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Review

Formulating project-level building information modeling evaluation framework from the perspectives of organizations: A review

Ying Zhou[a,*], Lieyun Ding[a], Yang Rao[a], Hanbin Luo[a], Benachir Medjdoub[b], Hua Zhong[b]

[a] School of Civil Engineering and Mechanics, Huazhong University of Science and Technology, Hubei, PR China
[b] School of Architecture, Design and the Built Environment, Nottingham Trent University, United Kingdom

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ABSTRACT

This study identifies Building Information Modeling (BIM) benefits in the presentations of previous project participants and specialties. Based on recent data, a framework for evaluating the project-level BIM benefits from the perspectives of different stakeholders involved in the project is proposed. In order to maximize the benefits for each user or stakeholder, the functions and methods for implementing BIM on construction projects are explained. The results show that the advantages of implementing BIM in construction projects can be effectively evaluated by the proposed framework. Results presented herein provide documentation to improve the understanding of BIM benefits to all construction industry stakeholders.

1. Introduction

Building Information Modeling (BIM) has been widely used in the whole life cycle of infrastructure projects, including civil and mechanical engineering projects, to improve the efficiency and effectiveness of these projects [1]. The utilization of BIM has grown significantly in recent years and it has been used to support various specialties in different phases from design to facility management of construction projects. The full impact of BIM principles and methodologies on the evolution of design tools in the Architecture/Engineering/Construction (AEC) industry has recently become a research area topic. In the past ten years, BIM has drawn the attention of researchers. From a prior research review, BIM can improve visualization, communication and integration in construction projects [2]. As an emerging technology, BIM has played an important role in the built environment [3]. Previous research found that the implementation of BIM can certainly improve construction efficiency and decision making throughout the life cycle of a project [4,5,6]. However, there is hesitation in adopting these creative tools and processes [7]. The main reasons for this reluctance to incorporate advanced technology are uncertainty about the competitive advantages and lack of awareness regarding the technologies and related benefits [8]. Currently, there is no agreed basic methodology to evaluate the advantages of BIM. Instead, there are various opinions regarding the benefits of BIM, leading to some misunderstanding. Thus, a standard evaluation framework is needed to assess BIM implementation [9]. Such a framework can help multiple participants and specialists understand and evaluate BIM benefits.

Prior case studies have been done to evaluate the advantages of BIM implementations on actual construction projects. Khanzode et al. analyzed the quantitative and qualitative benefits of using BIM tools in Mechanical, Electrical and Plumbing (MEP) systems [3]. A survey was conducted to clarify the ambiguity surrounding BIM and to identify the mutual benefits of adopting BIM [10]. Succar et al. proposed a method to evaluate BIM projects from five perspectives, which are BIM capability stage, BIM maturity level, BIM competencies, organizational scale, and granularity levels [11]. However, it cannot be used for quantitative evaluation of BIM projects. bimSCORE was developed to evaluate the maturity of a BIM project [12]. However, it utilizes the same evaluation factors for different projects in spite of their different objectives. Considering the necessity and importance of applying BIM technology in the built environment, it can be inferred that an evaluation framework, which facilitates the implementation of BIM technology, would enlighten practitioners about the potential of BIM applications in construction project management. This would then deepen their understanding about the advantages of using BIM in their own projects.

To develop an applicable evaluation framework, it is necessary to understand and define the requirements of the industry users and how to analyze the actual benefits. Won et al. conducted case studies to validate the applicability of a success level assessment model for BIM project (SLAM BIM) [13]. Actually, according to the research conducted by Bakis et al. [14], case study analysis is the most appropriate method for investigating the benefits of information technologies. Case study analysis has been the most adopted method in previous research (will

* Corresponding author.
E-mail address: ying_zhou@mail.hust.edu.cn (Y. Zhou).

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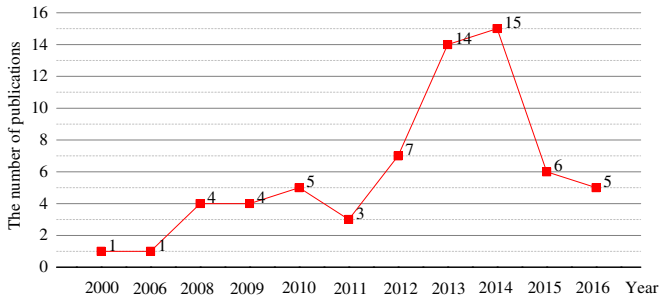

Fig. 1. Number per year of international journal publications related to BIM benefits evaluation research (journals listed in Table 1).

be explained in the following sections). However, the concerns of different participants are not quite the same, and these concerns change while the construction project moves forward.

Fortunately, much of the literature on actual implementation of BIM applications on construction sites is available in the form of papers and reports. Hence, this study collects and analyzes prior research to formulate and propose a project-level BIM benefits evaluation framework from the perspectives of different stakeholders involved in the project. The following section introduces the research approach. Section 3 analyzes the literature and extracts the various concerns of individual participants. In Section 4, an evaluation framework is formulated, and methods to calculate the benefits of BIM implementation are proposed. Specifically, in order to maximize the benefits for each type of user, the functions and methods of BIM implementation on actual construction projects are explained. The results can help construction industry practitioners better understand how to implement BIM technology to improve safety, reduce rework, reduce costs, and improve sustainability and effectiveness.

2. Research approach

The effectiveness of BIM implementation in various situations, such as educational and industrial settings, has been evaluated [15]. Despite the topic of BIM having been studied by academics [16,17,18,19], and professional industry groups [20,21,22], the financial investment in this innovative methodological and technological solution makes private sector clients very prudent [23]. Research has shown that the major hurdle for adopting BIM into standard industry practice is to justify the additional cost to achieve the benefits discussed [24]. Therefore, the development of the ability to quantify the benefits of adopting BIM is required [23,25].

In recent years, although there have been significant advances in BIM research and development, there is still a gap in providing a strong and reliable evaluation framework able to quantify BIM benefits. This paper is timely and aims to analyze and understand the existing BIM research map to:

- support the formulation of a BIM benefits evaluation framework;
- highlight the benefits for different stakeholders;
- understand the challenges of BIM implementation and suggest how they can be solved;
- forecast future research and development trends.

3. Review of BIM benefits

3.1. Characteristics of collected articles

To make the framework applicable to various projects and stakeholders, we have analyzed a large number of case studies from existing literature. There were 65 relevant international journal articles were analyzed. The number of articles by year of publication is shown in Fig. 1. The number of publications evaluating the benefits of BIM has grown considerably from 2006, with a substantial increase from 2011.

The list of publications analyzed includes (see Table 1) 29 research projects conducted in the United States between 2008 and 2016. The remaining research projects were conducted in different countries including the UK, Singapore, South Korea, Australia, Canada, Hong Kong, Germany, Israel, and Jordan. The analysis of these projects shows that since 2012 more countries/districts began to realize the importance of evaluating BIM benefits. Therefore, the formulation of an evaluation framework is both timely and necessary in order for the construction industry stakeholders to understand the importance of adopting BIM.

The analysis of the projects listed in Table 1 shows that the methods used for evaluating BIM benefits in individual projects are diverse and are classified into seven types [18,26]. These types listed in “Evaluation Methodologies” column of Table 1. In the “Project Participants” column, “all” means all the participants, specifically, including contractors, design agencies and owners. In the “phase” column, “all” means all the phases in construction management, specifically, including planning, design, construction and maintenance/operation phases.

From the review of the previous projects listed in Table 1, the previous papers are categorized into evaluation of project-level BIM benefits, such as [57] and organizational level BIM benefits, such as [4]. As the most important part of the nature of BIM is project management related tools and processes, thus, a standard project-level evaluation framework is needed to assess BIM implementation. It has a potential use for multiple participants in improving collaboration between stakeholders, reducing the time needed for documentation of the project and, hence, producing beneficial project outcomes.

3.2. Classification of articles based on adopted research methods

Fig. 2 illustrates the methods used based on the classification types given in [18,26]. “Case study and quantifiable findings” type utilizes case studies containing quantifiable measurements of BIM benefits. The “Case study” type analyzes BIM projects without quantifiable benefit measurements; e this type undertakes a qualitative approach. The “Case study and model or process” type utilizes a model or process to demonstrate how the benefits of BIM were obtained, but excludes quantifiable savings as a result of BIM utilization. The “Model or process” type proposes a framework or evaluation process, but is either (1) not used on an actual BIM project or (2) if claimed to be utilized on a project, this type does not present no any quantifiable results. The “Survey” type contains independent surveys including various questions targeting different stakeholders with different backgrounds. The survey aims to map those stakeholders' opinions and perceptions of the benefits obtained from BIM adoption. The “Survey and case studies” type contains a survey targeting a specific project on which BIM has been adopted and, in some cases, interviews of the project team members are conducted. Publications focusing on “Theory and general assumptions” have addressed mainly theoretical frameworks and discussed potential benefits without any benchmarking in a real project.

Fig. 3 illustrates for each year between 2000 and 2016, the proportions of the methods used to evaluate BIM benefits. Over time, the BIM evaluation methods are more diverse and varied with a convergence toward surveys and case study analysis.

3.3. Classification of articles by participants

Previous studies analyzed mainly the benefits of BIM considering the overall project lifecycle (Table 2) and all the participants listed in Table 1, see Fig. 4. As indicated in Table 2, the main focus of the literature is on the design and the construction phases. However, the primary concern of individual participant varies and changes by phase. Thus, in the following sections, this paper attempts to fill the gap by analyzing BIM benefits from the perspectives of individual participants