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REVIEW ARTICLE

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Critical review of studies on building information modeling (BIM) in project management

Abstract Building information modeling (BIM) and project management are two major research topics that accommodate large volumes of research efforts. BIM has been interpreted as a process technology that aids in enhancing project management. Hence, the investigation from an interdisciplinary perspective of the two concepts may bring new insights to understanding related research. In this paper, a structural approach is adopted in reviewing BIM studies in project management from 2005 to 2017 within identified target journals. This review aims to classify the major research directions and topics for BIM research in project management. Moreover, given BIM's potential for application in project management, this paper attempts to establish a fundamental research foundation for a new paradigm of project management that incorporates BIM, namely, BIM-based project management. The preliminary result suggests that BIM research in project management develops drastically in the examined duration. The research directions of BIM studies in project management include enabling BIM as a technology in project management; BIM application as a solution for specific project management scopes; integration issues of BIM that have been brought to project management; institutional environment and regulatory governance of BIM in realizing project management strategies; and analysis of effects and strategies of BIM adoption and implementation in projects. The directions and trends are then analyzed to develop a research route for BIM studies in project management. Finally, conclusions focus on the relations of the research directions, as well as the contributions and theoretical implications of this review. Future research areas are also recommended.

Keywords building information modeling (BIM), project management, review, BIM-based project management

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1 Introduction

Conventionally, production in the architecture, engineering, and construction (AEC) industry is implemented as projects, and project management is widely applied in the AEC process to organize efforts. However, the recent diffusion of information technology (IT) in the AEC industry has resulted to a phenomenal impact on different aspects of AEC projects (Alin et al., 2013). The digitizing paradigm requires the integration of IT and management practice in developing advanced approaches to organize the AEC process. As a disruptive technology, building information modeling (BIM) leads to hybrid practice in handling building information and organizing project production (Gledson, 2016; Çıdık et al., 2017; Davies et al., 2017). The potential of BIM in improving the efficiency of project management is worth exploring.

Similarly, BIM and project management are instrumental tools commonly adopted in the AEC process. They are applied to improve the efficiency of management process, promote coordination and collaboration among project participants, and enhance project interoperability with the lifecycle perspective. Moreover, the BIM approach involves the delivery of virtual building models, and building projects require the delivery of facilities; thus, the possibility for an integrated approach for project management implementation with BIM should be investigated.

The use of BIM in enhancing project management is widely acknowledged. Notably, BIM can initially be applied to improve the efficacy of information management. As an integrated technology for information management, BIM aids in improving communication, promoting multidisciplinary collaboration, and enhancing integrated project delivery (Azhar, 2011; Bryde et al., 2013; Porwal and Hewage, 2013). Moreover, BIM is a process technology (Succar et al., 2012; Miettinen and Paavola, 2014; Murphy, 2014); thus, it can influence project procedures and bring paradigmatic change to projects (Taylor and Bernstein, 2009; Froese, 2010; Azhar, 2011). However, the systematic implementation of BIM in AEC projects remains a practical issue.

The current BIM integration in projects faces challenges because it involves systematic approaches with project organizations, procedures, and legislation (Mancini et al., 2017). The scope of BIM application in projects is limited rather than comprehensive (Cao et al., 2014; He et al., 2016). Originally, BIM is supposed to be an information and communication technology (ICT) that integrates multidisciplinary collaboration throughout the project lifecycle; however, its benefits and efficacy have not been thoroughly utilized (Liu et al., 2017). Moreover, many countries have implemented measures to impel BIM implementation in their public projects. Given the compelling requirements of government regulations, many projects apply BIM only to satisfy regulatory requirements rather than add value to the building production process.

From the aforementioned scenario, exploring an integrated solution with BIM and project management appears to be of immense potential. Associating BIM with project management provides new insights into BIM implementation in the project context of AEC and contributes to the exploration of BIM in enhancing project management. Accordingly, the research questions to guide this review are as follows.

1) What is the current status of BIM research in project management?

2) What are the major trends and directions of the current BIM research in project management?

3) How can BIM research in project management contribute to the exploration of a possible approach in managing AEC projects with BIM?

This review serves to provide a preliminary theoretical foundation for a new approach in managing AEC projects with BIM, that is, BIM-based project management by investigating BIM research in project management.

2 Project management in the AEC industry

The different interpretations of the concept of "project" reach no universal understanding. Project Management Institute defines a project as "a temporary endeavor undertaken to create a unique product, service, or result" (PMBOK, 2013). In this definition, a project is considered a task toward a specific mission, and project management has been defined as "the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements" (PMBOK, 2013). Another common definition refers to a project as a temporary organization set to achieve a goal (Gaddis, 1959; Lundin and Söderholm, 1995; Packendorff, 1995; Shenhar and Dvir, 1996). Under this assumption, project management has been perceived as an integrated approach for delivering multifarious disciplines and procedures to achieve organizational synergy (Jugdev et al., 2001; Svejvig and Andersen, 2015). The prevalence of these two major definitions underlies the knowledge origins of technical and social sciences in the project management domain (Söderlund, 2004).

Project management in the AEC industry faces many explicit issues. AEC projects are growing in scale and becoming highly complex; thus, the massive information and data in a project can be overwhelming if not managed properly (Qazi et al., 2016; Luo et al., 2017; Mok et al., 2017). Moreover, a project involves teamwork from different disciplines and participation of different actors, and one of the major tasks for project management is to coordinate the multidisciplinary cooperation. The two issues can merge when the project is large and complex. Hence, an integrated systematic approach is required to manage project uncertainty and complexity (Atkinson et al., 2006; Bosch-Rekveldt et al., 2011; Brady and Davies, 2014; Khan et al., 2016). Finding solutions for emerging problems from technical and conceptual perspectives can inspire the development of project management.

3 Current BIM research in construction management

BIM has evolved and developed continuously in the past decades. At an early stage, the original BIM concept was referred to as "building description system" (Eastman, 1974) and then later as "building product models" (Björk, 1989; Eastman, 1999). Subsequently, it has gradually evolved from a simple digital solution in building into a comprehensive ICT that is not only limited in the technological discipline but also in building information management. Similar to project management, BIM has no unique definition. Eastman et al. (2011) referred to BIM as a "human activity that ultimately involves broad process changes in construction." Some researchers hold different views on BIM, such as "a set of interacting policies, processes, and technologies" (Succar et al., 2012), "a digital representation of a building, an object-oriented three-dimensional model, or a repository of project information" (Miettinen and Paavola, 2014), and "the development and use of digital representations of physical and functional characteristics of a facility" (Lu et al., 2014). BIM has been interpreted differently in various perspectives, and a standardized definition may fail to serve in different situations.

Some studies have interpreted BIM as a concept that involves context and process rather than a simple technology. Poirier et al. (2015) confirmed the profound organizational influence of BIM by referring to different contexts, such as industry, organization, and project. He et al. (2016) identified the management studies in BIM research through a systematic review that consolidates the multiple aspects of BIM. In addition, Chen et al. (2015) aimed to attach BIM to the building process through a framework developed from the review of related literature.

Some studies have investigated BIM in the project perspective. Some researchers have focused on the effects and benefits of BIM to building projects (e.g., Eadie et al. (2013) and Porwal and Hewage (2013)). Others have elaborated on how BIM changes the project execution and organizations (e.g., Taylor and Bernstein (2009), Sebastian (2011), and Lu et al. (2016)). Wang and Chong (2015) reviewed BIM studies regarding different project phases and suggested that BIM implementation should be associated with projects. Although these studies have preluded the research on BIM with the project perspective, the research scope in this area remains unclear. Seemingly, a comprehensive project view on BIM research can benefit the research in this area.

4 Research methodology

A few studies in construction management are examined to determine a structural approach for this review. A sophisticated searching method has been employed by Ke et al. (2009), Yi and Chan (2013), Osei-Kyei and Chan (2015), and Darko and Chan (2016) to conduct structural reviews. This paper refers to Yi and Chan (2013) in developing a structural search and review approach, as shown in Fig. 1. The stages of the review process are detailed in the following discourse.

4.1 Stage 1: Conducting a preliminary search

A preliminary search was conducted with the academic search engine "Scopus" to identify the target journals. In view of the relatively vague research scope of BIM and project management due to their diverse definitions, this review focuses on the critical BIM and project management research. Thus, the keywords that represent BIM are limited to "BIM," "building information modeling," "building information modelling," "building information model," and "building information models," with only "project management" to represent itself. The search was conducted as *Advanced Search* with the following code:

[TITLE-ABS-KEY ("Project management" AND "BIM") OR TITLE-ABS-KEY ("Project management" AND "Building information modeling") OR TITLE-ABS-KEY ("Project management" AND "Building information modelling") OR TITLE-ABS-KEY ("Project management" AND "Building information model") OR TITLE-ABS-KEY ("Project management" AND "Building information models")] AND [LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")] AND [LIMIT-TO (LANGUAGE, "English")].

All stages of the search were conducted on March 17, 2018.

4.2 Stage 2: Limiting the articles to target journals

The journals were identified according to the journal list categorized by Lu et al. (2014), Bröchner and Björk (2008), and Chau's ranking (Wing, 1997). Ten out of 20-five journals were retained, including Automation in Construction (AIC), Journal of Construction Engineering and Management (JCEM), Journal of Information Technology in Construction[1] (ITcon), International Journal of Project Management (IJPM), Journal of Computing in Civil Engineering (JCCE), Advanced Engineering Informatics (AEI), Construction Management and Economics (CME), Engineering Construction and Architectural Management (ECAM), Journal of Management in Engineering (JME), Construction Innovation (CI), and Project Management Journal (PMJ). At this stage, the result was limited to 113 articles.

4.3 Stage 3: Visual examination and categorization

During visual examination, the final round of the T/A/K search was conducted with the selected journals. IJPM and PMJ focus mainly on the project management domain; thus, only "BIM," "building information modeling," "building information modelling," "building information model," and "building information models" were applied as the search words for T/A/K search, without "project management" for searching the two journals. Four additional qualified articles published in the restricted duration were found in IJPM but none in PMJ. These articles were all related to project management. A total of 13 target articles were found and added to the collection. The total number of the articles was 115 after the duplicates were removed. However, during visual examination, five articles were eliminated. Three of them were

1) Journal of Construction Engineering and Management and Electronic Journal of Information Technology in Construction are combined as ITcon.

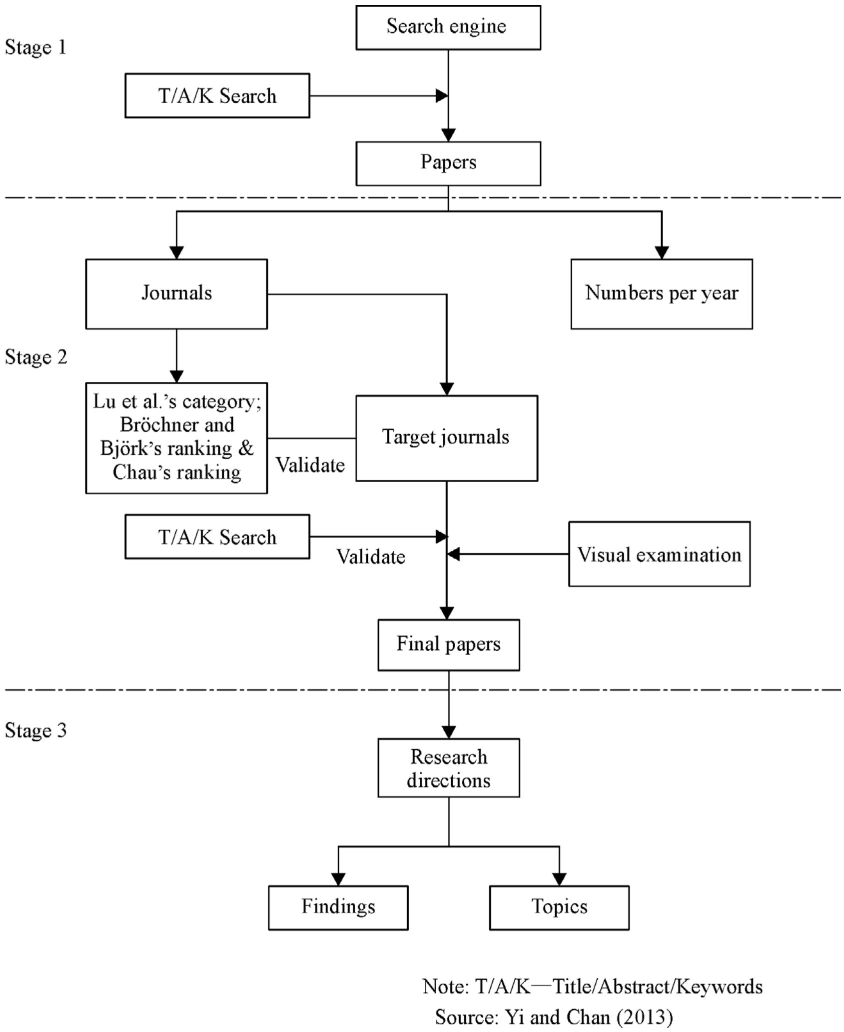


Fig. 1 Research framework

from IJPM, JCEM, and ECAM, were found to be unrelated to BIM, as these articles focused generally on ICTs, and BIM was used as an example of ICT and was discussed inadequately. While the other two articles focused on the application of Geographic Information System in project management in which BIM was only compared to as peer technology. These five articles were thus excluded from the list. Moreover, the present review focuses on BIM research in project management, which is a practice-oriented subject. Hence, seven additional articles on teaching and education related to BIM and project management were eliminated. The total number of the final papers were limited to 103 (Table 1).

5 Overview of BIM studies in project management

Overall, this review probes into the years of publications to

Table 1 Preliminary search and visual examination results in the target journals

Target journals	No. of papers found in the target journals	No. of the final papers
AIC	31	30
JCEM	21	19
ITcon	17	12
IJPM	11	9
JCCE	8	7
AEI	4	4
CME	6	6
ECAM	9	8
JME	4	4
CI	2	2
PMJ	2	2
Total	115	103

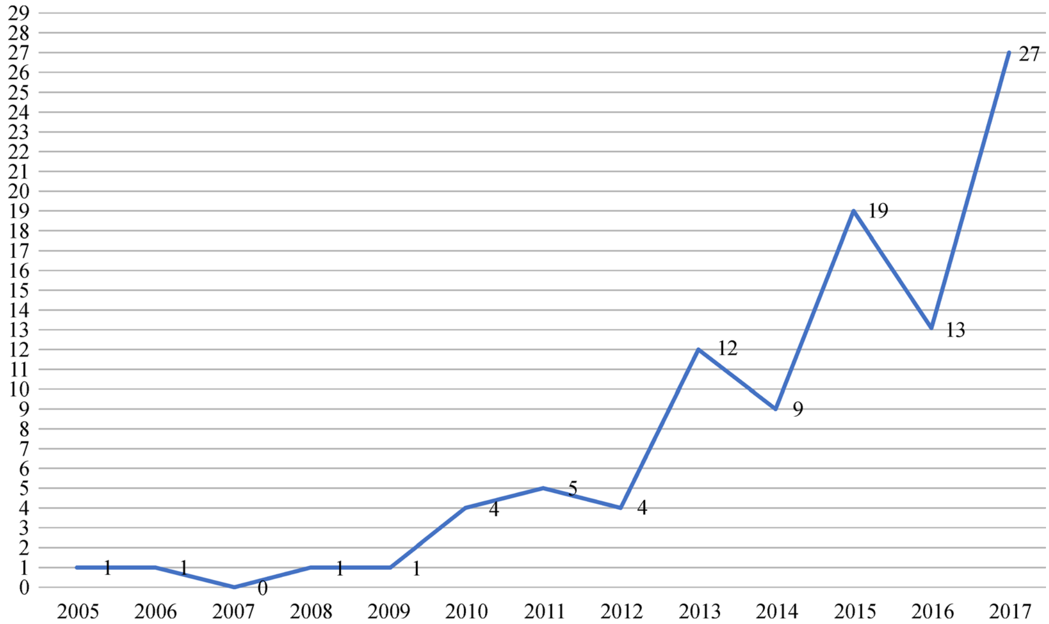


Fig. 2 Years of publication

conduct a preliminary analysis. Figure 2 shows a generally increasing trend for BIM studies in project management from 2005 to 2017. However, given the amount of publications across the years, three research stages were identified. The period of primitive research stage of BIM studies in project management is from 2005 to 2009, with no more than one publication in this per year. The frequencies of publications wave between four and five from 2010 to 2012 as the second stage. The third stage starts from 2013 where the frequencies of publications stay no less than nine per year with fluctuations but drastically increase with data available until 2017.

6 Investigation of research topics on BIM studies in project management

The general process to incorporate BIM with projects was investigated in this paper to map a route in BIM studies in project management. Succar (2009) identified three stages of BIM adoption to integrate delivery in a project with BIM: 1) realizing BIM modeling, 2) collaborating on a BIM model, and 3) incorporating BIM into the project system. With regard to the stages, a framework is proposed to map the directions, as illustrated in Fig. 3. The process of incorporating BIM into the project system as a composite ICT for project management tool is also considered. The project-wise adoption of BIM aims to 1) enable BIM as an ICT tool attached to a project context; 2) apply BIM as a solution or a tool for project management; 3) manage BIM ad hoc process in projects; and 4) assess the use of BIM in projects. The research directions are organized based on the framework illustrated in Fig. 3.

The framework provides a basic logic to organizing the category of the reviewed studies. However, research directions have been developed during the review process with the interpretation of the studies as an empirical approach to improve the solidity of this review. Details are presented in the following discourse.

6.1 Technical issues of BIM within projects

A relatively large number of studies report the efforts on enabling BIM within AEC projects. First, primary insights have been given to modules, objects, and relations of elements in BIM models and modeling processes. Niu et al. (2016) developed "smart construction objects" to model modular building elements for future smart design and construction. Isaac et al. (2016) introduced a methodology that enables the components of a BIM model in design to be automatically assembled without repetition on a modular level. This methodology may contribute to project management endeavors in further steps. Second, the relations and connections among different modules of BIM/IFC models have been probed

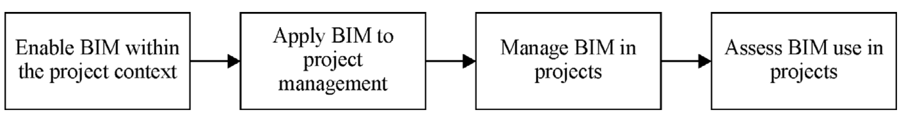


Fig. 3 Framework of mapping research directions of BIM research in project management

in a series of studies, such as those of Khalili and Chua (2015) and Isaac et al. (2016). Moreover, a few studies have focused on algorithms and tools to support modeling and visualization. BIM is also an IT process; thus, the application of its functions relies on particular algorithms for different purposes, such as module optimization and interface (Isaac et al., 2016) and IFC-based model optimization for change management (Oraskari and Törmä, 2015). BIM also requires tools to support the modeling, such as IFC model viewer (Fu et al., 2006) and multidimensional prototype (Chavada et al., 2012). Finally, technical interoperability is also a key issue in this area. Major interests include interoperability of data transfer (Kim et al. 2015), digital modules (Oraskari and Törmä, 2015), and software (Gökçe et al., 2013).

6.2 Application of BIM within a specific scope of project management

Given the wide scope of project management in the AEC process, associating BIM directly with major aspects of project management is difficult. However, extensive BIM studies in this domain are conducted for specific purposes or in a sub-area of project management. Among the traditional project objectives: time, cost, and quality namely, cost is the most popular topic. Object simulation with ontologies (Lee et al., 2014) and standardized specifications (Ma et al., 2013) based on BIM enable an intelligent approach to estimate building costs. BIM can also assist value management in the design stage (Park et al., 2016). Meanwhile, time is more often coupled with cost than quality when BIM has been adopted into a project (Gelisen and Griffis, 2013; Faghihi et al., 2016). In various domains of project management, BIM studies have encompassed decision making (Lu et al., 2016), safety management (Li et al., 2015; Zhang et al., 2015), workspace planning (Chavada et al., 2012; Choi et al., 2014), information management (Kähkönen and Rannisto, 2015), knowledge management (Nepal and Staub-French, 2016), building energy (Wu and Issa, 2014), and lean construction (Sacks et al., 2010). BIM application in project management also extends in all stages of the project life cycle because it can promote collaborative design activities (Fernando et al., 2013), bid and tendering (Ma et al., 2013), project control in construction (Sacks et al., 2005; Elbeltagi and Dawood, 2011), and lifecycle building data management (Jiao et al., 2013; Ramaji and Memari, 2016). Although project management requires a systematic approach to work efficiently, the studies in this direction are slightly fragmented.

6.3 System design and interface issues

With BIM introduced to building projects, system design and interface issues should be addressed. Information system is a relatively abstract concept; thus, it encompasses entities to be interfaced and multiple technologies to be integrated. Some efforts have been made to outline the information system with model-based building projects. Scherer and Schapke (2011) suggested an integrated approach for creating an information system with regard to various aspects of models, organizations, and procedures. Given that the process is relatively comprehensive, planning and designing the system remains a challenge. Akanmu and Anumba (2015) clarified "cyber-physical system," which was formed by ICT devices and related information processing referring to different layering clusters. The concept helps to classify the tangible parts of the information system. Moreover, framework studies contribute to the development of information systems, such as Monteiro et al. (2014) and Kim et al. (2015). A couple of studies have concentrated on cooperative interface approaches, such as cloud integration and platforming; however, these studies include different topics, such as frameworks and conditions for integration (Aram et al., 2013; Monteiro et al., 2014), as well as application and implementation of interface approaches (Jiao et al., 2013; Chong et al., 2014; Goulding et al., 2014). In addition, integrated applications of BIM and other major ICTs for project management are present, including RFID and BIM (Costin et al., 2015; Fang et al., 2016), laser scanning and BIM, (Bosché, 2012), virtual/augment reality and BIM (Golparvar-Fard et al., 2011; Goulding et al., 2014), and cloud technology and BIM (Jiao et al., 2013).

6.4 BIM institutional environment and regulatory system

Another research direction to investigate is on BIM institutional environment and regulatory system. With the institutionally driven force, a changing paradigm has been perceived in projects with the utilization of BIM (Taylor and Bernstein, 2009; Azhar, 2011), wherein organizational change and regulatory governance are required accordingly. The changing situation was discussed by Kokkonen and Alin (2016) from organizational perspective. Furthermore, a few studies have demonstrated that institutional change demands alignment, coordination, and collaboration embedded in the work routines of projects (e.g., Whyte and Lobo (2010), Brewer and Gajendran (2012), Alin et al. (2013), Alhava et al. (2015), and Poirier et al. (2016)). Moreover, well-established regulatory systems in various levels provide an environment for BIM execution in projects. Some studies provide insights into this topic (e.g., Patacas et al. (2015) and Dave et al. (2016)).

6.5 Effects and strategies of BIM adoption and implementation in projects

A few studies have considered BIM as a theoretical concept and explore BIM application from the organizational or project view. The effect and adoption of BIM on project level and strategies on micro and macro levels in project management have been examined. The effects of BIM on projects have been associated with project benefits (Bryde et al., 2013), time–effort distribution (Lu et al., 2015), and information mediation (Forsythe et al., 2015). Some studies have analyzed BIM adoption with respect to motivations of project organizations (Cao et al., 2017), key influential areas (Liu et al., 2017), and critical factors for adoption in the design process (Ding et al., 2015). Strategies for BIM implementation in projects on a macro level focus on industry practice and nationwide implementation. The industry view concerns mainly in the MEP discipline (Hanna et al., 2013; Boktor et al., 2014; Hanna et al., 2014). Similarly, nationwide studies have embarked largely on BIM implementation in projects in different countries, such as Australia (Forsythe et al., 2015), China (Ding et al., 2015), Malaysia (Rogers et al., 2015), Sweden (Gustavsson et al., 2012), and the UK (Eadie et al., 2013).

6.6 General studies on BIM with building projects

A few studies on BIM and project management have contributed to this research area by generally associating BIM with building projects. For example, Popov et al. (2010) introduced the concurrent situation of 5D BIM modeling that contributes to project management in the design and construction processes. From a technical view, Hassan (2013) elaborated on the collaboration mechanism with the introduction of IT solutions in building construction. Ciribini et al. (2016) demonstrated and explained the integration of the successive cooperation in different stages by probing into the implementation of a project with BIM. Chen et al. (2015) relied on previous BIM studies and aimed to establish a framework that couples BIM with the building process in various steps and disciplines. Mäki and Kerosuo (2015) presented a practical view gained from the project managers of a construction site to describe BIM application on project sites. However, a structural investigation is necessary to clarify how BIM can be systematically incorporated into projects for project management.

7 Analysis and discussion of the research trend

Several research directions of BIM studies in project management have been identified with the research topics, as summarized in Table 2.

Enabling BIM is the first step in implementing BIM-based project management. The major technical issues for BIM implementation with project management include data interoperability, objects and software, process optimization, and development of supporting tools. With regard to process and tools, obtaining the data and enabling information exchange are crucial in realizing BIM functions in projects. Information and data exchange is the first stage to build models and establish BIM that works with the AEC project context. During this process, tools and algorithms can optimize and support modeling and visualization.

Meanwhile, current studies that have reported on BIM applications in project management are fragmented. A systematic view is required to match BIM applications with the objectives of the various stages and requirements of different organizations. The mechanism of utilizing BIM applications in project management can contribute to further develop BIM and BIM-based project management approaches.

The systematic implementation of BIM in projects depends on information systems to function. Information

Table 2 Summary of research areas of BIM in project management

Research directions of BIM studies in project management	Research topics
Enabling BIM as a technology in project management	Development of BIM elements (e.g., modules, objects, and members); Relations and connections among modules of BIM models; Development of algorithms and tools; Technical interoperability
BIM application as a solution for a specific project management scope	Managing project objectives with BIM; Applications of BIM for various tasks of project management; BIM utilization in different stages of project management
Integration issues of BIM that have been brought to project management	Information systems; Cooperative interface approaches; Integrated applications of BIM and other major ICTs
Institutional environment and regulatory governance of BIM to realize project management strategy	Organizational changes brought by BIM; New mechanism or context for cooperation and collaboration in projects; Regulation and standardization
Analysis of the effects and strategies of BIM adoption and implementation in projects	Effect of BIM on a project; Analysis of project-wise BIM adoption; BIM implementation in projects on a macro level

systems have been barely clarified, although they are often referred to by BIM research in project management. This phenomenon may come from the complexity and vague scopes of the concepts. Moreover, the types of information system may vary for different purposes and contexts. Specifically, further exploration of project management information system (PMIS) can introduce the research of information systems, as well as the implementation issues of BIM in projects (Jung and Joo, 2011). Moreover, it can contribute to understanding information systems in BIM-based projects by employing the concept of a cyber-physical system to describe the parts of the systems under PMIS. Furthermore, an overall view to engage the front and back ends of the systems with respect to the actors and project structures remains an optional research angle.

Another issue that needs to be accommodated by institutional environment and standardization is organizational change and the changing ways of collaborative work. This issue involves organizational structure perspectives and standardization of additional BIM processes and products. The institutional environment uses system regulations and work culture to influence the organizational behavior formally and informally, respectively.

The implementation of BIM in project management also requires exploration in specific perspectives. Strategies and measures at different levels, such as project, industry, and national levels, have been covered in BIM studies on project management; thus, future studies can possibly focus more on the project level considering that projects are a genre adopted in the industry to organize building production. However, other aspects of BIM, such as efficacy and benefits, are investigated at all levels to provide motives for BIM adoption in projects and promotion in the industry.

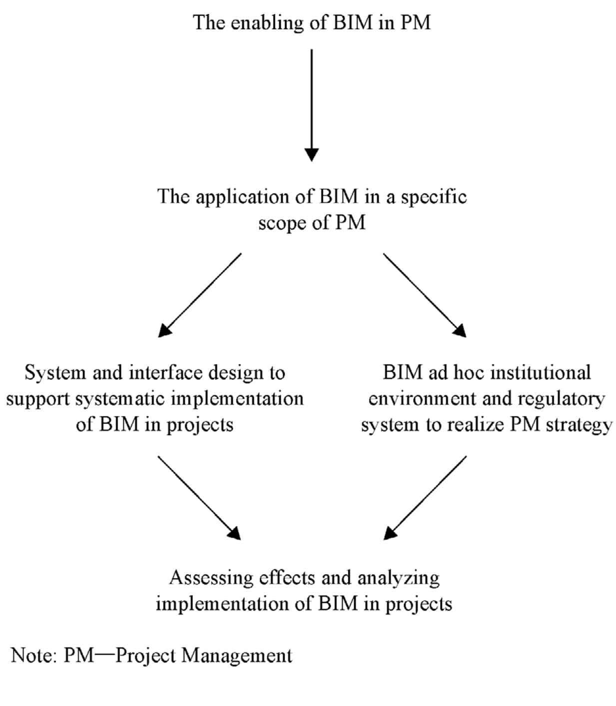
Accordingly, research directions are correlated with one another with priorities identified. The research route of BIM studies in project management is mapped in Fig. 4. Enabling BIM technology indicates a great priority, followed by the application of BIM as a solution in a specific scope of project management. On the basis of these achievements, managerial and organizational issues of BIM and regulatory governance of BIM are employed to safeguard the implementation and realize the objectives of project management. Finally, the assessment and analysis of BIM adoption in projects provide evidence in justifying the BIM-based project management approach.

This research route reflects how BIM studies in project management are clustered and mapped. It highlights the building blocks of theoretical foundation for BIM-based project management. However, considerable work is required to shape a solid approach for BIM-based project management.

8 Conclusions

BIM diffuses across the AEC industry worldwide and changes the practice of the AEC industry and projects. A comprehensive understanding of how BIM works for projects and how projects respond to the introduction of BIM can contribute to the appropriate application of BIM in project management. The research gap of this issue is addressed in this review.

The major research directions of BIM research in project



Note: PM—Project Management

Fig. 4 Research route of BIM studies in project management

management have been identified based on the systematic review of BIM research articles. The primary research effort is to address technical issues of BIM and enable it within projects. These studies have employed knowledge in IT to the AEC domain. Another direction of applying BIM to a specific scope of project management demonstrates how BIM contributes to the sub-areas of project management, such as project control and safety management. In addition, information systems and institutional environment are essential for the systematic implementation of BIM. Efforts have been exerted in this area to explore the incorporation of BIM into the project system of AEC projects. Finally, a few studies have generally associated BIM with project management regarding process, efficacy, and benefits. All research directions contribute to sketching the changing paradigm of projects with BIM diffused in their various aspects of AEC projects.

This review contributes to advancing the research and practice for BIM and project management. Once BIM is integrated to project management, it becomes a customized and integrated ICT rather than a simple simulation technology with limited applications in specific areas and disciplines. By contrast, BIM can aid project management with further capabilities, particularly in information management and collaborative working. Overall, studying BIM in project management helps develop a BIM-based project approach that links BIM implementation into project management in the AEC process.

Although the application of BIM in teaching and education is not a major topic in this review, it is a relatively common topic in BIM research. It is important in building capabilities of BIM and developing a BIM culture in project management in AEC projects. Given that the present review is limited to BIM studies in project management, this paper leaves it for future studies.

To develop BIM research in project management, the research objectives are clarified with five major purposes, that is, to 1) enable BIM in different project stages; 2) apply BIM in a specific scope of project management; 3) manage BIM-related issues; 4) govern BIM with regulation and standardization; and 5) promote BIM use in projects with the analysis of its effect and strategies for adoption. However, these areas have not been fully explored. Thus, a highly systematic and goal-oriented approach should be adopted, considering that project management is a complex and systematic methodology that involves the integration of various aspects and participants. This area can be the focus of future research.

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Appendix: Reviewed articles

Park J., Cai H., Perissin D.	2018	JCCE
Pishdad-Bozorgi P., Gao X., Eastman C., Self A.P.	2018	AIC
Hamledari H., Rezazadeh Azar E., McCabe B.	2018	JCCE
Ma Z., Zhang D., Li J.	2018	AIC
Zhang L., Wen M., Ashuri B.	2018	JCCE
Pärn E.A., Edwards D.J., Sing M.C.P.	2018	AIC
Zhang S., Pan F., Wang C., Sun Y., Wang H.	2017	JCEM
Mansuri D., Chakraborty D., Elzarka H., Deshpande A., Gronseth T.	2017	AIC
Oraee M., Hosseini M.R., Papadonikolaki E., Palliyaguru R., Arashpour M.	2017	IJPM
Tezel A., Aziz Z.	2017	ITCon
Kehily D., Underwood J.	2017	ITCon
Kalasapudi V.S., Tang P., Turkan Y.	2017	AIC
Chang C.-Y., Pan W., Howard R.	2017	JCEM
Kifokeris D., Xenidis Y.	2017	JCEM
Niknam M., Karshenas S.	2017	AIC
Pärn E.A., Edwards D.J.	2017	AIC
Chen K., Lu W., Wang H., Niu Y., Huang G.G.	2017	JCEM
Chong H.-Y., Fan S.-L., Sutrisna M., Hsieh S.-H., Tsai C.-M.	2017	JCEM
Son H., Kim C., Kwon Cho Y.	2017	JME
He Q., Wang G., Luo L., Shi Q., Xie J., Meng X.	2017	IJPM
Park J., Cai H.	2017	AIC
Park C.-S., Kim H.-J., Park H.-T., Goh J.-H., Pedro A.	2017	IJPM
Cao D., Li H., Wang G., Huang T.	2017	IJPM
Zheng L., Lu W., Chen K., Chau K.W., Niu Y.	2017	IJPM
Kam C., Song M.H., Senaratna D.	2017	JCEM
Fuchs S., Scherer R.J.	2017	AIC
Zhang J., El-Gohary N.M.	2017	AIC
Davies K., McMeel D.J., Wilkinson S.	2017	ECAM
Franz B., Leicht R., Molenaar K., Messner J.	2017	JCEM
Edirisinghe R., London K.A., Kalutara P., Aranda-Mena G.	2017	ECAM
Tezel A., Aziz Z.	2017	ECAM
Murphy M.E., Nahod M.-M.	2017	ECAM
Mei T., Wang Q., Xiao Y., Yang M.	2017	ECAM
Wang J., Shou W., Wang X., Wu P.	2016	CME
Biagini C., Capone P., Donato V., Facchini N.	2016	AIC
Ciribini A.L.C., Mastrolembo Ventura S., Paneroni M.	2016	AIC
Poirier E., Forgues D., Staub-French S.	2016	CME
Ramaji I.J., Memari A.M.	2016	JCEM
Faghihi V., Reinschmidt K.F., Kang J.H.	2016	AIC
Kokkonen A., Alin P.	2016	CME

Niu Y., Lu W., Chen K., Huang G.G., Anumba C.	2016	JCCE
Fang Y., Cho Y.K., Zhang S., Perez E.	2016	JCEM
Isaac S., Bock T., Stoliar Y.	2016	AIC
Nepal M.P., Staub-French S.	2016	ITCon
Lu Q., Won J., Cheng J.C.P.	2016	IJPM
Dave B., Kubler S., Främling K., Koskela L.	2016	AIC
Zhang S., Teizer J., Pradhananga N., Eastman C.M.	2015	AIC
Costin A.M., Teizer J., Schoner B.	2015	ITCon
Oraskari J., Törmä S.	2015	AIC
Chen K., Lu W., Peng Y., Rowlinson S., Huang G.Q.	2015	IJPM
Chang C.-Y.	2015	IJPM
Patacas J., Dawood N., Vukovic V., Kassem M.	2015	ITCon
Lu W., Fung A., Peng Y., Liang C., Rowlinson S.	2015	JME
Khalili A., Chua D.K.H.	2015	JCCE
Kim H., Lee H.-S., Park M., Chung B., Hwang S.	2015	JCCE
Teizer J.	2015	AEI
Mäki T., Kerosuo H.	2015	CME
Rogers J., Chong H.-Y., Preece C.	2015	ECAM
Krystallis I., Demian P., Price A.D.F.	2015	CME
Alhava O., Laine E., Kiviniemi A.	2015	ITCon
Ding Z., Zuo J., Wu J., Wang J.Y.	2015	ECAM
Kähkönen K., Rannisto J.	2015	CI
Forsythe P., Sankaran S., Biesenthal C.	2015	PMJ
Li H., Lu M., Chan G., Skitmore M.	2015	AIC
Akanmu A., Anumba C.J.	2015	ECAM
Goulding J.S., Rahimian F.P., Wang X.	2014	ITCon
Choi B., Lee H.-S., Park M., Cho Y.K., Kim H.	2014	JCEM
Gelisen G., Griffis F.H.	2014	JCEM
Monteiro A., Mêda P., Poças Martins J.	2014	AIC
Boktor J., Hanna A., Menassa C.C.	2014	JME
Hanna A.S., Yeutter M., Aoun D.G.	2014	JCEM
Wu W., Issa R.R.A.	2014	JME
Lee S.-K., Kim K.-R., Yu J.-H.	2014	AIC
Chong H.-Y., Wong J.S., Wang X.	2014	AIC
Fernando Prof. T., Wu Dr. K.-C., Bassanino Dr. M.	2013	ITCon
Eadie R., Browne M., Odeyinka H., McKeown C., McNiff S.	2013	AIC
Hanna A., Boodai F., El Asmar M.	2013	JCEM
Aram S., Eastman C., Sacks R.	2013	AIC
Jiao Y., Wang Y., Zhang S., Li Y., Yang B., Yuan L.	2013	AEI
Lu W., Peng Y., Shen Q., Li H.	2013	JCEM
Alin P., Maunula A.O., Taylor J.E., Smeds R.	2013	PMJ
Hassan I. N.	2013	ITCon
Gökçe K.U., Gökçe H.U., Katranuschkov P.	2013	JCCE
Bryde D., Broquetas M., Volm J.M.	2013	IJPM
Ma Z., Wei Z., Zhang X.	2013	AIC
Bynum P., Issa R.R.A., Olbina S.	2013	JCEM
Chavada R., Dawood N., Kassem M.	2012	ITCon
Gustavsson T.K., Samuelson O., Wikforss Ö.	2012	ITCon
Brewer G., Gajendran T.	2012	CI
Bosché F.	2012	AEI
Golparvar-Fard M., Peña-Mora F., Savarese S.	2011	JCEM
Elbeltagi E., Dawood M.	2011	AIC
Scherer R.J., Schapke S.-E.	2011	AEI
Zhang J.P., Hu Z.Z.	2011	AIC
Hu Z., Zhang J.	2011	AIC
Sacks R., Koskela L., Dave B.A., Owen R.	2010	JCEM
Whyte J., Lobo S.	2010	CME
Sacks R., Radosavljevic M., Barak R.	2010	AIC
Popov V., Juocevicius V., Migilinskas D., Ustinovichius L., Mikalauskas S.	2010	AIC
Sacks R., Treckmann M., Rozenfeld O.	2009	JCEM
Leicht R., Messner J.	2008	ITCon
Fu C., Aouad G., Lee A., Mashall-Ponting A., Wu S.	2006	AIC
Sacks R., Navon R., Brodetskaia I., Shapira A.	2005	JCEM

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