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EDITORIAL

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Introduction

The architecture engineering construction (AEC) industry has been plagued by notoriously low efficiency, high error rates, and large budget and time overruns. The main cause has been inadequate and inefficient information management mainly based on two-dimensional (2D) drawings. The concept of building information modelling (BIM) and the related methods and technologies have been deployed to overcome the insufficiency and budget and time overruns by replacing conventional non-digital practices with the integrated management of design, construction, operation, and maintenance information throughout the lifecycle of a project. For the past few decades, the adoption of BIM, the roots of which can be tracked back to the 1970s (Eastman *et al*. 1974), has dramatically increased across the world.

Advancements in software and hardware technologies have been the main enablers of the deployment and development of BIM. Examples of such BIM technologies include object-based and parametric modelling, automated design quality and compliance checking, interoperability, scan–BIM, BIM–fabrication, field BIM management, BIM facility-management, digital twins, and mobile- and cloud-based BIM collaboration. Nevertheless, numerous BIM projects have clearly demonstrated for the past two decades that the mere adoption of BIM technologies does not guarantee the success of BIM projects and that the outcomes differ greatly depending on how these technologies are deployed and by whom (Kang *et al*. 2013). A relatively new annual international workshop, "When social science meets lean and BIM", is one of the efforts to address such non-technical issues related to BIM.

This special issue aimed to quantitatively and qualitatively report the impact of such non-technical managerial elements of BIM on the performance of BIM projects. Examples of such non-technical drivers of BIM adoption include legal and contractual issues, lean implementation of BIM, coordination, cooperation and collaboration strategies, team building and management, education and training of human resources, inter- and cross-enterprise organization, social interactions between project teams, security of BIM information, intellectual property and copyright, BIM service fee structures, policies, and other management issues related to BIM.

This editorial briefly reviews some of the above-mentioned BIM management issues from the people, process, and policy points of view and introduces the articles published in this special issue. Of more than 20 papers submitted for this special issue, three insightful papers were selected for publication. Finally, the future directions and issues related to non-technical aspects of BIM are discussed.

The PPT framework

In the adoption of a new technology, the people and the process are often recognized as the essential factors in addition to technology itself. This concept is referred to as the people, process, and technology (PPT) framework. The PPT framework is so prevalent that the definite origin is unknown, and many variations have been produced. Such variants include the people, process, and policy (PPP) framework (Trivedi 2017), the people, process, technology, and policy (PPTP) framework (Trivedi 2018), and the Macro-Diffusion Responsibilities Model based on policy, process, and technology players (Succar and Kassem 2015). Although the policy may not be another essential factor for technology adoption, undoubtedly, the policy can play a significant role – sometimes a positive role as a catalyst or sometimes a negative role as a retarder for the adoption of a new technology. Other variations include the technology, organization, and environment (TEO) framework (Tornatzky and Fleischer 1990) and Leavitt's (1972) Diamond. Leavitt's Diamond consists of technology, people, the structure, and the task (Leavitt 1972). Since Leavitt's Diamond was proposed in the 1960s, some have regarded Leavitt's Diamond as the origin of the PPT framework.

BIM as a technology also needs users (people) and best practices (processes) to be adopted by the industry as well as a policy to facilitate the adoption process. Many studies have been conducted to understand how different ways of deploying BIM affect a project. The following sections recapitalize some of them.

BIM processes

In the beginning of BIM adoption, the impact of BIM on a project and many success stories were reported (Khemlani 2006, Lê *et al*. 2006, Eastman *et al*. 2008).

BIM was then and is still used most widely for design coordination and clash detection (Young *et al*. 2007, Kreider *et al*. 2010, NBS 2019). A challenge was how to quantify the impact of "avoided" errors through BIM-based design coordination. Sacks *et al*. (2005) reported that the adoption of BIM could potentially reduce at least 2% of rework in precast concrete projects by analyzing the design errors that could have been avoided if BIM were adopted in the projects. Additionally, Giel and Issa (2013) compared the BIM and non-BIM projects with similar properties to demonstrate how much BIM could save.

One of the common methods to calculate the return on investment (ROI) of BIM at that time was to convert all of the rework costs associated with avoided errors into savings. One criticism about such a method was that it is assumed that all the "avoided errors" through BIM could not be detected during the traditional 2D design coordination process. Lee *et al*. (2012b) proposed a method to calculate the design errors by categorizing avoided errors through BIM-based design coordination into three levels: easy to identify, a 50% chance to identify, and difficult to identify during the traditional 2D design coordination process; the authors assigned a different weight to each avoided error depending on the likelihood of identification during the traditional 2D design coordination process. Studies then began reporting that the benefits of BIM did not come for free and that there was a certain trade-off. Leite *et al*. (2011) reported that BIM models with a higher level of detail could help project participants make a better decision, but this required two to eleven times more time to increase one level of detail.

However, as the prevalence of BIM increased, it became clear that not all BIM projects were successful. Several studies looked into different BIM coordination strategies in successful and failed BIM projects. Jang *et al*. (2019) learned how a contractual sequence can change the involvement attitude of BIM project participants in design coordination and value engineering during the preconstruction activities and eventually impact the cost of the project. Furthermore, Lee and Kim (2014) quantitively and qualitatively analyzed the significance of the "information equality" created among project participants by deploying different design coordination strategies and its impact on the BIM coordination productivity. Still, a large number of BIM projects are conducted using both 2D drawings and BIM models. Park and Lee (2017) showed how the changes in the design-approval sequence in a 2D-and-BIM mixed project environment changes the key players of a project, the social dynamics between the project participants, the design review time, and the quality of the design review using social network analysis.

Since 2010, it has been understood that a partial standardization of BIM processes is required to realize efficient BIM project management. One of the most important sets of standards developed in this context is the British Standards (BS) Publicly Available Specification (PAS) 1192-2 "Specification for information management for the capital/delivery phase of construction projects using building information modelling (BSI 2013)". The document describes the general execution of BIM projects, including the purposes and required contents of both the employer's information requirements (EIR) and the BIM execution plan (BEP), and elaborates on the requirements for "data drops"—the information and a set of documents that should be handed over to the client at particular project stages. The BS PAS 1192-2 later became the international standard ISO 19650 (ISO TC 59/SC 13 2018). This set of standards has become very influential, and many projects have been conducted worldwide implementing its principles.

BIM people

The "people" issues are often recognized as the most challenging obstacle to the BIM adoption (Sacks *et al*. 2018b). Resistance to new technology is one example. During BIM adoption, the "Dunning Kruger Effect" (Kruger and Dunning 1999) is often observed; engineers may be overconfident of their cognitive ability to check and find errors before construction (Lee *et al*. 2016). On the other hand, some BIM users are too modest to reveal "the BIM imposter syndrome", viz., to deny that they are BIM users although they use several BIM tools in their work (An and Lee 2017). At the same time, the ability to use BIM tools is regarded as the fundamental skill of BIM users (Zuppa *et al*. 2009, Barison and Santos 2011, Succar *et al*. 2013, Wu and Issa 2014, Uhm *et al*. 2017). The lack of BIM experts and structured training and certification programmes is another issue. Many countries, including South Korea, Singapore, and the UK, as well a number of national organizations have developed a BIM certification programme (Sacks *et al*. 2018b). Nonetheless, none of them has the strong authority to be accepted as an industry standard yet. To fill this gap, buildingSMART International has been developing an international standard for BIM certification.

Universities are an important source of young engineers. Sacks *et al*. (2018b) interviewed universities around the world regarding the BIM education curriculum at the undergraduate level and learned that universities generally took one of the following three strategies. The first strategy is to offer no BIM-focussed course at the undergraduate level, assuming that the BIM skills required by each subject will be learned from the courses related to each subject. For example, students will learn BIM-based structural engineering skills from existing structural engineering courses, BIM-based cost estimation skills from existing cost estimation courses, and BIM-based energy simulation from existing energy-simulation-related courses. The second strategy is to provide one or two BIM modelling or introductory classes. The third strategy is to convert an existing course structure into a BIM-focussed course structure.

Many new jobs and roles related to BIM have been created. Examples of BIM roles include BIM managers, BIM coordinators, and virtual design and coordination (VDC) managers. Quite a few studies have been conducted to identify the specific job competencies required by different roles in BIM projects (Zuppa *et al*. 2009, Barison and Santos 2010, 2011, Joseph 2011, Abdulkader 2013, Succar *et al*. 2013, Wu and Issa 2014, Uhm *et al*. 2017). Among them, Uhm *et al*. (2017) collected 242 job postings and analyzed the job competencies required by the different roles in BIM projects based on the Occupational Information Network (O*Net)—the job and competency classification system of the US. Through the role and position analysis, Uhm *et al*. also found that a BIM manager and a VDC manager played the same role although they were sometimes perceived as two different roles with a slightly different function and responsibility.

Another line of studies has focussed more on the social dynamics within a BIM project team. Neff *et al*. (2010) argued that BIM is a "boundary object" that facilitates inter-organization communication based on the social science framework. The boundary object is a term that originated from the study by Star and Griesemer (1989), who defined boundary objects as "objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" and who claimed that "the creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting social worlds". When the term "boundary object" is replaced with the term BIM or BIM model in the definition of Star and Griesemer, it becomes clear what the social role of BIM is in an organization.

Additionally, Jang and Lee (2018) analyzed the impact of organizational factors on the design coordination time. The number of participants, the heterogeneity of participants, and the level of decision makers involved in a design issue increased the coordination time. Jang *et al*. underlined the importance of the lean BIM approach, such as Obeya (big room) and Shojinka (flexible manpower line), to expedite decision-making processes and to reduce the coordination time.

BIM policies

The drive by the government, the major client of public construction projects, is essential for BIM adoption by the construction industry because the construction industry is strongly fragmented and is bound by strict regulations. BIM policies range from a firm mandate of BIM in all publicly procured projects through legislation changes, where necessary, to provide financial and organizational aid down to low-level encouragement and support. Singapore, Finland, Korea, the USA, the UK, and Australia form the international avant-garde in BIM policy making. In all of these countries, the government and its subsidiary authorities have played a key role in demanding and fostering the adoption of BIM, however, by implementing significantly diverging approaches.

As far back as 2004, Singapore made it obligatory to submit construction documents for public construction projects via an internet platform "Corenet" (Khemlani 2006). This included the submission of BIM models in the software-neutral IFC format. BIM penetration in the Singaporean construction sector is accordingly among the highest worldwide. The BIM guidelines by the Building and Construction Authority (BCA) were in their second edition in 2013 (BCA 2013).

In Finland, public authorities have required the use of digital building models for all public projects since 2007 with projected costs in excess of 1 million euros (Senate Properties 2007). Since then, comprehensive experience in the execution of BIM projects has been gathered; this has been anchored in the "Common BIM requirements", a set of guidelines that were published in 2012 (buildingSMART Finland 2012).

Furthermore, in the US, major governmental building owners, such as the General Service Administration (GSA) and the US Army Corps of Engineers (USACE), have required the use of BIM methods for project execution for many years (GSA 2007). USACE has published a comprehensive BIM roadmap and provides templates for BIM authoring tools as well as contract requirements on their website (USACE 2012). Also, major private owners are, to a large extent, demanding BIM in their construction projects. Additionally, the National Institute of Building Sciences (NIBS) published the first version of the National BIM standard back in 2007 (NIBS/bSa 2012). An important role for the practical implementation of BIM is played by the American Institute of Architects (AIA). For example, it provides a set of templates for contractual agreements in BIM projects. Together with the Associated General Contractors (AGC), AIA supports the BIMForum, which publishes the level of developments (LOD) guide annually (BIMForum 2017). Apart from these US-wide efforts, there is a great range of BIM standards and guidelines at different governmental and administrative levels, for example, from the state level down to the individual city level.

A particularly remarkable example is the construction strategy of the British government, which was initiated in 2011 with the declared objective of reducing costs and lowering the carbon footprint of construction projects through the use of BIM methods and technologies. The UK government also aimed to put the British construction industry "at the vanguard of a new digital construction era and position the UK to become the world leaders in BIM" (Maude 2012) in order to acquire a significant competitive advantage on the international market. The key aspect of the 2011 UK construction strategy was to demand "fully collaborative 3D-BIM", which corresponds to BIM Level 2, for all centrally procured construction projects from 2016 onwards. At the time of writing, this goal has been mostly met. This is supported by an annual BIM survey that reports a significant increase in the adoption of BIM methods by the UK construction industry over the past years (ref).

Many other European countries have started initiatives for implementing BIM in the public construction sector as well. Some of them already require the use of BIM, and others plan to do so very soon. Among the most advanced countries are Finland (buildingSMART Finland 2012), Sweden (buildingSMART Finland 2012), Norway (Statsbygg 2013), and the Netherlands (Rijksgebouwendients 2013).

In 2014, France initiated its "plan de transition numérique du bâtiment" (PTNB; Delcambre 2014) with significant investments to support the transition towards digital technologies. The PTNB published a roadmap in 2015 (PTNB 2015), a BIM guide specifically addressing the needs of the building owners in 2016 (PTNB 2016), and a standardisation strategy in 2017 (PTNB 2017). Additionally, the French region of Burgundy had deployed BIM models for managing building operations across 135 sites, consisting of mostly high schools, back in 2004 (Le Moniteur 2013). Today, the regional council works exclusively within a BIM-based process for construction, maintenance, and building operations.

In Germany, the Ministry of Transport published a BIM Roadmap in 2015 that defines the mandatory use of BIM methods for all federal infrastructure projects from 2020 onwards (BMVI 2015). In this context, significant standardization work is being carried out (VDI 2014), guidelines and templates for EIR and BEP are being developed, and a number of BIM pilot projects are being conducted. The German approach is unconventional in that BIM is first becoming mandatory for the infrastructure sector before being adopted for building public housing. The German railway operator Deutsche Bahn, as one of the largest infrastructure construction clients, plays a particularly important role. It has published detailed BIM guidelines (Deutsche Bahn 2017) and achieved a significant level of BIM adoption in its projects.

In Spain, a steering committee was established in 2015, and a provisional timetable was set with the recommended use of BIM in public sector projects by March 2018, mandatory use in public construction projects by December 2018, and mandatory use in infrastructure projects by July 2019 (esBIM 2019). Also, Austria and Switzerland have started intensive work on BIM standardization (Austrian Standards 2015, Bauen Digital Schweiz 2018).

In Asia, aside from Singapore, South Korea, China, and Japan are the most advanced countries with respect to BIM adoption. Korea has a relatively long history of BIM adoption and had already published its first BIM roadmap in 2010. The first BIM guidelines were published in 2011 and have been frequently updated since then. They included details on how BIM models should be developed incrementally throughout the design and construction phases and defined the minimum requirements for various use cases, such as design review, 3D coordination, and cost estimation. The Ministry of Land, Infrastructure, and Transport of Korea (MOLIT) announced that it would mandate BIM for any public construction projects over KRW 500 million from 2016 by gradually increasing the application scope from 2010. As a result, 60% of industry practitioners used BIM to some extent in 2012 in South Korea (Bauen Digital Schweiz 2018; Lee *et al*. 2012a). This was a huge leap because, in 2008, only large contractors and architectural firms had just begun to adopt BIM (Lee *et al*. 2008).

In contrast, China started to develop BIM guidelines and standards in 2001 (Liu *et al.* 2017). In 2011, the Ministry of Housing and Urban-Rural Development (MOHURD) released the "Outline of Development of Construction Industry Informatization (2011–2015)", which emphasized BIM as a core technology to support and improve the construction industry. In 2016, MOHURD issued an updated version of their "Outline of Development of Construction Industry Informatization (2016–2020)" that proposed enhancing the integrative applications of information technologies like BIM, big data, etc. However, according to Liu *et al*. (2017) and (Jin *et al.* 2015), the main barriers to the successful adoption of BIM in China include: cultural resistance; the low cost of manpower; the lack of domestic BIM data exchange standards, evaluation criteria, and BIM project implementation standards; and the lack of qualified BIM professionals.

In Japan, the term BIM is used for building projects, and the term "construction or civil information modeling (CIM)" is used for civil engineering projects or "construction information modeling (CIM)" for both building and civil engineering sectors (Tateyama 2017; Teh 2019). The Japanese government published the first "CIM introduction guide" in 2007 (Yamamoto *et al.* 2019). In 2016, the Ministry of Land, Infrastructure, Transport, and Tourism of Japan (MLIT) announced the i-Construction initiative and policy to increase construction productivity by integrating information and communication technologies including BIM into construction practices (Tateyama 2017). The i-Construction initiative mandates the use of BIM in excavation (cut and fill) work in over 3 million-dollar road and levee projects from April 1, 2016 and is planning to expand its scope of application to tunnel and bridge projects (Fukuchi 2017).

Meanwhile, the BIM implementation strategy of Australia is mainly influenced and driven by the UK's pioneering efforts. In 2012, "The National Building Information Modeling Initiative (NBI)" report was published as a strategy for the "the focused adoption of BIM and related digital technologies and process for the Australian built environment sector" (Australian Parliament 2016).

A more detailed review on the people, process, and policy issues regarding BIM is available in Chapter 8, "Facilitators of BIM Adoption and Implementation", of the third edition of the BIM Handbook (Sacks *et al*. 2018a), Part III: "BIM-Based Collaboration" of BIM Technology Foundations and Industry Practice (Borrmann *et al*. 2018), and "BIM for Design Coordination" (Leite 2019).

Special issue articles

The three articles selected for this special issue reflect current developments in the context of BIM policy and management and provide new insights. All three papers similarly base their theoretical analysis on actual data from real-world BIM projects, thus, overcoming the argument of ungrounded claims on BIM efficiency introduced by Fox (2014) and others.

Aibinu and Papadonikolaki (2020) discuss how BIM adopters can find an economically efficient implementation strategy. They debate how the effort spent on individual BIM-related tasks in the project lifecycle can be used as a metric for assessing the performance of BIM implementation. They present quantitative data collected from an in-depth case study of a BIM-enabled design and build project and subsequent interviews with three project actors and 11 BIM experts. By analyzing the data, they were able to identify delayed data provision as a major source of inefficiency in the BIM process, thereby, revealing the pivotal role of the procurement structure and suggesting the need for the timely involvement of key project participants.

Akintola *et al.* (2020) criticize the lack of theoretical perspectives capable of explaining the nature of change in work practices involved in BIM adoption. The authors argue that implementing BIM within professional work practices induces their evolution through dysfunctions created within the systems and their resolution. They present cases of professional organizations in South Africa that have implemented BIM within their organization and in multi-organizational projects as well as provide an activity-theory-based re-description of the data to develop new theoretical insights. In doing so, they analyze the changes in professional work practices and are able to reveal the dynamics between and within the interconnected system of actors, their object, tools, rules guiding work, roles they assume, and the stakeholders. The findings imply that the implementation of BIM significantly changes work practices within organizations but gradually and over time.

Lindblad and Guerrero (2020) analyze the role of the client in promoting BIM implementation and explore the different roles public client organizations can enact to promote innovation. To this end, they conducted an explorative case study at the largest transport infrastructure client in Sweden, exploring two strategies that have simultaneously been deployed to promote innovation. The organization studied is, on one hand, trying to steer the industry by demanding BIM and actively influencing the supply chain while, on the other hand, promoting innovation by providing more flexibility in projects, enabling suppliers to propose new solutions and emphasizing market competition. Even though the overarching goals are similar in both strategies, the research finds that the simultaneous use of the policies create intra-organizational tension within the client organization. The findings contribute to the understanding of clients as key actors for promoting innovation in the construction industry and assist in comprehending the impacts of policy making.

Future directions

While it is unquestionable whether the adoption of BIM provides value to the AEC industry and its clients, it remains to be determined in further field study how BIM is best introduced and fostered. In particular, the impact of strategic policies by a country or by an individual (public) client need to be understood better than we do today. While there are clear indications that a combination of the robust BIM mandate by the public and private clients on one hand and the proactive adoption of BIM by the industry on the other hand will significantly accelerate the BIM adoption process. Future study is required to better understand how to achieve the maximum cost-benefit ratio and the goals of each project from the BIM policy and management point of view. With much larger numbers of BIM projects carried out worldwide today, empirical and data-driven research can now be conducted, which is necessary to create deeper insights and a better understanding of BIM policies and management factors grounded in the theories developed in the past.

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