanners, the digital champions explained the varying degrees to which they belonged to different internal and external and project teams. All of them acted within the Firm, however, their activities varied depending on their penetration beyond mid-level project teams and specifically connecting with senior executives and business managers. Table 2 presents the data on the multi-membership and boundary spanning of the interviewees (first column), and namely internal (second and third column) and external engagement (fourth column). The digital champions crossed different boundaries. The eighth interviewee, Hans, stated that a more open organisational structure for leading innovations is needed and namely stated that *"with lots of rules we lose innovation. (…) BIM and innovation do not go hand in hand"*.

Table 2: Multi-membership and boundary spanning of the Digital Champions.

Name	Internal engagement with project teams (number of projects and comments)	Internal engagement with senior management	Project-related engagement with external stakeholders
Adam	6 projects, but not all as a champion	-	-
Barb	8 projects, mainly at the front-end of projects	-	-
Colin	4 projects, from which only 1-2 as a champion	-	Yes
Debra	10 projects, mainly at the front-end of projects	-	Yes
Ewan	7 projects formally and many more informally	-	Yes
Filip	6 projects at varying stages	Yes	Yes
Gina	5 projects, 2 of which are project bids	Yes	Yes
Hans	2 projects	-	-

After delving more into the data, it was revealed that whereas the digital champions crossed various boundaries, they were involved in different phases of the projects. All of the interviewees stated that they are primarily members of internal teams and additionally became involved informally in projects, after all according to the first interviewee, Adam, the Firm does not formally identify the role of digital champions and he added: *"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"*. Also, Ewan stated that involvement in projects comes "*via relationships not through formal structure"*. Similarly, their degree of involvement in projects varied from only being involved bids to only supporting technical tasks. Few digital champions went further into engaging with senior management internally for *"mediating with the top managers" (*Gina) and raising awareness of champions *"to acknowledge them"* (Filip). Simultaneously, most of the interviewees engaged beyond their teams to *"lead relationships with clients"* (Debra) and *"deal with resistance from collaborators, suppliers and client teams"* (Gina).

DIGITAL CHAMPION AS KNOWLEDGE SHARING FACILITATORS

From the design of interviews and the questions, the digital champions were asked on their roles and daily routines on sharing knowledge are supported from their skills and competences. To ensure that the interviewees will provide a detailed account of their contribution to sharing knowledge in the Firm, they were asked to reflect on both the competences that allowed them to share knowledge, as well as provide the research team with concrete examples of sharing knowledge. The data on daily routines were particularly requested to confirmed and contextualise their roles. Table 3 tabulates the data per interviewee. The first column from the left contains the interviewee identifier and the second their competences and daily routines using in vivo codes.

Table 3: Knowledge transfer competences and daily routines of Digital Champions.

Name	Competences (in vivo codes)	Daily routines (in vivo codes)
Adam	*Awareness of how disciplines work, change management*	*Writing BIM documents, integrating digital data*
Barb	*Open-mind, mind-set of sharing, soft skills, knowledge is power, questioning ability*	*Centrally sharing knowledge across champions through repositories, meetings and social media, training teams*
Colin	*Knowledge of BIM standards, soft skills, change management*	*Delivering digital innovations, leading from the front-end of projects, engaging with stakeholders, selecting appropriate people for BIM teams*
Debra	*Use of technology, understanding and selecting software packages, communication, negotiation, influence, persuasion*	*Meeting with clients and co-workers, leading internal teams, developing and mentoring graduates, sharing good practices across the board*
Ewan	*Knowledge dissemination, understanding technology and BIM standards, understanding of the interfaces between people and processes*	*Upskilling people, meeting with clients, mentoring appendices, writing macros*
Filip	*Deliverables management, time management, project management, salesman's pitch, knowledge spreading*	*Meeting with internal teams, transferring knowledge from experienced people to the whole project team*
Gina	*Hard skills, work with different people and tools, mediation, engagement with people, delegation, soft skills, salesman*	*Meeting with clients, calling and emailing people, offering training, promoting BIM and digital*
Hans	*Changing people and their ethics, knowledge of developments in the firm, communication*	*Training and meetings with internal teams, promoting knowledge sharing among individuals*

The data from Table 3 reveals that the digital innovation champions mobilised soft skills and competences to manage individuals, teams and projects. Some of them were focused more on technical tasks, e.g. Adam and Hans stated that routines evolve around working with Navisworks (BIM management software) and maintaining the CDE on a

day-to-day basis. Contrariwise, Barb, Debra and Filip stated that they could not define their routines as they varied enormously daily and consisted by many meetings. Ewan and Colin were involved in daily routines comprised by both hard, technical and implementation of innovative ways of working as well as many meeting and people-focused activities.

DIGITAL CHAMPIONS AS COLLABORATION FACILITATORS

Apart from knowledge sharing, communication and the role boundary brokers are mobilised in collaboration facilitation. Drawing upon Table 2, all of them influenced collaboration in internal teams, ranging 2-10 teams at any given moment, and collaboration of project teams, beyond their organisational boundaries. Table 4 presents the data on how the digital champions used communication in their daily work to facilitate collaboration by translating meaning and mediating in conflicts. Although knowledge transfer was the most discussed category of communication emerging from interviews, also resolving conflicts and translating meaning were part of the boundary brokers' routines. The second column of table 4 presents descriptive codes from the digital champions on how they manged conflicts to bridge boundaries among actors. Similarly, the third column presents data on how they translated meaning across internal or external domains, consistent with crossing organisational and project-related boundaries.

Table 4: Analysis of the Digital Champions' role in collaboration (descriptive codes).

Name	Mediation in conflicts	Translation of meaning
Adam	Mediating between the architect and the senior technicians	Bringing the project team together to discuss the execution plan
Barb	Monitoring information exchanges; Keeping track of the project schedule	Delegating work among project team and pushing them outside comfort zone
Colin	Connecting experienced people and recent graduates (reverse mentoring)	Continuously engaging with external stakeholders
Debra	-	Continuously engaging with external stakeholders and then the internal team
Ewan	-	Bringing the project team up to speed regarding client requirements and government mandates
Filip	Managing conflicts arising from time management	Facilitating team's understanding of various datasets and file formats; Continuously engaging with external stakeholders
Gina	Dealing with resistance from external stakeholders	Pointing the project team to the right direction, giving them answers
Hans	Facilitating and supporting the transition of senior designers and engineers; Changing people's work ethics	Answering questions of project team about BIM models

VALIDATION SESSION ON PROMOTING KNOWLEDGE ON DIGITAL INNOVATION

To validate the data findings presented in the previous sub-section, some representative quotations from Barb, Colin and Debra and preliminary findings were presented again

to a wider sample of the Firm. The quotations selected were provocative to trigger reactions in the online forum. For example, Barb had shared: *"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"* and Debra: *"I think there are pockets of great things being done. But at the moment it is pockets, rather than cross the board".* By accessing the online knowledge platform of the Firm, the research team had access to a wider pool of informants, beyond the network of the digital champions, to validate the data and also potentially enrich them. As described in the "Data Validation" sub-section, the quotations were accompanied by text encouraging the platform users and Firm employees to reflect on how knowledge is shared internally.

As a result, ten Firm employees were involved in the thread by either directly responding or being 'called' in the thread by colleagues mentioning them in the thread (action upon which they were notified in the work email to respond). The feedback included suggestions to reward the champions of knowledge transfer, in order to 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 the fact that the Firm uses over 9 different online systems to share knowledge, e.g. and shared a *"view on active dissemination where telling a story to get the information is across would definitely be an improvement on an information dump"* (User-B).

DISCUSSION AND IMPLICATIONS

CROSSING BOUNDARIES ACROSS GROUPS, KNOWLEDGE, COMPETENCES AND PEOPLE

This paper set out to seek how boundary brokers can facilitate knowledge of digital innovations and BIM to support innovation adoption and digital transformation in organisations. To this end, the paper adopted a structurational view of communication (Levina 2005), drawing upon Giddens' (1984) duality of structure and agency, according to which the boundary brokers as agents shape and are shaped by the phenomenon of knowledge transfer for sustained innovation adoption. Therefore, this paper focused on the role of agents as knowledge brokers to increase the adoption of digital innovation. From the empirical data set, it was established that these agents crossed various types of boundaries in order to communicate, either for knowledge transfer or facilitation of collaboration in teams.

For Nonaka and Takeuchi (1995) knowledge-creating organisations can engage in continuous innovation when the *"consistently create new knowledge, disseminate it widely throughout the organization, and quickly embody it in new technologies and products".* Project managers' role is brokering across domains, as is that of 'multi-membership' individuals (Koskinen 2008). Indeed, the empirical data revealed that also the knowledge brokers of digital innovation and BIM had influence at four network levels within and outside their organisation, regardless of whether they were centrally positioned in an organisation (Levina and Vaast 2005). The data sample revealed an extended network of internal and external relations of the digital champions (see Table 2). The digital champions casually crossed hierarchical (internally) and organisational (externally) boundaries. Namely, the digital champions were frequently engaging with:

- internal project teams;

- external project stakeholders;

- senior management within their firm;

- intra-firm network of digital champions.

To this end, and by revisiting the assumptions of this paper at the second section containing the theoretical background of the study, arguably the digital champions performed more roles than of the knowledge brokers. Swan et al. (2016) had categorised boundary roles into five roles: knowledge broker, internal consultant, avant-garde, service provider and orphaned child. Drawing upon Table 3 and Table 4, the digital champions also acted as 'internal consultants' and 'service providers', which are roles positioned more central, closer to the front-end of projects that knowledge brokers, who are positioned at the back-end of the projects, at the client-facing part. Based on their competences and daily routines (see Table 3), Barb, Debra, Filip and Gina were also hands-on service providers, whereas based on their contribution to mediation and translation of meaning, all digital champions acted as internal consultants, crossing thus knowledge boundaries among people.

As the domain of digital innovation and BIM is a young filed in scholarship, there is a growing field of study on the background and skills of new or existing specialised roles for digital innovation. Indeed, individuals are called to undertake roles, beyond the disciplines that they were initially trained (Jaradat et al. 2013). Scholars have focused on the emergence of new roles (Akintola et al. 2017; Davies et al. 2017; Liu et al. 2016) and report an ambiguity in naming and categorising such roles. The data from this paper, revealed that these roles were not typically new, but informal additional roles next to existing positions of the interviewees (see Table 1 and quotation of Adam). On the contrary, scholars discussing changes in existing roles (Davies et al. 2015; Jaradat et al. 2013; Papadonikolaki and Oel 2016) report on the discrepancies between the existing or expected competences of these knowledge brokers, which tend to be more technical and mono-disciplinary and the functions they are called to cover in order to facilitate knowledge transfer, e.g. soft skills, change management, communication, negotiation, influence, persuasion (see Table 3). Therefore, these knowledge brokers are crossing boundaries apart from between teams but also of their desired 'soft' versus 'hard' existing competences. To this end, apart from hierarchical and organisational, they crossed professional boundaries.

Apart from the function of communication to support knowledge transfer, it also facilitates collaboration. Undoubtedly, knowledge brokers translate meaning and can support innovation adoption not only within firms but also across them. After all, the adoption of digital innovations and BIM is a complex inter-organisational exercise (Grilo et al. 2013), which might activate conflicts in inter-disciplinary teams (Davies et al. 2015; Dossick and Neff 2010). According to Table 4, the digital champions not only continuously engaged with external stakeholders, as it would have been expected due to their multi-membership attributes, they shared knowledge by acting as translators of meaning to clients and project members beyond their organisation. Because, their role was primarily intra-organisational, they used their brokering qualities and communication tools to facilitate how teams internal in the Firm and across projects, beyond the Firm, collaborated. At the same time, they translated meaning and acted as salespersons to increase awareness of BIM and digital innovation across hierarchical levels (see Table 3, third column and Table 4, third column). The

boundary brokers were also activated in the resolution of team conflicts internally and externally (see Table 4, second column) that might emerge due to disciplinary fragmentation (internally, see Adam and Hans), generation gap (internally, see Colin) or commercial interest (externally, see Gina).

CONTRIBUTION TO THEORY AND KNOWLEDGE

This paper added to theory in the fields of organisational management and construction innovation. At a higher-level, it re-visited the theory of boundaries and boundary brokers and reaffirmed its relevance to management science (Alin et al. 2013; Chang et al. 2013) and especially innovation (Kimble et al. 2010). To this end, it emphasised on the importance of agency on transferring knowledge to increase innovation adoption. The study contributed to the theory of boundary brokers by providing rich empirical data and evidence from construction innovation and in particularly digital innovation (see Tables 2, 3 and 4). At a 'field' theory level, the paper contributed to the body of knowledge of digital innovation adoption and namely, BIM adoption and its organisational repercussions. The study confirmed the socio-technical nature of digital innovation champions (Davies et al. 2017; Emmitt 2016), thought the theoretical lens of boundary brokers, as opposed to the technical view of emerging BIM roles (Akintola et al. 2017). From a methodological point of view, the study added to scholarship, by combining an original synthesis of data collection, comprising both participants' interviews and validation and additional data collection through online platforms, specifically designed for knowledge management.

RESEARCH LIMITATIONS AND FUTURE RESEARCH

Apart from contributing to theory knowledge and methodology, this paper outlined throughout the methodology and data presentation sections, possible ways to extend this study by additional data collection and validation points. One of the limitations of the research design, was the focus on interviewing only the digital innovation champions as a source of information. This was done intentionally, to delve into their qualities, skills and routines. As this study progresses, interviewing project managers, consultants or other similar roles that have experience engaging with multiple digital champions, would be useful for understanding how these boundary roles are perceived, especially due to their limited time of involvement as digital innovation champions might engage in multiple projects with differing roles (Table 2).

Indeed, the validation component of the methodology attempted to engage with more roles in the Firm and sought input from various other roles. However, a research limitation was that the short period (one week) that the feedback from the online platform was collected. In the future, the validation component could be extended and replicated over a period of time to seek more participants and discussions. Naturally, due to the in-depth single case study focus, the study attempted to present rich descriptions of the firm, through embedded research. In the future, this study could be replicated in similar-sized firms to gain more insights into how issues of knowledge transfer, boundary spanning and brokerage are mobilised.

PRACTICAL IMPLICATIONS AND PROPOSITIONS

The secondary set of data, which expanded and included feedback from various employees, additionally contained insights on the challenges of disseminating knowledge across the firm. Some challenges reported were rigid organisational structure, impression management (see previous sub-section). The new challenges emerging form the validation session was the lack of incentive schemes to recognize the knowledge sharing efforts from all employees, as well as the volume of new knowledge and the type and governance of knowledge management systems. Whereas this study focused on a large-scale inter-disciplinary firm, the following strategies for nurturing and supporting knowledge brokers and developing their boundary spanning competences might be relevant to other firms in the AEC:

- Holding a horizontal structure for knowledge transfer within firms;

- Increasing firms' awareness on the contribution of knowledge brokers;

- Providing training to develop knowledge brokers' leadership potential;

- Creating appropriate channels and procedures to disseminate knowledge;

- Incentivising to establish and cultivate a culture of shared knowledge.

The implications for practice and other project-based organisations is that agency and boundary spanning individuals are key for transferring knowledge across projects and firms. Whereas their role could be ephemeral, there is a need to increase their intra-firm boundary-spanning capabilities and their inter-firm coordination and their contribution to management, education and policy-making.

CONCLUSIONS

Sustaining innovations is an important organisational challenge for firms that decide to adopt new processes and technologies. The study focused on the adoption of digital innovations in AEC and how these are disseminated and sustained through the organisational role of boundary brokers. Due to the strong link between intra-firm communication and innovation spread, these organisational roles carry knowledge and boundary brokering attributes. Namely, after studying a sample of eight out of the 24 digital innovation champions from a single multi-disciplinary design, engineering and management firm, it was revealed that these champions cross apart from knowledge boundaries, additionally hierarchical boundaries, by engaging with both the work-floor level and the senior management, organisational boundaries, by directly engaging with clients and external stakeholders to facilitate teams' collaboration in projects, and professional boundaries, by developing soft competences and engaging in tasks that typically were not prescribed in their job descriptions.

The study set out to address the question of how boundary brokers facilitate knowledge of digital innovations and BIM to support digital transformation in firms. Arguably, apart from crossing the knowledge, hierarchical, organisational and professional boundaries mentioned above, the digital champions acted as not only knowledge brokers but also as internal consultants and at instances as service providers, in a hands-on fashion. Theoretically, this paper revisited theories of boundaries and emphasised on the agential aspect of knowledge transfer and expanded the body of knowledge of construction innovation and in particular with regards to digital

innovation and BIM. The practical implications of the study relate to the need to activate organisational mechanisms for breaking rigid horizontal structures in firms, developing knowledge brokers' leadership potential, create and maintain channels and procedures to transfer knowledge as well as incentivising and rewarding individuals to establish and cultivate a culture of shared knowledge in organisations.

REFERENCES

Abernathy, W. J., and Clark, K. B. (1985). "Innovation: Mapping the winds of creative destruction." *Research policy*, 14(1), 3-22.

Akintola, A., Venkatachalam, S., and Root, D. (2017). "New BIM Roles' Legitimacy and Changing Power Dynamics on BIM-Enabled Projects." *Journal of Construction Engineering and Management*, 143(9), 04017066.

Alin, P., Iorio, J., and Taylor, J. E. (2013). "Digital boundary objects as negotiation facilitators: spanning boundaries in virtual engineering project networks." *Project Management Journal*, 44(3), 48-63.

Angen, M. J. (2000). "Evaluating interpretive inquiry: Reviewing the validity debate and opening the dialogue." *Qualitative health research*, 10(3), 378-395.

Barrett, M., and Oborn, E. (2010). "Boundary object use in cross-cultural software development teams." *Human Relations*, 63(8), 1199-1221.

Brown, J. S., and Duguid, P. (1998). "Organizing knowledge." *California management review*, 40(3), 90-111.

Cao, D., Li, H., Wang, G., and Huang, T. (2017). "Identifying and contextualising the motivations for BIM implementation in construction projects: An empirical study in China." *Int J Proj Manag*, 35(4), 658-669.

Carlile, P. R. (2004). "Transferring, translating, and transforming: An integrative framework for managing knowledge across boundaries." *Organization science*, 15(5), 555-568.

Chang, A., Hatcher, C., and Kim, J. (2013). "Temporal boundary objects in megaprojects: Mapping the system with the integrated master schedule." *International Journal of Project Management*, 31(3), 323-332.

Creswell, J. W. (1994). *Research design: Qualitative & quantitative approaches*, Sage Publications., Thousand Oaks, California, USA.

Criscuolo, P., Salter, A., and Sheehan, T. (2007). "Making knowledge visible: Using expert yellow pages to map capabilities in professional services firms." *Research Policy*, 36(10), 1603-1619.

Dainty, A., Leiringer, R., Fernie, S., and Harty, C. (2017). "BIM and the small construction firm: a critical perspective." *Building Research & Information*, 1-14.

Davies, K., McMeel, D., and Wilkinson, S. "Soft skill requirements in a BIM project team." *Proc., 32nd CIB W78 Information Technology for Construction Conference (CIB W78 2015)*, 108-117.

Davies, K., Wilkinson, S., and McMeel, D. (2017). "A review of specialist role definitions in BIM guides and standards." *Journal of Information Technology in Construction (ITcon)*, 22(10), 185-203.

Davies, R., Crespin-Mazet, F., Linne, A., Pardo, C., Havenvid, M. I., Harty, C., Ivory, C., and Salle, R. "BIM in Europe: innovation networks in the construction sectors of Sweden, France and the UK." *Proc., Proceedings of the 31st ARCOM*, Association of Researchers in Construction Management.

Dodgson, M., Gann, D. M., and Salter, A. (2007). ""In case of fire, please use the elevator": Simulation technology and organization in fire engineering." *Organization Science*, 18(5), 849-864.

Dossick, C. S., and Neff, G. (2010). "Organizational divisions in BIM-enabled commercial construction." *Journal of construction engineering and management*, 136(4), 459-467.

Eastman, C. (1999). *Building Product Models: Computer Environments, Supporting Design and Construction*, CRC Press, Boca Raton, Florida, USA.

Emmitt, S. (2016). "The construction design manager–a rapidly evolving innovation." *Architectural Engineering and Design Management*, 12(2), 138-148.

Engwall, M. (2012). "PERT, Polaris, and the realities of project execution." *International Journal of Managing Projects in Business*, 5(4), 595-616.

Fox, N. J. (2011). "Boundary objects, social meanings and the success of new technologies." *Sociology*, 45(1), 70-85.

GCCG (2011). "Government Construction Client Group: BIM Working Party Strategy Paper."

Giddens, A. (1984). *The constitution of society: An Outline of the Theory of Structuration*, Polity Press, Cambridge, USA.

Grilo, A., Zutshi, A., Jardim-Goncalves, R., and Steiger-Garcao, A. (2013). "Construction collaborative networks: the case study of a building information modelling-based office building project." *Int J Comput Integ M*, 26(1-2), 152-165.

Gu, N., and London, K. (2010). "Understanding and facilitating BIM adoption in the AEC industry." *Automation in Construction*, 19(8), 988-999.

Holzer, J. (2012). "Construction of Meaning in Socio-Technical Networks: Artefacts as Mediators between Routine and Crisis Conditions." *Creativity and Innovation Management*, 21(1), 49-60.

Jaradat, S., Whyte, J., and Luck, R. (2013). "Professionalism in digitally mediated project work." *Building Research and Information*, 41(1), 51-59.

Kimble, C., Grenier, C., and Goglio-Primard, K. (2010). "Innovation and knowledge sharing across professional boundaries: Political interplay between boundary objects and brokers." *International Journal of Information Management*, 30(5), 437-444.

Koskinen, K. U. (2008). "Boundary brokering as a promoting factor in competence sharing in a project work context." *International Journal of Project Organisation and Management*, 1(1), 119-132.

Lee-Kelley, L., and Blackman, D. (2012). "Project training evaluation: Reshaping boundary objects and assumptions." *International Journal of Project Management*, 30(1), 73-82.

Levina, N. (2005). "Collaborating on multiparty information systems development projects: A collective reflection-in-action view." *Information Systems Research*, 16(2), 109-130.

Levina, N., and Vaast, E. (2005). "The emergence of boundary spanning competence in practice: implications for implementation and use of information systems." *MIS quarterly*, 335-363.

Liu, Y., van Nederveen, S., and Hertogh, M. (2016). "Understanding effects of BIM on collaborative design and construction: An empirical study in China." *International Journal of Project Management*.

Maaninen-Olsson, E., Wismén, M., and Carlsson, S. A. (2008). "Permanent and temporary work practices: knowledge integration and the meaning of boundary activities." *Knowledge Management Research & Practice*, 6(4), 260-273.

Merriam, S. B. (1998). *Qualitative research and case study application in education*, Jossey-Bass, San Francisco, USA.

Miettinen, R., and Paavola, S. (2014). "Beyond the BIM utopia: Approaches to the development and implementation of building information modeling." *Automation in construction*, 43, 84-91.

Miles, M. B., and Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*, Sage Publications Inc., Thousant Oaks, CA.

Nam, C. H., and Tatum, C. B. (1997). "Leaders and champions for construction innovation." *Construction Management & Economics*, 15(3), 259-270.

Nonaka, I., and Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation*, Oxford university press.

Oraee, M., Hosseini, M. R., Papadonikolaki, E., Palliyaguru, R., and Arashpour, M. (2017). "Collaboration in BIM-based construction networks: A bibliometric-qualitative literature review." *International Journal of Project Management*, 35(7), 1288-1301.

Papadonikolaki, E. (2016). *Alignment of Partnering with Construction IT: Exploration and Synthesis of network strategies to integrate BIM-enabled Supply Chains*, A+BE Series | Architecture and the Built Environment, Delft.

Papadonikolaki, E. "Grasping brutal and incremental BIM innovation through Institutional Logics." *Proc., Proceedings of the 33rd Annual ARCOM Conference*, Association of Researchers in Construction Management, 54-63.

Papadonikolaki, E., and Oel, C. v. (2016). "The Actors' perceptions and expectations of their roles in BIM-based collaboration." *Proceedings of the 32nd Annual Association of Researchers in*

Construction Management Conference (ARCOM 2016), P. Chan, and C. J. Neilson, eds., Association of Researchers in Construction Management Manchester, UK, 93-102.

Papadonikolaki, E., Verbraeck, A., and Wamelink, H. (2017). "Formal and informal relations within BIM-enabled supply chain partnerships." *Construction Management and Economics*, 1-22.

Papadonikolaki, E., and Wamelink, H. (2017). "Inter- and intra-organizational conditions for supply chain integration with BIM." *Building Research & Information*, 1-16.

Robson, C., and McCartan, K. (2016). *Real world research*, John Wiley & Sons.

Rogers, E. M. (2003). *Diffusion of innovations*, Free Press, New York.

Ruuska, I., and Teigland, R. (2009). "Ensuring project success through collective competence and creative conflict in public–private partnerships–A case study of Bygga Villa, a Swedish triple helix e-government initiative." *International Journal of Project Management*, 27(4), 323-334.

Saldanā, J. (2009). *The Coding Manual for Qualitative Researchers*, SAGE Publications Ltd, London, UK.

Sarantakos, S. (2005). *Social Research*, Palgrave Macmillan, Melbourne.

Shenhar, A. J., and Dvir, D. (2007). *Reinventing project management: the diamond approach to successful growth and innovation*, Harvard Business Review Press.

Star, S. L. (2010). "This is not a boundary object: Reflections on the origin of a concept." *Science, Technology, & Human Values*, 35(5), 601-617.

Star, S. L., and Griesemer, J. R. (1989). "Institutional ecology,translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39." *Social studies of science*, 19(3), 387-420.

Succar, B., Sher, W., and Williams, A. (2012). "Measuring BIM performance: Five metrics." *Architectural Engineering and Design Management*, 8(2), 120-142.

Swan, J., Scarbrough, H., and Ziebro, M. (2016). "Liminal roles as a source of creative agency in management: The case of knowledge-sharing communities." *human relations*, 69(3), 781-811.

Yin, R. K. (1984). *Case Study Research: Design and Methods*, SAGE Publications, Beverly Hills, California.