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Practices and effectiveness of building information modelling in construction projects in China

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ABSTRACT

Based on an investigation of 106 projects involving the use of building information modelling (BIM), this paper examines current BIM practices in China, and assesses how various practices alter their effectiveness. The results reveal that in current practice BIM is principally employed as a visualization tool, and how it is implemented is significantly associated with project characteristics. BIM use in the majority of the surveyed projects is seen to have positive outcomes, with the benefits of improved task effectiveness being more substantial than those related to efficiency improvement. The results also provide evidence that project characteristics significantly influence the success of BIM use; however, more substantial contributing factors to BIM effectiveness are the extent of integrated use and client/owner support. While indicating that current BIM practices involve both technological and organizational problems, the findings also provide insights into how the potential for BIM could be better exploited within the industry.

1. Introduction

Performance problems such as cost overruns and schedule slippages have long plagued the construction industry and have prompted practitioners to explore new approaches in streamlining the design and construction process [1]. Particularly salient among these approaches in the past decade is the concept of building information modelling (BIM) [2,3]. As a fundamentally new way of creating, sharing and utilising facility lifecycle data [4], BIM can be used in a number of areas such as clash detection, sustainability analysis, cost estimating, construction scheduling and offsite fabrication throughout the project lifecycle [5–7]. If used appropriately, BIM can facilitate a more integrated design and construction process and generate substantial benefits in terms of, for instance, fewer design coordination errors, more energy-efficient design solutions, faster cost estimation, reduced production cycle times and lower construction costs [4,8,9].

Despite its great potential, the advancement of BIM in the construction industry is still in a relatively infant stage, and the technology's actual diffusion rate among industry practitioners worldwide is still much lower than expected [10]. For those practitioners who have already been involved in BIM use, a relatively high percentage is still "just scratching the surface of how much value BIM can provide" [11]. While there are currently a variety of issues impeding the progress of BIM in the industry [12–15], one of the most effective facilitating manoeuvres lies in eliciting experiences and lessons from current BIM practices to provide momentum and insights for the future [7,8,16].

Based on an investigation of 106 recent projects involving the use of BIM, this study aims to provide an overview of current BIM practices in the Chinese construction industry, and gain insights into how these practices differ from each other in their effectiveness. In outlining current practices, two specific BIM issues are particularly examined: (1) areas where BIM is currently applied in the design and construction stages; and (2) the roles of project participants. Quantitative analyses are then performed to examine whether and how these practices are associated with related project attributes. In order to provide further comparisons of the practices involved, a quantitative assessment is also made of how BIM practice characteristics, together with related project attributes, influence the perceived effectiveness of BIM use in different project contexts.

The rest of the paper is organized as follows. The next section presents the research background, including a review of literature related to BIM practices and effectiveness. Section 3 outlines the research method, and Section 4 presents the analyses of the survey and interview data. Section 5 discusses the research findings and implications. Section 6 concludes the paper.

2. Research background

The concept of BIM can be traced back to the working prototype "building description systems" proposed by Eastman in the mid 1970s

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[17]. Due to its great potential benefits but still relatively limited application in practice, BIM has become a highly active research topic in recent years [3,18]. The vast majority of studies have focused primarily on technical issues, including exploring potential areas in which BIM could be beneficially used [19–26] and enhancing interoperability among different modelling tools [27–30]. The purposes of these studies mainly relate to validating or improving the technical feasibility of related BIM prototypes, including the further integration of these prototypes with other technologies such as laser scanning and radio frequency identification (RFID).

In view of the possible gap between technical feasibility and practical adoption, there is an increasing research effort to examine empirically how BIM is currently used in design and construction activities [12,31–33]. To date, most of these investigations have been conducted in the form of case studies of individual construction projects, and in particular those in North America and Europe which are at the forefront of BIM deployment in the industry [31–33]. Through examining the detailed processes of BIM use in specific projects, these case studies are valuable in providing professionals with an in-depth understanding of concrete project benefits and possible obstacles to using BIM in specific project contexts [34]. However, activities in a single project can only characterise one aspect of industry practices, and it is often difficult to generalise practitioners' ad hoc experiences in single case projects [7,35]. As examples of BIM practices across the industry accumulate, there is a strong need for further research to statistically synthesise the anecdotal evidence from different project contexts and, therefore, provide industry practitioners with a more generalised understanding of how BIM could be used more effectively in the design and construction process [15,36].

The value and effectiveness of BIM have also attracted increasing scholarly interest in recent years. Drawing on secondary data from academic and practitioner sources, Bryde et al. [8] qualitatively assess how the use of BIM could influence the key success criteria related to project outputs. Giel and Issa [9] and Barlish and Sullivan [37] conduct case studies to quantitatively examine the value of BIM, finding that the calculated returns on investment (ROI) vary greatly between projects. These studies collectively suggest that many of the project benefits brought about by BIM are actually qualitative or relatively intangible [9,37]. Even for such quantitative benefits as reduced change orders and fewer requests for information (RFIs), the related quantification process is still quite challenging as a large amount of information needs to be accurately recorded and extremely similar projects without BIM need to be available for necessary comparisons [8,37,38]. Moreover, as separate projects generally use BIM for different project benefits, it is not always appropriate to rank project practice success based solely on comparing absolute benefit values [4,5]. In order to structurally compare the effectiveness of BIM practices in different projects and draw conclusions on how they are influenced by related BIM use characteristics and project attributes, this study focuses on examining three perceived effectiveness variables: BIM-based task efficiency improvement, BIM-based task effectiveness improvement, and overall BIM success. The conceptual research model of this study is shown in Fig. 1.

3. Research method

3.1. Survey instrument

This study is part of an industry-wide investigation to assess the state of BIM adoption and implementation practices in the Chinese construction industry. With its intrinsic advantage of allowing replicability and thus enabling structured comparisons across different projects, a questionnaire survey was used as the main method of collecting project-based data. Following Eisenhardt [39], a mix of other data collection methods, including interviews, direct observation and document analysis, was also used in order to better design the survey and to gain more detailed information relating to the surveyed projects.

As the starting point, an exploratory investigation was carried out to gain a preliminary understanding of current BIM use practices in China. This included semi-structured interviews with related industry professionals from organizations that have pioneered BIM use, the first author's 3-month ethnographic observation of an industrial project in Shanghai, and the researchers' short observations and document analysis of several other projects. Based on information gleaned from these interviews and observations as well as related literature, a draft of the survey questionnaire was developed to collect project-based data on BIM-related practices. The questionnaire was then sent to 23 respondents to conduct a pilot study, with the aim of assessing the appropriateness of the questionnaire scope, identifying ambiguous expressions and testing the validity of related constructs. Based on respondents' feedback, the questionnaire was further revised and subsequently distributed to targeted construction projects.

The questionnaire associated with this study was structured into four sections. The first section concentrates on general information of the surveyed project. The second section evaluates the extent to which BIM has been used in different application areas. The third section focuses on the roles of the key project participants involved. In the last section, respondents are asked for their perceptions of the effectiveness of BIM usage in the surveyed projects.

3.2. Sampling and data collection

Only Chinese mainland construction projects using BIM were considered. Since the use of BIM is still relatively rare in China, a completely random sampling method could not be used to elicit cases from a specific project database. Instead, a wide variety of different kinds of typical BIM projects and appropriate project respondents were identified by several methods, including searching through related

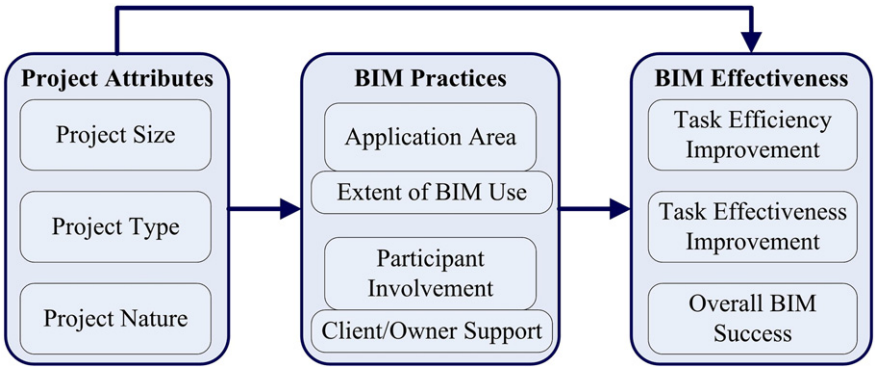

Fig. 1. Conceptual research model.