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Review

A scientometric review of global BIM research: Analysis and visualization

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ABSTRACT

In the recent years, building information modeling (BIM) has transformed the architecture, engineering, and construction industry, and attracted attentions from both researchers and practitioners. However, few studies have attempted to map the global research on BIM. This study conducts a scientometric review of global BIM research in 2005–2016, through co-author analysis, co-word analysis and co-citation analysis. A total of 614 bibliographic records from the Web of Science core collection database were analyzed. The results indicated that Charles M. Eastman received the most co-citations and that the most significant development in BIM research occurred primarily in the USA, South Korea and China. Additionally, BIM research has primarily focused on the subject categories of engineering, civil engineering and construction & building technology, and the keywords "visualization" and "industry foundation classes (IFC)" received citation bursts in the recent years. Furthermore, 10 co-citation clusters were identified, and the hot topics of BIM research were: mobile and cloud computing, laser scan, augmented reality, ontology, safety rule and code checking, semantic web technology, and automated generation. This study provides researchers and practitioners with an in-depth understanding of the status quo and trend of the BIM research in the world.

1. Introduction

Building information modeling (BIM), defined as shared digital representation of physical and functional characteristics of any built object that forms a reliable basis for decisions [1], has been transforming the architecture, engineering, and construction (AEC) industry in many countries [2]. From the mid-2000s, AEC industry practitioners started to adopt BIM in projects. To enhance BIM adoption, various researches on BIM have been conducted in the last decade. Some researchers focus on the technical issues relating to BIM, while others deal with the non-technical issues. Obviously, BIM is not just a technology, but also a project management tool and process [3], which consists of all aspects, disciplines, and systems of a facility within a model and enables all project participants (owners, architects, engineers, contractors, subcontractors and suppliers) to collaborate more accurately and efficiently than traditional processes [4]. Thus, several benefits brought by BIM have been reported, such as significant project cost and time savings [5], reduced errors and omissions, reduced rework, maintained repeat business [6], and enhanced construction productivity [7].

In the last decade, BIM research has been diverse and more emerging technologies have been integrated into BIM. For example, BIM is capable of facilitating 3D printing implementation [8] and has been used in the 3D printing of small-scale models and large-scale buildings, respectively [9]. Mahdjoubi et al. [10] developed a model to help deliver real-estate services by integrating 3D laser scanning and BIM. Wang et al. [11] proposed a conceptual framework that integrates BIM with augmented reality (AR) in order to enable the real-time visualization of the physical context of each construction activity or task.

Previous researches also include reviews of BIM research. For example, Tang et al. [12] surveyed the techniques that can be utilized to automate the process of reconstructing as-built building information models from laser-scanned point clouds; Cerovsek [13] provided a review of the standards for data exchange and features of over 150 AEC/O (Architecture, Engineering, Construction, and Operation) tools and digital models, and proposed a framework for enhancing both BIM tools and schemata; and Volk et al. [14] presented a review of BIM implementation and research in existing buildings, and identified challenges that hindered BIM implementation. However, limited efforts have been made to outline and visualize the research trends of BIM research.

Scientometrics is defined as the "quantitative study of science, communication in science, and science policy" [15, pp.75], and includes the measurement of impact, reference sets of articles to investigate the impact of journals and institutes, understanding of scientific citations, mapping scientific fields and the production of indicators for use in policy and management contexts [16]. This study

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attempts to conduct a scientometric review of the scientific literature relating to BIM and gain a snapshot of this research field in 2005–2016. The findings can provide researchers with a better understanding of the current state of the BIM research in the world and identify the hot topics in the literature. All of the bibliographic records used in this study have been published by the Web of Science (WOS) core collection database.

2. Method

This study analyzed all the articles in the WOS core collection database, which consists of the most important and influential journals in the world [17,18], and includes most publications on BIM. After pre-analysis and comparison, the following retrieval code is used in the WOS core collection: *TS* = (*building information model* AND BIM**). Here, "*" denotes a fuzzy search and "TS" means an article subject. In this study, only journal articles were selected for analysis, while book reviews, editorials, and conference papers were excluded. This is because journal articles usually provide more comprehensive and higher-quality information than other types of publications, and most reviews in the area of construction management have only covered journal articles [19–21]. Additionally, the research areas obviously irrelevant to BIM (e.g., biology, medicine, agriculture, etc.) were excluded as well. Finally, a total of 614 bibliographic records were collected in early January 2017. The first journal article on BIM [22] was published in 2005. Thus, the time span of these records was 2005–2016. Fig. 1 shows the distribution of the 614 bibliographic records in 2005–2016. The total number of records significantly increased in 2012–2015, but dropped slightly in 2016.

The software package CiteSpace can visualize and analyze literature of a scientific knowledge domain, which is broadly defined to capture the notion of a logically and cohesively organized body of knowledge [23]. Domain analysis has been recognized as an advantageous scientometric approach to discovering the implications hidden in a vast amount of information and tracing development frontiers [18,24]. CiteSpace is strong in mapping knowledge domains through systematically creating various accessible graphs [23]. Therefore, CiteSpace 5.0 was used to analyze the literature of BIM.

Three types of bibliometric techniques were applied in this study: (i) co-author analysis that seeks author co-occurrences, country co-occurrences, and institution co-occurrences; (ii) co-word analysis that processes keywords or terms to analyze word co-occurrences; and (iii) co-citation analysis that identifies co-cited authors, co-cited articles, and co-cited journals. These techniques have been recommended by previous studies of a similar nature [18,25]. In addition, cluster analysis was performed based on the co-citation analysis results, and citation bursts showing a surge of citations of publications were detected. In CiteSpace, the burst detection is based on the algorithm developed by Kleinberg [26].

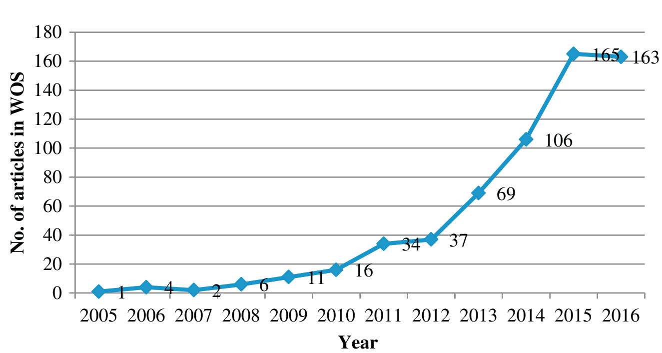

Fig. 1. The number of articles on BIM in the WOS core collection in 2005–2016.

Table 1
The top 10 most productive authors.

Author	Institution	Country	Count	Percentage
Rafael Sacks	Technion - Israel Institute of Technology	Israel	20	3.3%
Xiangyu Wang	Curtin University	Australia	16	2.6%
Charles M. Eastman	Georgia Institute of Technology	USA	14	2.3%
Ghang Lee	Yonsei University	South Korea	11	1.8%
Burcu Akinci	Carnegie Mellon University	USA	10	1.6%
Raja R A Issa	University of Florida	USA	10	1.6%
Hyoungkwan Kim	Yonsei University	South Korea	10	1.6%
Jochen Teizer	RAPIDS Construction Safety and Technology Laboratory	Germany	10	1.6%
Jun Wang	Curtin University	Australia	10	1.6%
Peter E D Love	Curtin University	Australia	9	1.5%

3. Results and discussions

3.1. Co-author analysis

The information of the article authors is available from the bibliographic records, which enables the identification of the leading researchers, institutions and countries for BIM research. Thus, a co-authorship network and a network of co-authors' institutions and countries/regions were generated.

3.1.1. Co-authorship network

According to the number of journal publications, the top 10 most productive authors were identified. As shown in Table 1, Rafael Sacks (Technion-Israel Institute of Technology), Xiangyu Wang (Curtin University) and Charles M. Eastman (Georgia Institute of Technology) occupied the top three positions.

A co-authorship network is shown in Fig. 2, where each node represents an author and the links between the authors denote the collaboration established through the co-authorship in the articles. The network pruning was used to remove excessive links through Pathfinder, which is recommended by Chen and Morris [27]. Finally, there were 146 nodes and 173 links in the co-authorship network. The node size represents the number of publications, and the thickness of the links indicates the levels of the cooperative relationships in a given year. The colors of links, e.g., blue, green, yellow, orange and red, correspond to different years from 2005 to 2016, as shown in Fig. 3.

In terms of the collaboration, there are several closed-loop circuits in Fig. 2, indicating that the researchers in these circuits have established strong collaboration, such as the circuit of Rafael Sacks, Charles M. Eastman, and Yeon-Suk Jeong. In addition, several research communities were identified, where many authors worked with one or two highly productive author. For example, Xiangyu Wang and Jun Wang were the two central authors of a research community, including Martijn Truijens, Yi Jiao, Shih-Chung Kang, etc.; and Inhan Kim was the central author of a research community, consisting of Zhenhua Shen, Karam Kim, Jungho Yu, etc. In graph theory, Freeman's betweenness centrality is defined as the ratio of the shortest path between two nodes to the sum of all such shortest paths [28]. A node with a high betweenness centrality usually connects two or more large groups of nodes with the node itself in-between, and can be detected by a purple ring in CiteSpace. With such nodes, clusters in a network can be separated [29] and revolutionary scientific publications can be identified [30]. In Fig. 2, Charles M. Eastman (centrality = 0.13), Jun Wang (centrality = 0.11), Jochen Teizer (centrality = 0.11) and Yong-Cheol Lee (centrality = 0.1) are nodes with purple rings, and they connect different groups of authors.