Visualization Analysis of BIM Research Hotspot and Evolutinal Trend

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Abstract. Building Information Modeling (BIM) has gained rapid development and received broad worldwide attention among researchers and architects. To grasp the research progress of BIM is of great significance for researchers and enterprises engaged in BIM related studies and plotted a science knowledge map by with the visualization tool CiteSpace, and used bibliometric analysis to compare BIM studies published from 2008 to 2018 in China and abroad from three perspectives: knowledge base, research hotspot and evolutional trend. The research result shows that BIM studies abroad focus on interdisciplinary fields, but Chinese BIM studies focus more on application of BIM technologies in actual projects. Research on integration of BIM with Internet, big data, cloud computing and other information technologies is bound to become a new research trend of BIM in China.

1. Introduction
Building Information Modeling (BIM) combines 3D digital technology, architectural technology and information technology to build an integrated building database to facilitate efficient cooperation among all parties involved to fulfill a construction project. With breakthroughs and wide application of digital technology in different fields in China, “digital building” is becoming a major technological basis for transformation of the building industry, and BIM technology gains further development in architecture. BIM technology, as an emerging information technology in architecture, has been widely studied in China and abroad, and the research topics, content and methods vary. It will be of great significance for researchers and enterprises engaged in BIM related studies and work to understand the research progress on BIM. Therefore, on the basis of bibliometric analysis, the author made use of CiteSpace to sort studies on Scopus and CNKI from 2008 to 2018. By way of science knowledge maps, the author intends to present the research hotspots and evolutionary trend of BIM studies in China and abroad in hopes of providing a theoretical basis for further studies on BIM.

2. Data processing
In texts, to make comprehensive analysis and compare studies in China and abroad, the author collected Chinese data and foreign data, as shown in Table 1.

2.1. Data source
CNKI, as a database of Chinese studies, covers a wide range of resources, boasts strong reference searching functions and rich and comprehensive studies. Scopus, as a database of foreign studies, covers a wider scope of subjects and reveals the research status of one same topic on different realms. In terms of data collection, this study made use of databases of Scopus and CNKI to avoid the author’s subjective preferences and biased knowledge maps concluded from journals chosen according to the authors’ preferences, and thus avoid deviation in analysis of the knowledge framework of subjects.
Table 1. Data source

| Data base       | Retrieval method | Key terms                          | Years      | Subject                              | Documents | Search Results |
|-----------------|------------------|------------------------------------|------------|--------------------------------------|-----------|----------------|
| Scopus          | Subject Search   | BIM、Building Information Modeling | 2008-2018  | Engineering Civil, Oncology, Construction Building Technology, etc. | Article   | 5801           |
| CNKI core journal | Subject Search   | BIM、Building Information Modeling | 2008-2018  | Basic science, engineering technology, etc. | Article   | 1334           |

2.2. Data pre-treatment

As the format of documents provided by different databases varies, the documents downloaded from CNKI and Scopus needed to be converted into the format of Web of Science for further analysis by CiteSpace. Documents downloaded from CNKI and Scopus were pre-treated by CiteSpace. The pre-treatment steps are as follows.

1) Pre-treat data from CNKI: building to folders. One folder named “input” was for original data downloaded from CNKI, and another named “output” was for data converted by CiteSpace. The conversion page was CNKI, and the corresponding folder was selected on the navigation box. Note that downloaded data were saved in the folder “input”, and the downloaded files were named as “download_”;

2) Pre-treat data from Scopus: building two folders, one for original data and another for converted data. Note that .ris files downloaded from Scopus were saved in the folder “input”, and the files were named as “download.ris”. On the function area of Scopus on the data conversion interface of CiteSpace, to load the folders according to the steps mentioned above and click Scopus (RIS) → WoS after the loading is completed.

3. BIM Research Hotspot and Evolutionary Trend in China

This chapter will analyse the BIM research hotspots and evolutionary trend in China, on the basis of which, the research status on BIM in China is concluded.

3.1. Research Hotspot Analysis

In CiteSpace, “keyboard” is selected as the network node, and the parameters are adjusted to make the knowledge map clearer. High-frequency keyword clustering map in domestic BIM field is shown in Figure 1. The node represents the keyword, and the larger the node is, the more frequent the keyword occurs. The connecting line between nodes indicates the co-occurrence relation between keywords, and the colour of the connecting line represents the time for co-citation of nodes. The thicker the connecting line between the nodes is, the more the corresponding keywords were co-cited.
According to Figure 1, other keywords with BIM as the centre include “informatization”, “BIM technology”, “application”, and “project management”. All these nodes have purple halos, which indicates the high centrality of the nodes. As a whole, several keywords have high centrality and high frequency of occurrence, and other directions have low attention level and the research field is dispersive. The size of nodes on the knowledge map shows large gaps, which means the research depth of the corresponding research direction is inconsistent, the research direction is limited and there are few research hotspots. In detail, BIM studies in China from 2008 to 2018 focus on highly centralized keywords: “informatization”, “construction”, “project management”, and “design”.

3.2. Analysis of Evolutionary Trend
According to the setting above, “keyword” is selected as the network node, to run CiteSpace, select the time-zone view. The time sequence chart of burst terms of BIM studies in China is shown in Figure 2.

Figure 2. The time sequence chart of burst terms of BIM studies in China
In general, BIM studies in China has evolved from modelling-based theoretical studies to practical studies of precision building and green building. It shows that BIM studies in China have undergone three stages: the generation stage, the fast development stage and in-depth application stage.

1) generation stage (2008-2009): As shown in Figure 2, the keywords in China that have been strongly mutated include “BIM”, “building information model”, and BIM studies in China is still at
the theoretical level. In 2009, Hong Kong and Taiwan established BIM Society and Engineering Information Simulation and Management Centre, and Hong Kong released the BIM application standards. Since then, BIM technology enters the vision of Chinese researchers and experts.

2) fast development stage (2010-2014): since 2010, the mutated keywords shifted to “coordinated design”, “visualization”, “informatization”, “project management”, “application” and “engineering technology”. In 2011, the Ministry of Housing and Urban-Rural Development of P.R.C. (MOHURD) released the “2011–2015 development outline for informatization of the building industry” to promote the BIM technology from design to application, which boosted BIM research in China. With the megatrend of informatization globally, information technology in China has seen wide application in different fields. As Figure 2 shows, the research hotspots in China have shifted from design topics like “coordinated design” and “parameter design” to application and management. In 2013, MOHURD issued “Letter to Solicit Suggestions for Application of BIM Technology in the Building Industry”. BIM researchers have shifted their research focus to application of BIM technology to green building and high-rise buildings, and the idea informatized building began to draw more attention. With the support of the government and studies by universities, Chinese architectural projects, though in its early stage of development, has expanded into practical fields like project maintenance, project management, construction technology, collision testing and whole-life cycles.

3) in-depth application stage (2015-2018): In 2015, MOHURD issued the “Guidelines to Promote Application of Building Information Model”, which heralded the in-depth application stage of BIM studies. At this stage, new keywords like “in-depth design”, “green construction”, “construction management”, “secondary development”, “assembled building” and “simulation” occur, which indicates increased attention to in-depth design, green building simulation and optimization. Meanwhile, BIM-based construction management, safety management, coordinated management and engineering management are also new research topics for researchers. As Figure 2 shows, application of BIM technology has expanded from the traditional building industry to urban rail transit system, bridge building, new buildings and other urban infrastructure projects.

4. BIM research hotspots and evolutionary trend abroad

This chapter focuses on analysis of the basis of the knowledge framework. To understand the knowledge basis can allow researchers to identify the development and research foundation of BIM studies. On this basis, this chapter concludes the research status quo if BIM research abroad.

4.1. Identification of knowledge basis

4.1.1. Reference co-citation analysis

According to the configuration parameters above, “Cited Reference” was selected as the network node to make reference co-citation analysis. In the clustering view mode, clustering algorithms can be used to find clusters of studies with high rates of citation. Zhao Liang proposed that clustering analysis of frequently-cited reference can reflect the evolutionary process of a subject and reveal the potential knowledge framework in this field [1]. This paper made clustering analysis of 5801 cited studies by LSI (Latent Semantic Indexing algorithm), and obtained co-citation clustering knowledge map of BIM research references abroad, as shown in Figure 3. The network density was 0.0108, the modularity (Q value) was 0.7156 and met the requirement of exceeding 0.3, which means the clustering structure divided was effective. The mean silhouette was 0.4091, which means the clustering result was reliable. Labels in Figure 3 show the clustering number and identifier words. References of BIM studies abroad had eight keyword clusters, as shown in Table 2. Clustering No. 1 and 2 were selected as examples for interpretation.
Figure 3. Co-citation clustering knowledge map of BIM research references abroad

1) The clustered identifier words in Cluster 1 were selected using projection-based augmented reality. The number of nodes was 21, meaning that there were 21 frequently-cited research papers in this cluster. Among them, the most representative reference was “Beyond the BIM Utopia: Approaches to the Development and Implementation of Building Information Modeling” by Miettinen R. According to reference analysis of key nodes in the cluster, it can be concluded that this cluster is mainly discussions about building information modelling, construction, and laser scanning point cloud, automatic restoration, assembly, building maintenance, automatic safety planning and quality.

2) the identifier word of Cluster 2 is “general contractor”. The number of nodes is 20, indicating that there are 20 frequently-cited references in this cluster. Among them, the most representative one is “Developing BIM-assisted As-built Schedule Management System for General Contractors” by Tserng HP. According to key node reference analysis in the cluster, it can be concluded that this cluster focuses on discussions on benefit-cost analysis, urban agriculture, assessment building information, effective asset management, intelligent BIM recording model, cloud computing application, and building project management.

Table 2. Overseas BIM literature co-citation important clustering and clustering identifier words

| Cluster ID | Size | Silhouette | Top terms                                      | Years            |
|------------|------|------------|------------------------------------------------|------------------|
| 1          | 21   | 0.627      | Using projection-based augmented reality       | Miettinen R (2014)|
| 2          | 20   | 0.746      | General contractor                              | Tserng HP (2014) |
| 4          | 18   | 0.954      | Building information modeling                   | Dimitrov A (2015) |
| 5          | 17   | 0.733      | Knowledge-based building management system       | Eastman CM (2008) |
| 6          | 12   | 0.805      | Building information modeling                   | Smith DK (2009)  |
| 7          | 12   | 0.768      | Architectural precast facade                    | Hartmann T (2008) |
| 9          | 9    | 0.898      | ACE industry                                    | Lee G (2006)     |
| 11         | 5    | 0.926      | Construction engineering                        | Sacks R (2010)   |

4.1.2. Journal co-citation analysis
Parameters were configured according to the above settings, and “Cited Journal” was selected as the network node to perform journal co-citation analysis, and the international journal co-citation network map was obtained, as shown in Figure 4. The Figure shows the general conditions of journal co-citation of international BIM studies from 2008 to 2018. Some references included in these journals have become classic and core references of BIM studies globally, and the journals hence become core journals.
Figure 4 shows that BIM studies that are frequently cited are from journals like Automation in Construction, BIM Handbook, Advanced Engineering Informatics, Journal of Construction Engineering and Management and Journal of Computing in Civil Engineering, etc. The citation frequency and centrality of Automation in Construction are both high, meaning it is an influential journal and serves as a powerful intermediary in the network, with many journals creating a co-citation network through this node. Automation in Construction, established in 1992, is an international journal that publishes original research papers and covers references about the application of information technology in design, engineering, construction, building maintenance, and management. BIM Handbook, different from other journals, is an academic monograph. Published in 2008, BIM Handbook proposed the idea of information sharing in design, construction, and management through digital models and put forward the BIM theory that is revolutionary in the building industry. Advanced Engineering Informatics, with its focus on “knowledge” and “engineering practice”, is an international journal. In addition, journals like Journal of Construction Engineering and Management, Journal of Computing in Civil Engineering, Journal of Information Technology in Construction, Energy and Building and International Journal of Project Management rank top in terms of citation frequency and are classic and influential journals in BIM studies.

4.2. Analysis of research hotspots

Based on the parameters set above, a knowledge map of frequently-used keywords in BIM studies abroad is produced, as shown in Figure 5. As Figure 5 shows, apart from some outstanding keywords like “Architectural design”, “Building information modelling”, “Information theory”, “BIM”, the centrality of other keywords is evenly distributed. The research hotspots are scattered, there are many large nodes, and the research is not confined to one single direction. There are many connecting lines between nodes, which indicates the abundance of interdisciplinary research topics and close connections.
As there are many clusters, the BIM research hotspots abroad are concluded into three aspects: information technology, guidelines and application function. 1) application of information technology in design, construction and management is an upgrading process which involves IFC, QR code, RFID, digitalization, cloud computing, 3D laser scanning and others. IFC standards are the data port of BIM research. 2) guidelines are to make the plans more operable and involves collision detection, green building, in-depth design and dynamic management. 3) application functions mainly include visualization design, pipeline layout, construction progress simulation, construction organization simulation, digital construction, operations maintenance management, coordinated design and others.

4.3. Analysis of evolutionary trend
Based on the parameters set above, Figure 6 presents the keywords with strong mutation in BIM studies abroad, which reflects the research fronts of BIM studies abroad.

From 2008 to 2010, keywords with strong mutation in international BIM studies include Three dimensional (59.326), Civil engineering (54.0428), Building information modelling (35.446), In building (25.3761), Building design (21.6061) and others, which indicates that 3D, architectural design, information exchange have entered the in-depth research stage, and information technology, HRM, computer simulation, 3D modelling, building materials have become new research hotspots in that time. From 2015 to 2018, strongly mutated keywords include Design (39.4323), Process engineering (27.9944), Human resource management (17.3086), which indicates that HRM is the major research focus in this time period, and design, technique engineering, education, building specifications have entered the in-depth research stage.

5. Conclusion
1) research hotspot: keywords that frequently occur in foreign BIM studies are closely connected to each other, and aside from paying attention to fundamental theories, BIM studies also delve into information technology, guidelines and in-depth application. Information technology like IFC, digitalization, cloud computing, 3D laser scanning, guidelines like 3D modelling, green building, in-depth design, information management, and in-depth application like pipeline layout, construction progress simulation, construction organization simulation, digitalized building, operations maintenance and management. Compared with BIM studies abroad, relevant studies in China focus on keywords like informatization, construction, project management, design, visualization from 2008 to 2018, and most of them are theoretical studies, but there are few interdisciplinary studies.
2) evolutionary trend: at an earlier stage, international researchers focus on studies on 3D, building design, design, construction, information exchange, computer software and computer aided design. In recent years, BIM+ information technology, HRM, computer simulation, 3D modeling, building materials, technique engineering, education, building specifications have emerged as the new research direction. BIM studies in China have shifted from the concept and prevalence of building information models at the early stage to more in-depth research fields like in-depth design, green building, construction management, secondary development, assembly building and simulation. In these years, despite the rapid development of BIM studies in China, integrated application studies of information technology have made slow progress.

![Figure 6. High mutation strength keywords in BIM studies abroad](image)

To upgrade BIM studies in China and boost development of BIM research, the following suggestions are proposed. First, Chinese researchers should broaden their vision and explore interdisciplinary studies on BIM. When learning from BIM studies abroad, they should also find “BIM+” plans suitable for China’s architecture industry and lay a solid theoretical foundation for BIM research. Second, they need to seek cooperation and conduct cooperative studies, break the limit of institutional mode of cooperation, and realize diversified and international cooperation. Last, with regard to application, they should link their research with development of Chinese building enterprises, extend the depth and breadth of BIM application, accumulate rich experience and realize innovation in application of BIM technology.

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