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Understanding Building Information Modelling Collaborative Practices in the UK Construction Industry

Daniel Quevedo Seguel

MSc Management of Information Systems and Digital Innovation
Department of Management
London School of Economics and Political Science

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ABSTRACT

From the nineties onwards, several reports in the UK have claimed that the construction industry is one of the most unproductive sectors. In this context, building information modelling (BIM) has been presented as a collaborative methodology or technology that can improve productivity levels within organisations, as well as when working among different enterprises. With this objective, the British government mandated the use of BIM in the development of public projects in 2011 as a way of enhancing collaboration among the numerous participants of the edification process. However, little attention has been paid to how the actual collaboration occurs. Dominant narratives, normally issued from managerial and engineering perspectives, tend to overlook and simplify social aspects as collaboration. By focusing on social aspects, the present work draws on practice theory and the concepts of enactment and technologies-in-practice to analyse the actions and practices that occur in the coordination process of projects. In summary, this study proposes that people do not necessarily enact BIM in collaborative manners and that it is instrumental to investigate more precise concepts such as synchronisation and exploration in order to understand technological change and provide relevant insights for the industry.

Introduction

Some authors use the term "fragmented" (Isikdag & Underwood; 2010) to describe the construction industry because it is composed by a large number of differentiated individuals and organisations belonging to public or private sectors, who are highly specialised on specific tasks and participate at all stages of the edification process, from the requirement to the delivery of the building. This requires substantial effort for the coordination of every task and activity. Therefore, construction is a field that is at considerable risk of inefficiencies and waste of resources.

Latham's report "Constructing the team" (Latham; 1994) and Egan's report "Rethinking construction" (Egan; 1998) assessed and described the UK construction industry as ineffective, adversarial and inefficient in understanding customer needs. These documents provided recommendations such as a better understanding of customer needs, enhancing partnering and collaborative work, measurement of performances and rethinking processes to reduce cost and time. From then on, the public sector adopted different actions, namely the development of complementary reports, the establishment of new organisations, public-private partnerships and implementing strategic plans. In 2011, BIM (building information modelling) was mandated by the Minister for the Cabinet Office as an official technological requirement to be utilised for the development of public projects oriented towards accomplishing productivity and sustainability goals. It has been thought of as an instrument to delegate certain actions in technology or a methodology, which will theoretically allow the industry to tackle its deficiencies trough collaboration.

Although many use the term "BIM" to refer to a technology and others refer to it as a methodology, this article conceives it as both (Azhar et al.; 2012, Succar; 2009). Beyond this definition, it can be argued that BIM is based on 3D parametric models capable to host rich information, potentially available for use in different stages of the edification process by clients, architects, engineers, constructors, public agencies, etc. A specific complex phase is the coordination of projects, where all the engineering designs are put together with the architectural design to be fitted. Primarily because of its visual qualities, BIM is considered as an enabler that helps to identify clashes among elements in order to promptly rectify projects and to reduce errors and costs.

Popular narratives define BIM as collaborative. Usually, these perspectives based on managerial, engineering and economic disciplines are related to rational and calculated planning of work and do not examine human behavioural issues. Relationships among the participants of coordination are ignored, minimised or simplified as things related to standards or technical interoperability among BIM

Corresponding Author
Email Address: dh.quevedoseguel@gmail.com

software. Therefore, because of its capacity to analyse and understand the complexity of human processes, social science approaches are suitable for enriching our comprehension. Thus, instead of adopting approaches that dictate how people should organise work and use technology, this research observes and analyses how the actual work is performed.

This work focuses on the tension of using technology to expect certain results in unfavourable contexts. It has been claimed that the construction industry is characterised by an adversarial atmosphere that is rooted in cultural attitudes (Latham; 1994, Egan; 1998). It can be observed in diverse aspects, such as the treatment to workers (Egan; 1998) or structures like contracts and tender procedures that facilitate conflict and defensive stances, especially in the client/contractor and contractor/subcontractor relationships (Latham; 1994). Since numerous work relations are created in all stages of edification processes, a reasonable query emerges: How is collaboration enacted by using BIM in this so-called adversarial construction industry?

This analysis is based on the practice theory, which considers the everyday practice as the building block of social orders. This approach provides valuable vocabulary and concepts to gain rich insights about the human organisation of work and serves as a sensitive lens to study social phenomena (Nicolini; 2012). In particular, the concept of "technologies-in-practices" developed by Orlikowski (Orlikowski; 2000) from the perspective of human agency is valuable in comprehending how people enact technology in their particular contexts and its consequences. Accordingly, it is possible to obtain sector-specific insights for the use of IT.

Literature Review

Practice Theory Literature Review

Several information systems scholars address the gap between planned activities by using technologies and the actual performance of those activities (Boudreau, Robey; 2005, Orlikowski; 2000, Dery et al.; 2006). From one side, technical rational approaches are often related to technological deterministic perspectives, which are dominant in the field of BIM. These discourses carry several assumptions, such as regarding the capabilities of the technical features of hardware, software, and applications to ensure that certain organisational structures or social orders occur when used. Practice theory, from a socio-technical perspective, provides a valid lens for nondeterministic studies regarding innovation with technology in the context of organisations. By focusing on the daily actions of people, this umbrella concept (Gherardi; 2012) offers ideas and concepts that facilitate a better understanding of the complexity of technology among human groups. However, a universal manner of application of this theory is not available (Gherardi; 2012) and some suggest the notion of a "broad family of theoretical approaches, connected by a web of historical and conceptual similarities" (Nicolini; 2012).

It is possible to find elements of the social practice theory in the works of several authors of diverse theoretical origins, but common roots are predominantly found in the works of philosophers Wittgenstein and Heidegger (Reckwitz; 2002). They criticise the dualistic view of the world that is based on Rene Descartes' ideas and the physical scientific approach, where entities and the mind are separated. Other researchers from the social sciences, such as Pierre Bourdieu and Anthony Giddens develop theories based on these authors' ideas in the context of their own times. Particularly, Giddens' structuration theory has been foundational (Giddens; 1984). However, since the author does not account for a clear application of the theory in the technology studies domain, different scholars from different approaches developed their own interpretations.

Wanda Orlikowski extends Giddens's "structures in practice" model to "technologies-in-practice" concept as a feasible structure that is enacted in the recurrent use of technology (Orlikowski; 2000). This perspective addresses the focus on human agency since people can choose to enact technologies in different manners, but also recognises the influence of several factors and structures by considering the context as an essential aspect in this understanding of practices. Thereby, this model explains the relationship between both sides of the dualism between agency and structure.

The researcher shifts the view that users "embody structures" contained in the IT artefact to focus on the "emergent" new structures since humans interact recursively with the technological properties available. Furthermore, the technology-centred idea that users "appropriate" the characteristics inscribed in technology is replaced with the concept of "enactment" that positions people's actions as the starting point to study the way it enacts the emergent structures in the context of interactions with the technology at hand. This extends the scope of user possibilities to perform circumvent uses of technologies. It could be by ignoring them, inventing new ones or working around them, which could even result in a scenario that is contrary to the expectations of technology designers (Orlikowski; 2000).

The same author and Susan Scott, have worked on the notion of sociomateriality that accounts for the relevance of material agency and the inseparability between the technical and the social aspects, which offers interesting perspectives for the understanding of technology in organisational contexts (Orlikowski & Scott; 2008). However, this article focuses on theories described in the abovementioned paragraphs since they provide useful lenses for the study of the theme in question.

Building Information Modelling Literature Review

This review observes two primary characteristics in BIM literature. First, there is an increase in the number of publications in recent years that coincides with the 2011 UK public mandate. Second, the largest portion of articles is related to BIM in the engineering, managerial and economics fields and only a low portion is written from social areas that try to comprehend human action.

A marked engineering tradition can be observed from its origins in the nineties related to computer-aided design (CAD) areas of research when technical concerns such as feeding vectorial data and 3D models were popular (Grilo & Jardim-Gonçalves; 2010).

Over time, different themes and perspectives emerged. Some scholars developed new concepts such as building product models (Eastman; 1999) that were later related to the BIM term. From the raise of publications number, approaches from engineering, managerial, economic or organisational perspectives were rarely elaborated purely from each perspective and they were developed intertwined with each other. For instance, recurrent interests from a managerial/engineering view such as automation and optimization of processes or IFC as language have been popular. Similarly, popular themes from a managerial/economic perspective have been related to productivity issues or cost-benefit analysis; for example, "Return of investments or ROI", "BIM as decision making tools" or "BIM for calculation".

This diversification of interests also includes papers that consider, at some point, social or organisational aspects. These publications range from articles mentioning collaboration or adoption aspects as relevant in superficial levels to a few other examples related to BIM research from theories related to the social sciences (Santos et al.; 2017).

Collaboration in the first-mentioned group is assumed to always be beneficial and realisable when solving interoperability (technical) challenges, such as in the case of using a server as a BIM collaborative platform (Singh et al.; 2011). Others subtly recognise collaboration as a human ability (Isikdag & Underwood; 2010). However, it is only concerned with the means and guides for communication and presumes that collaborative dynamics will emerge and subsequently improve productivity. Some explicitly position human factors, albeit in the absence of social explanations. One illustrative example is Bilal Succar who develops a research and delivery framework for BIM (Succar; 2009) that is intended at integrating every aspect and approaches and assumes these as managerial resources that will behave as expected. Other researchers such as Grilo and Jardim-Gonçalves develop a model to measure the impact of interoperability by examining employees and cultures (Grilo, Jardim-Gonçalves; 2010) recognising the complexity of human action and organisations; however, they do not extend on this topic. These examples represent the dominant approach that is focused on planning models to guide action.

Alternatively, there are a few but valuable articles based on social sciences theories that better explain the complexity of human activity at work. Henrik Linderoth analyses the implementation of BIM from an actor-network theory perspective, by discussing how technology defines new relationships and roles and how these new definitions are aligned with the original network (Linderoth; 2009). In another article, the same author opines that BIM sensemaking is an important component of the social analysis and argues about the relevance of actors in understanding the institutional logics that shape periodic actions and thereby affect the use of technology (Linderoth; 2016).

Anne Kokkonen and Pauli Alin adopt a similar stand and indicate that during daily activities, people create practices by means of reflective learning when they implement BIM. They argue for the increasing need for flexibility in practitioner expertise since this must be created and re-created over time (Kokkonen & Alin; 2016).

Research Study

Methodology

This work presents a qualitative research study that is aimed at studying the particular activities of the coordination of projects by using BIM as a piece of study. This stage is representative of the relational practices among different agents.

Semi-structured interviews, a flexible and powerful format (Rabionet; 2011) that allows raising more and better-oriented questions, has been used in this research. Surveys consider four individuals that work with Autodesk Revit® software in different companies in the UK. They have been involved in the coordination of projects from different roles, as shown in Chart 1.

Regarding the limitations of the method, some interviewees did not respond to every question for reasons such as confidentiality, lack of time or experience. However, it did not affect this investigation since the information gathered was valuable enough for proceeding with the analysis.

Conceptual Framework

Addressing to the research question, Orlikowski's technologies-in-practice (Orlikowski; 2000) model has been adopted. The author has developed a lens based on practice theory that seeks to continue the discussion about technological and organisational change, particularly extending the structurational approach to include emergence and enactment of valuable terms.

She argues for the potential to observe technology enacted in practice as a structure influenced by norms, interpretative schemes and facilities that users have in hand. The study also defines three different types of enactments that have structural consequences in the status quo of organisations: inertia, where users choose to use technology to retain their existing processes; application, where people use technology to augment or refine their way of doing things and change, where users substantially alter their proceedings (Orlikowski; 2000).

These ideas are valuable in order to observe the coordination of a projects stage, since the manner in which BIM is used has the capacity to reinforce or transform the status quo within organisations and also at intra-organisational levels.

Figure 2: Enactment of Technologies-in-Practice. Source: Orlikowski, W. (2000).

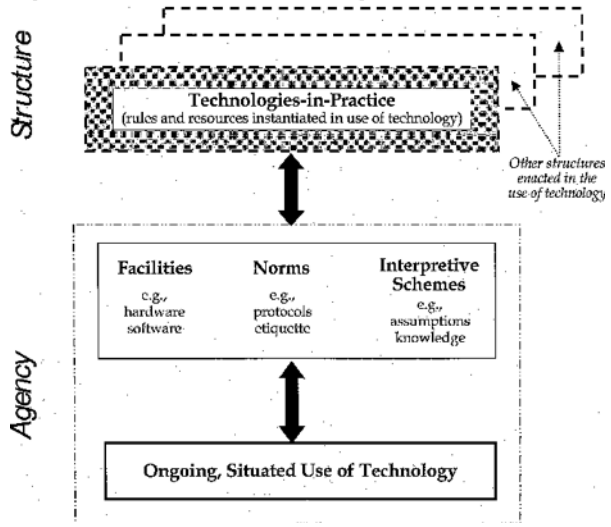
In the next chapter, four mentioned cases are

Role	Interviewee	Type
Building Services	Services 1	Semi-Structured Skype meeting
Structural Engineering	Structural 1	Semi-Structured Skype meeting
Architecture	Architect 1	Semi-Structured Skype meeting

Chart 1: Interviewees Summary Table

presented under the light of these frames in a table that facilitates observing them in parallel. They are described according to the technology-in-practice chosen by users for each case. Subsequently, the cases are analysed by considering the observations made in the use of the model, the existing literature and the information collected.

Figure 2 **Enactment of Technologies-in-Practice**



Cases

The interviewees enacted technologies-in-practice in different manners: (See Table 2 on the next page)

Individual-Productive Technologies-in-Practice

"Services 1", a specialist in mechanical services, self-trained in Revit and with experience in coordination, was hired in a Building Services office to be in charge of implementing BIM for a data centre project. According to him, he could not involve other offices to work with BIM since others did not possess that expertise. Thus, he decided to model every project which resulted in all of the information for coordination passed through him. "Services 1" commented that the coordination was improved because everyone could observe and correct the clashes on time. In parallel, he mentioned that it impressed some engineers outside the office who had never seen BIM being applied to their projects, thus he further took the opportunity to provide new, fast and didactic methods to improve the quality of the process with him as coordinator.

In this case, technology is used to obtain personal benefits by leveraging a new position of power in a context where it is not usual for building services specialists to lead and organise workflows. Since other participants used BIM in low levels, it can be said that they adopted the inertia type of enactment that facilitated a way for the interviewee to take advantage of this context.

Collective-Problem-Solving Technologies-in-Practice

"Structure 1", a Spanish engineer in charge of the structural services at the London branch of an international office, coordinated an airport project with architects established in Spain. The interviewee stated that they did not adopt British Standards Level 2, but the project had significantly better communication than others with those standards. They adapted their own work manners in a comfortable way for both sides under the vision that the project is a car pushed by everyone. They relied on strong Revit capabilities to create templates, special elements and views to better understand problematic points, transfer information and make design decisions. On some occasions, "Structure 1" travelled to Spain to coordinate directly with the architects and technical teams. He commented that the people involved were highly motivated and had in place an architect leader who ensured everyone´s opinion felt as important, which made him feel like belonging to a new family. According to him, it has been his best coordination experience because of the personal relations that were established. This manner of using this software based on collective visions of solving a common challenge reinforced the value of cooperation and the existing work practices of the company.

Process-Support Technologies-in-Practice

"Coordinator 1" is part of a U.S. firm and is employed in the UK branch developing big-sized projects of a different kind. The specialists involved in the projects can develop their projects at different locations. This company believes that working in Revit increases efficiency, and they have been trying to accommodate standards among locations. "Coordinator 1", mentioned about the efforts that they invest in homologating the work in different projects but opined that there are several factors that influence the way projects are developed. He highlights, in an example, the client requirements in assigning a specific engineering office that does not use Revit. He claimed that different conditions change the process. In order to overcome inefficiencies, "Coordinator 1" has been in charge of integrating UK and U.S. standards for generating a mixed guide to work based on existing resources more than on using their own methods.

In parallel, "Coordinator 1" also stated that the company has made efforts to improve communications among specialists by providing a multi-platform system that allows calls and screen sharing. He also commented that the firm values meetings and

Table 2 Types of Enactment—Conditions, Actions, and Consequences

Type of Enactment	Interest in using the Technology	Interpretive Conditions	Technological Conditions	Institutional Conditions	Technology-in-Practice	Processual Consequences	Technological Consequences	Structural Consequences
Inertia	Low	Limited technical knowledge	•Networked personal computer •Customizable groupware tool	•Hierarchical •Individualistic •Competitive	*Limited-Use*	•None	•None	Reinforce and preserve status quo
Application	Very High	Extensive technical knowledge	•Networked personal computer •Customizable groupware tool	•Nonhierarchical •Collaborative •Participative	*Collaboration*	•Increased effectiveness in development •Improved collaboration	•Changes to the tool •Changes to the data	Reinforce and enhance status quo
	Moderate	Moderate technical knowledge	•Networked personal computer •Customizable groupware tool	•Hierarchical •Individualistic •Competitive	*Individual-Productivity*	•Increased efficiency in communication	•Changes to the data	Reinforce and enhance status quo
	High	Detailed technical knowledge	•Networked personal computer •Customizable groupware tool	•Communal •Cooperative	*Collective-Problem-Solving*	•Increased effectiveness in problem solving •Increased cooperation	•Adaptations to the tool •Changes to the data	Reinforce and enhance status quo
	Very High	Competent technical knowledge	•Networked personal computer •Customizable groupware tool •Call tracking tool	•Team-focused •Cooperative •Learning-oriented	*Process-Support*	•Increased effectiveness in customer service •Increased efficiency in communication	•Adjustments in the tool •Changes to the data	Reinforce and enhance status quo
Change	High	Competent technical knowledge	•Networked personal computer •Customizable groupware tool •Call tracking tool	•Team-focused •Cooperative •Learning-oriented	*Improvisation*	•Redefined work distribution •Shift in type of collaboration •Change in ways of learning	•Adaptations to the tool •Changes to the data	Transform status quo

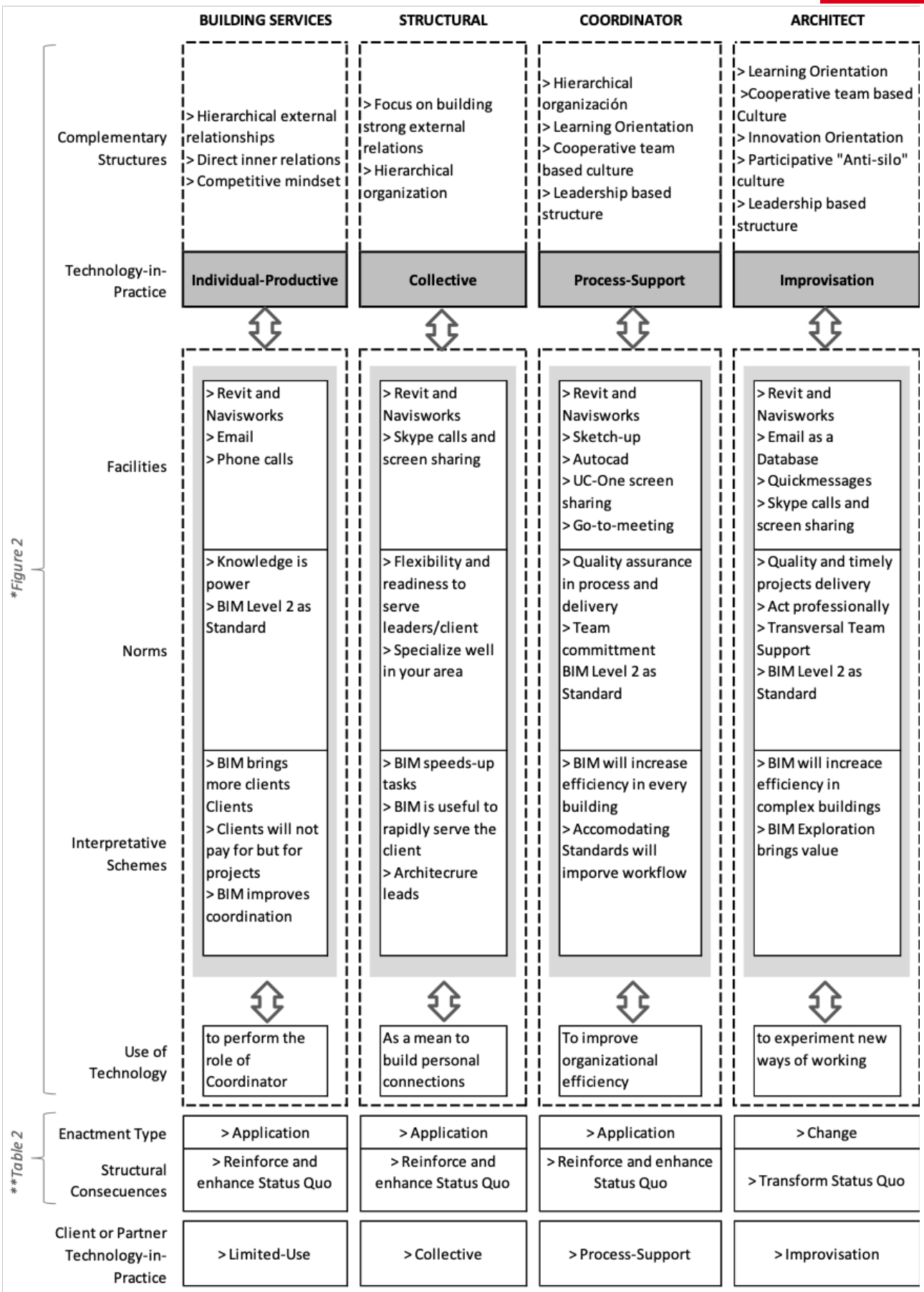
Table 2. Enactment of Technologies in Practice. Source: Orlikowski, W. (2000).

encourages everyone to provide opinions.

Improvisation Technologies-in-Practice

"Architect 1" is part of a design team in a global company specialized in architecture, engineering and coordination of healthcare projects, which characterized the specific technical and normative requirements. They implemented Revit expecting to increase efficiency among teams, not only applying the software provider rules, but also encouraging people to explore new ways of working. The interviewee became proficient in Revit over time, along with colleagues who have been a part of the creation and definition of new processes. Their team, similar to other teams, relies on a Revit-experienced architect leader who communicates their workflows to the department of digital practice that in turn supports and encourages the permanent exploration and improvement of processes within the architectural team as well as in the work with the engineering teams.

Architect 1 stated that they perform diverse manners of working, supported by an array of technological and non-technological communication forms. The company developed an in-house platform that is linked to Skype with several features such as quick messages, calls and screen sharing that is used for coordinating projects and share knowledge with colleagues in other cities. A "hashtag open email system" allows them to browse any specific topic, as well as to share knowledge or to ask anyone inside the firm and its international branches. Architect 1 mentioned that they sometimes adopted non-conventional forms of working such as chatting with the colleague in the next seat or modelling and



*Orlikowski, W. (2000). Enactment of Technologies in Practice. Figure 2
**Orlikowski, W. (2000). Types of Enactment-Conditions, Actions, and Consequences. Table 2

Chart 2: Developed by the Author

coordinating with all engineers in front of only 1 computer.

According to Orlikowski, the value found in ongoing experimentation and change may reinforce the existing structures such as learning orientation, participative anti-silo culture and cooperative team based culture, which is coherent with the interviewee's Revit-learning process since it was implemented in the office.

Discussion

With regards to our research question, two lines of discussion are followed.

First, there is no guarantee that collaboration or any other kind of relationship can occur. Thus, it can not be seen as inscribed neither in the artefact nor in the standards. In chart 2, the "Use of technology" line indicates the diverse aspects that are relevant to people that are coherent with the existing structures, facilities, norms and interpretative schemes. The enactment of technologies-in-practice as a structure resulted in diverse elections of use. In the first case, BIM collaboration was not selected. Considering the norm "knowledge is power" the user opted to enact technology for re-positioning himself in the role of the coordinator (Linderoth; 2009), to benefit himself or the organization he represented. In the second case, even when not based on BIM Level 2 standards, the interviewee collaborated in accommodating the work to be comfortable to both sides, based on their flexibility and readiness to serve the client. The third case sought to ensure quality in accommodating standards to rule actions and account for BIM as supportive of performing efficient processes; however, it is not evident if and how collaboration occurs. The fourth case presents collaboration occurring in formal and informal ways. In the end, people chose how to enact technology.

Therefore, BIM does not necessarily implicate collaboration. Moreover, Building Services 1 individual productivity technology-in-practice enactment may lead to support his view of BIM as an effective tool for individual gains by demonstrating personal value, which could reinforce non-collaborative practices (Orlikowski; 2000).

Second, broadening the focus from collaboration to more precise terms would be valuable. Coordination processes can be affected by numerous and changing factors that bring variability to the processes. The information gathered shows that not only collaboration but different social dynamics can happen, which are relevant to better understand this phenomenon. Thus, two concepts are presented.

On the one hand, synchronisation is a more precise concept that provides value to the process. In the construction sector, organisations buy services to other specialist offices or individuals by configuring a strong path-dependent manner for operation. In practice, since specialists develop their agreed service, they can merely fulfill their contract and not necessarily do it in collaborative manners, especially in the context of several participants competing with each other. Therefore, even when BIM work on the cloud allows every specialist to observe the moment when other specialists are developing and modifying the project in real time (as is the aim of UK BIM Level 3) they would be merely performing their work in a synchronised manner. Differentiating this term from collaboration allows focusing on the benefits of synchronisation for productivity, as well as enhancing the comprehension about what to expect from others, thus augmenting trust levels.

On the other hand, experimentation term recognises the value of flexibility. Improvisation technology-in-practice in the fourth case accounted for change as a type of enactment because it significantly modified the artefact by generating new BIM templates and developing applications to communicate across offices (Orlikowski; 2000). Moreover, it modified workflows in the permanent exploration of new manners to work with or without technology and the organisational structure by creating the area of digital practice to support managing knowledge and innovation. By borrowing aspects from the existing standards or BIM execution plans (BEP), by developing templates and by organising groups based on expertise, they built a base of resources to work with that was supported by project leaders. This way, teams and individuals adopted tailored processes for each project, accompanying them with **several and** flexible methods of work that led to finding feasible solutions (Kokkonen & Alin; 2016). They relied on an array of technological and non-technological solutions to design and coordinate projects and felt the liberty to physically and virtually meet in diverse manners.

This case accounts for a balance between automation and flexibility and shows the human choice for experimenting with new processes as a valuable manner to face complexity.

In this manner, extending the prevalent focus on collaboration to other terms such as synchronisation and experimentation, as well as others that may emerge is necessary to gain precision in BIM knowledge. Ensuring such precision is meaningful for the public sector in the development of policies, standards and setting industrial strategies and for the private sector in the comprehension of these trends not as merely operative but as an organisational and business issue.

Further research on the topic is required to extend the concept of emergent BIM processes based on practice theory where the focus is on the actual use of technology. As this study indicates, several themes may arise from this approach. Some could study how building execution plans (BEP) are enacted under the perspective of the emerging practices, where change is usual (Kokkonen & Alin; 2016) or how emergent practices define new roles (Linderoth; 2009) in the use of BIM. Similarly, it would be enriching to explore complementary aspects of BIM use from the perspective of social sciences in order to broaden the little but informative literature available.

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