Boundary Spanning in BIM-enabled Early Facilities Management Involvement: From A Sociomaterial Perspective

Pei MA[1] and Isabelle CHAN[1]

[1] Department of Real Estate and Construction, University of Hong Kong, Hong Kong, China

Abstract

Due to mistakes, omissions, and inadequate considerations in previous phases, the project operational phase has been placed heavy burdens, which can be effectively mitigated by involving specialists with post-occupancy knowledge in the design process, known as early facilities management involvement (EFMI). Diverse and extensive pieces of knowledge, which reside with different stakeholders, are needed in the EFMI collaboration. It has been proven that boundaries between highly specialized stakeholders impede cross-discipline collaboration and knowledge sharing. In this case, both endeavors from building information modeling (BIM)-enabled artifacts and stakeholders are entailed in bridging boundaries, which serve as boundary objects and boundary spanners, respectively. However, the effectiveness of BIM-enabled artifacts in improving knowledge sharing has been debated. The boundary-spanning mechanisms have been far from well-established. This study aims to explore how BIM-enabled artifacts play a role in boundary spanning under the EFMI context. Sociomateriality is adopted as the underlying theoretical lens. A qualitative strategy following critical realism was applied. Moreover, a case study was employed, in which a newly-build stadium project was investigated. Findings reveal that boundary objects can display inherent incompleteness and induce spanners to raise questions. More importantly, the effectiveness of boundary objects in boundary spanning is significantly influenced by the degree to which boundary objects serve to narrow knowledge gaps between spanners and support core technical abilities, which concern the knowledge amount and types of spanners. By providing theoretical and practical deliberations of boundary spanning, this study mitigates the debate around the benefits of boundary objects and enriches the existing literature on how knowledge boundaries are bridged and how boundary objects and spanners intertwine. Also, it enlightens practitioners on EFMI adoption and technology-enabled collaboration.

Keywords: Early facilities management involvement; Boundary spanning; Boundary object; Building Information Modelling

Early Facilities Management Involvement (EFMI)

There is a growing consensus that project management in the architecture, engineering, and construction (AEC) industry should hold a life-cycle mindset (Guo et al., 2010; Levy, 2018). The operational phase is typically the longest phase within the project life cycle and the main contributor to whole life cost (Boussabaine & Kirkham, 2004). Noticeably, some problems encountered in this phase can be attributed to mistakes, omissions, or inadequate considerations in previous phases. Examples include but are not limited to the lack of safe access for equipment maintenance, inconvenient barrier-free facilities, and unreasonable space planning. These problems place heavy burdens on operational life, and it is always hard to compensate for them (Mohammed & Hassanain, 2010).

One effective method of coping with the difficulties mentioned above is to involve specialists, who have professional facilities management (FM) knowledge and experience, in the design process, an approach referred to as early facilities management involvement (EFMI) (Meng, 2013). By incorporating FM knowledge into the design process, EFMI is beneficial to improve project quality and cost effectiveness and efficiency over the long term, enhance the operability, maintainability, and serviceability of facilities, and satisfy clients' requirements and end-users' needs (Fatayer et al., 2019; Meng, 2013; Mohammed & Hassanain, 2010). Moreover, EFMI echoes the mindset of life-cycle management.

Boundary Spanning in the EFMI Context

Although the tangible and intangible benefits of EFMI have been recognized, EFMI has confronted various obstacles in practice (Meng, 2013). Amongst, difficulties in communication between stakeholders are pervasively reported, as they inhibit knowledge sharing and EFMI collaboration (Kalantari et al., 2017; Kordestani Ghalenoeei et al., 2021; Meng, 2013). Projects in the AEC industry are knowledge-intensive. Diverse stakeholders or professional groups specialize in different professional fields and have their own terminology, points of view, thinking modes, and interests, which may give rise to knowledge boundaries among them. It has been established that knowledge boundaries impede cross-discipline communication and collaboration (Kalantari et al., 2017). Hence, the primary difficulty of EFMI adoption is knowledge sharing and communication across boundaries, and EFMI practices can be viewed as processes of boundary spanning.

Bridging boundaries relies on both humans and artifacts, which can be defined as boundary spanners and boundary objects, respectively. In the EFMI context, boundary spanners are representatives of multiple stakeholders who engage in EFMI collaboration. Various technological artifacts are used in cross-discipline discussions and act as boundary objects. Building information modeling (BIM)-enabled artifacts, including but not limited to BIM models and BIM-enabled analysis results, have been gaining in popularity and increasingly used for multi-discipline collaboration and knowledge sharing (Demian & Walters, 2014; Papadonikolaki et al., 2019; Wang & Meng, 2018). They embed rich information and create common spaces where inter-stakeholder discussions can take place yet are flexible enough to meet the local needs of all parties, which coincides with the definition of boundary objects proposed by Star and Griesemer (1989). In recent years, BIM-enabled EFMI has been advocated (Jensen et al., 2019; Kalantari et al., 2017).

Research Gap and Research Aim

Despite high expectations of the abilities of BIM-enabled artifacts to facilitate cross-discipline collaboration and bridge knowledge boundaries, not all practices achieve original goals; indeed, many produce unanticipated outcomes. Improvements in collaboration and knowledge boundary spanning enabled by BIM-enabled artifacts have received support from some studies (Barlish & Sullivan, 2012; Demian & Walters, 2014) but been questioned by others (Dainty et al., 2017; Neff et al., 2010; Papadonikolaki et al., 2019). The causes of these puzzling phenomena are complicated. However, the existing literature falls short of providing a mechanism explaining how a boundary object plays a role in boundary spanning and how boundary spanners perceive boundary objects' effectiveness in resolving technical problems. Based on the research background, this study aims to explore how BIM-enabled artifacts, serving as boundary objects, play a role in boundary spanning under the EFMI context.

Theoretical Lens

Studies on boundary-spanning mechanisms and how technological artifacts or boundary objects play a role in boundary spanning have been escalating in prevalence. With further research development using the theoretical lens of sociomateriality, some studies focus on how boundary objects are utilized and then intertwine with spanners and why they support or constrain spanners' goals (Daniel et al., 2017; Uppström & Lönn, 2017). Sociomateriality posits that the social and the material are constitutively intertwined in everyday life (Orlikowski, 2007). Furthermore, constitutive intertwining does not privilege either humans or material, nor does it link them by mutual reciprocation, but explores how organizational practices are constituted through sociomaterial agencies (Doolin & McLeod, 2012; Orlikowski, 2007).

Some scholars suggest critical realism as an appropriate foundation to study sociomateriality (Leonardi, 2013; Mutch, 2013). Critical realism follows a realist ontology and an interpretive epistemology (Zachariadis et al., 2013). Based on the critical realism, the abstract framework of the core concepts of sociomateriality is shown in Figure 1. Humans have intentionality, and technological artifacts have materiality. Then, what is actually becoming interlocked in sequences or entangled in practice is social agency and material agency (Leonardi, 2011, 2012, 2013). Humans often exercise their social agencies in response to an artifact's material agency, which refers to the capacity of the artifact to act apart from sustained human intervention (Leonardi, 2012). In other words, humans approach technological artifacts with diverse goals and attempt certain functions of artifacts. Humans will make decisions and choices depending on whether they perceive that an artifact affords or constrains their goals. Consequently, social and material agencies become intertwined and result in imbrication.

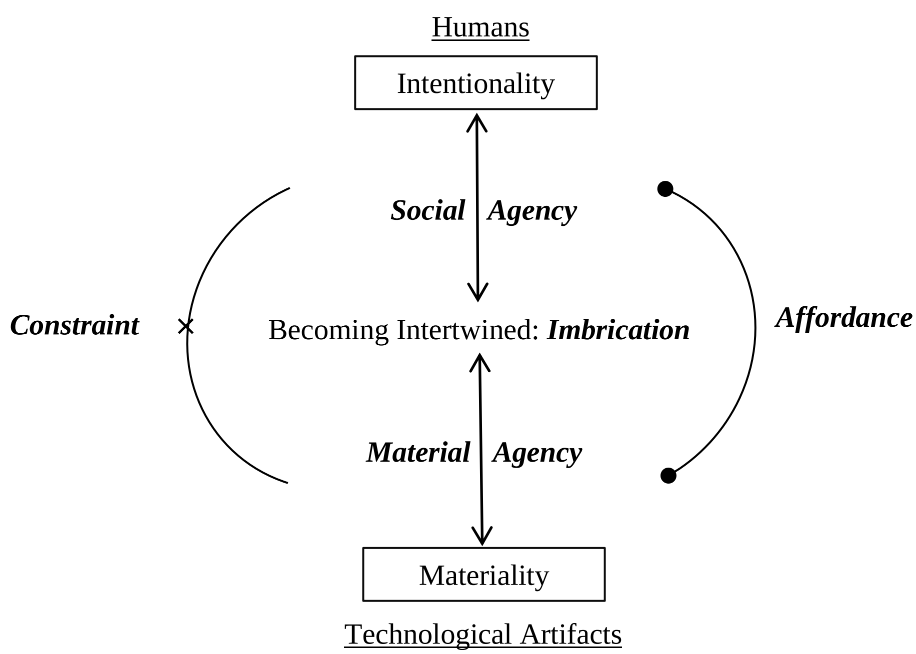

Figure 1 The abstract framework of the core concepts of sociomateriality (adapted from Leonardi (2012))

Particularly, sociomateriality provides a vocabulary that can explain how and why boundary objects emerge and evolve and how they achieve their effects at particular times and in particular places (Doolin & McLeod, 2012). To uncover the mechanisms behind BIM-enabled EFMI practices, this study adopts sociomateriality as its underlying theoretical lens.

Research Method

This study follows the stream of sociomateriality research from the critical realist perspective. Moreover, the role of an intensive or qualitative strategy is to provide a more profound explanation as this strategy is more capable of complicated mechanism identification (Sayer, 2000; Zachariadis et al., 2013). Thus, this study suits a qualitative strategy. As an empirical inquiry, a case study "investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2018, p. 50). Hence, the case study method is appropriate for this study.

An in-depth single-case study was conducted. The case was selected according to the following criteria. First, FM specialists should be involved in the design process. Second, FM specialists should contribute their professional knowledge and provide suggestions and specify requirements to improve design solutions. Third, BIM-enabled artifacts should be used in the discussions and negotiations between stakeholders. Consequently, one newly-build stadium project adopting BIM-enabled EFMI was selected, namely the N case. In the N case, EFMI considerations focus on the visionary planning of long-term venue use, and BIM models were used to facilitate the EFMI discussions about space planning. Semi-structured interviews were conducted with key informants who had participated in BIM-enabled EFMI discussions and were from different stakeholders. Each interview lasted from one and a half to two hours. All key stakeholders, including FM specialists, the design team, the main contractor, and the construction supervision, were represented in the pool of interviewees.

Key Findings

In the N case, the BIM-enabled artifacts utilized were mainly BIM models, for which the material agency obviously manifested in visualization and simulation. First, the visualization functions of BIM models offer advantages in concretely providing visual representations and intuitively displaying spatial positions of physical components and their relationships. The information embedded in 2D drawings is highly abstract and simplified, while BIM models represent abstract knowledge concretely and clearly. These BIM models are themselves concrete but represent the abstract in detail and accurately. Hence, they bridge the concrete and the abstract. Second, in a broad sense, the process of modeling is that of feasibility verification and digital simulation. For yet-to-be-built projects, models can be viewed as open-ended projections of what projects would be. Through ex-ante simulation and verification of design solutions, stakeholders are able to estimate in advance whether considerations from all parties are fulfilled so as to control and improve project quality in a proactive manner.

Furthermore, as boundary objects, BIM models have an inherent material agency, that is, interpretative flexibility. BIM models can be read in a way that enables stakeholders with different professional backgrounds to simultaneously make sense of and capture their concerns. The interpretative flexibility of BIM models is a result of their own incompleteness (Ewenstein & Whyte, 2009). BIM models embed design knowledge and construction knowledge, but they are not fully defined and, consequently, attract the attention of stakeholders, especially FM specialists. Inevitably, their own incompleteness induces stakeholders to raise questions for further development, as perceived by the architect in the N case.

> *"BIM models make it easier for FM personnel to capture what they want. When they review models, they can grasp points they care about and find out whether there are any problems, which is convenient for them to ask questions. In this way, time and cost of communication will be saved, and efficiency will be improved."*

More importantly, the perceived effectivenes of BIM-enabled artifacts are influenced by two factors. First, the effectiveness is perceived when BIM-enabled artifacts narrow the knowledge gaps between highly-specialized stakeholders. A professional in one discipline may be a newcomer in another. Although FM specialists working on the N case had accumulated a certain ability to read 2D drawings from previous project experience, highly symbolized 2D symbols still put them under pressure when imagining the yet-to-be-built venue and understanding the design. Hence, large gaps in knowledge amount were still apparent between them and the designers, concerning the spatial imagination after reading 2D drawings. The concrete and comprehensive representations of abstract 2D drawings narrowed these gaps, helping FM specialists to envision themselves within a realistic scene, as recognized by the interviewees.

> *"Many people cannot read 2D drawings well. Needless to say, layman. Sometimes, it is even difficult for us to understand drawings of other disciplines. 2D symbols are highly symbolized, and a simple 2D symbol represents several pieces of information, which is hard for people without rich professional knowledge to understand. However, visualization of BIM models makes it easier for FM specialists to capture what they want."*

Second, spanners' perceptions are influenced by the degree to which BIM-enabled artifacts support core technical abilities. In the N case, space planning and venue operation were the most required core abilities but were not supported by BIM models. This explains the response of the FM specialist.

> *"BIM models' effects are limited in space planning. BIM acts as a tool and cannot bring qualitative changes."*

In short, in the N case, stakeholders with multiple professional backgrounds adopted BIM models to facilitate their resolutions of EFMI issues. With the functions of visualization and simulation, BIM models represented abstract knowledge concretely, realized ex-ante simulation and verification, and provided interpretative flexibility. Notably, the perceived effectiveness of BIM models is governed by the degree to which BIM models can support core technical abilities and narrow knowledge gaps. As such, the knowledge boundaries during the EFMI collaboration were successfully bridged, and the effectiveness or affordance of BIM models in spanning boundaries was perceived by stakeholders. During the boundary-spanning process, boundary objects and spanners (BIM models and stakeholders) gradually intertwined with each other.

Conclusion and Implications

To deeply understand how boundary objects play a role in boundary spanning, this study conducts BIM-enabled EFMI as the research context, adopts sociomateriality as the theoretical lens, and employs a critical realism-based qualitative research method. The single case study provides fruitful empirical evidence and rich insights.

Key findings indicate that boundary objects provide a sound common space for knowledge exchange by invoking a shared place of practice at the same time as enabling local understandings. By displaying inherent incompleteness, boundary objects assemble multiple-discipline knowledge throughout cross-disciplinary collaboration, all of which are results of collaboration among spanners. Although technological boundary objects are highly expected to facilitate knowledge sharing and boundary spanning, not all original goals can be realized. Notably, the degree to which technological boundary objects narrow knowledge gaps between spanners and the degree to which they support the core technical abilities of spanners significantly influence the perceived effectiveness of boundary objects. Hence, the knowledge types needed in boundary spanning and the knowledge amount of spanners should be considered when choosing proper technological objects and analyzing the effectiveness of boundary object adoption.

This study enriches insights into how boundary objects facilitate boundary spanning, deepens understanding of interweaving between boundary objects and spanners, and offers an explanatory lens for further investigation of complicated social phenomena. Also, this study offers some practical implications. For instance, the influence factors of boundary objects' effectiveness, such as the degree to which boundary objects narrow knowledge gaps, provide analytical angles to select the appropriate technological artifacts and evaluate their performance.

References

Barlish, K., & Sullivan, K. (2012). How to measure the benefits of BIM — A case study approach. *Automation in Construction*, *24*, 149-159. https://doi.org/10.1016/j.autcon.2012.02.008

Boussabaine, H., & Kirkham, R. L. (2004). *Whole life-cycle costing : risk and risk responses*. Blackwell Pub.

Dainty, A., Leiringer, R., Fernie, S., & Harty, C. (2017). BIM and the small construction firm: a critical perspective. *Building Research & Information: Digitizing building information: organizational and policy implications*, *45*(6), 696-709. https://doi.org/10.1080/09613218.2017.1293940

Daniel, E., Hartnett, E., & Meadows, M. (2017). Don't throw rocks from the side-lines A sociomaterial exploration of organizational blogs as boundary objects. *Information technology & people (West Linn, Or.)*, *30*(3), 542-561. https://doi.org/10.1108/ITP-02-2015-0036

Demian, P., & Walters, D. (2014). The advantages of information management through building information modelling. *Construction management and economics*, *32*(12), 1153-1165. https://doi.org/10.1080/01446193.2013.777754

Doolin, B., & McLeod, L. (2012). Sociomateriality and boundary objects in information systems development. *European journal of information systems*, *21*(5), 570-586. https://doi.org/10.1057/ejis.2012.20

Ewenstein, B., & Whyte, J. (2009). Knowledge Practices in Design: The Role of Visual Representations as `Epistemic Objects. *Organization studies*, *30*(1), 07-30. https://doi.org/10.1177/0170840608083014

Fatayer, F. A., Hassanain, M. A., Abdallah, A., & Al-Hammad, A.-M. (2019). Investigation of facilities management practices for providing feedback during the design development and review stages. *International Journal of Building Pathology Adaptation*, *37*(5), 597-614.

Guo, H. L., Li, H., & Skitmore, M. (2010). Life-Cycle Management of Construction Projects Based on Virtual Prototyping Technology. *Journal of Management in Engineering*, *26*(1), 41-47. https://doi.org/10.1061/(ASCE)0742-597X(2010)26:1(41)

Jensen, P. A., Rasmussen, H. L., & Chatzilazarou, S. (2019). Knowledge transfer between building operation and building projects. *Journal of facilities management*, *17*(2), 208-219. https://doi.org/10.1108/JFM-05-2018-0030

Kalantari, S., Shepley, M. M., Rybkowski, Z. K., & Bryant, J. (2017). Designing for operational efficiency: facility managers' perspectives on how their knowledge can be better incorporated during design. *Architectural Engineering and Design Management*, *13*(6), 457-478. https://doi.org/10.1080/17452007.2017.1348333

Kordestani Ghalenoeei, N., Saghatforoush, E., Athari Nikooravan, H., & Preece, C. (2021). Evaluating solutions to facilitate the presence of operation and maintenance contractors in the pre-occupancy phases: a case study of road infrastructure projects. *International journal of construction management*, *21*(2), 140-152. https://doi.org/10.1080/15623599.2018.1512027

Leonardi, P. M. (2011). When Flexible Routines Meet Flexible Technologies: Affordance, Constraint, and the Imbrication of Human and Material Agencies. *MIS quarterly*, *35*(1), 147-167. https://doi.org/10.2307/23043493

Leonardi, P. M. (2012). Materiality, sociomateriality, and socio-technical systems: What do these terms mean? How are they different? Do we need them. In *Materiality organizing: Social interaction in a technological world* (pp. 25-48). Oxford: Oxford University Press.

Leonardi, P. M. (2013). Theoretical foundations for the study of sociomateriality. *Information and organization*, *23*(2), 59-76. https://doi.org/10.1016/j.infoandorg.2013.02.002

Levy, S. M. (2018). *Project management in construction*. McGraw-Hill Education.

Meng, X. (2013). Involvement of Facilities Management Specialists in Building Design: United Kingdom Experience. *Journal of Performance of Constructed Facilities*, *27*(5), 500-507. https://doi.org/10.1061/(ASCE)CF.1943-5509.0000343

Mohammed, M. A., & Hassanain, M. A. (2010). Towards improvement in facilities operation and maintenance through feedback to the design team. *The Built and Human Environment Review*, *3*, 72-87.

Mutch, A. (2013). Sociomateriality — Taking the wrong turning? *Information and organization*, *23*(1), 28-40. https://doi.org/10.1016/j.infoandorg.2013.02.001

Neff, G., Fiore-Silfvast, B., & Dossick, C. S. (2010). A CASE STUDY OF THE FAILURE OF DIGITAL COMMUNICATION TO CROSS KNOWLEDGE BOUNDARIES IN VIRTUAL CONSTRUCTION. *Information, communication & society*, *13*(4), 556-573. https://doi.org/10.1080/13691181003645970

Orlikowski, W. J. (2007). Sociomaterial Practices: Exploring Technology at Work. *Organization studies*, *28*(9), 1435-1448. https://doi.org/10.1177/0170840607081138

Papadonikolaki, E., van Oel, C., & Kagioglou, M. (2019). Organising and Managing boundaries: A structurational view of collaboration with Building Information Modelling (BIM). *International Journal of Project Management*, *37*(3), 378-394. https://doi.org/10.1016/j.ijproman.2019.01.010

Sayer, R. A. (2000). *Realism and social science*. SAGE.

Star, S. L., & 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. https://doi.org/10.1177/030631289019003001

Uppström, E., & Lönn, C.-M. (2017). Explaining value co-creation and co-destruction in e-government using boundary object theory. *Government information quarterly*, *34*(3), 406-420. https://doi.org/10.1016/j.giq.2017.08.001

Wang, H., & Meng, X. (2018). Transformation from IT-based knowledge management into BIM-supported knowledge management: A literature review. *Expert Systems with Applications*.

Yin, R. K. (2018). *Case Study Research and Applications : Design and Methods* (Sixth ed.). SAGE Publications, Inc.

Zachariadis, M., Scott, S., & Barrett, M. (2013). Methodological Implications of Critical Realism for Mixed-Methods Research. *MIS quarterly*, *37*(3), 855-879. https://doi.org/10.25300/MISQ/2013/37.3.09