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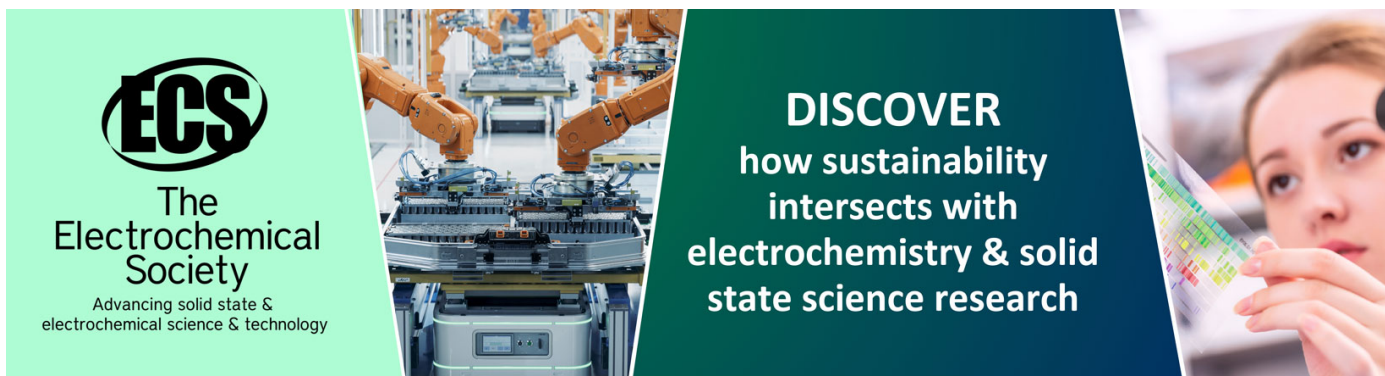
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# Mapping the field of Building Information Modeling(BIM) based on bibliometric analysis

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**Abstract.** Building information modeling(BIM) makes great contributions to empowering the construction industry and it has been adopted widely in many fields. To capture existing circumstance and future trend of BIM in the perspective of bibliometric analysis, we analyse 1247 papers related to BIM publications which are collected from the Web of Science database with time span defined as “all years”. Results concerning the publications and its citation structure, the network of co-authorship in countries/region and institutes, the network of co-citation in cited references, and keywords co-occurrence are presented in this paper, and VOSviewer software is used as a visualising analysis tool. This paper not only summarizes the research progress of BIM but also provides a useful method for the future evaluation of construction field.

## 1. Introduction

Building information modeling (BIM) has been widely used in many disciplines because of its potential advantages in enhancing integration, interaction, information visualization, sharing and communication, especially in the industry of architecture, engineering and Construction [1]. In recent years, many studies have been done to review the past development and propose new research trends for BIM. For instance, the concepts of computer-integrated construction and BIM [2], the development of building product modeling [3], and the useable techniques for achieving automatic reconstruction [4]. However, there are limitations in these reviews, most of them are typically qualitative, subjective. And it's important to provide a quantitative analysis as well as repeatable results in this field so that researchers can have better understanding towards BIM.

Bibliometrics is a relatively mature and essential branch of intelligence science which depends on statistics and visualization methods to explore patterns and the structures of certain disciplines [5]. And a lot of journals have been analysed with bibliometrics, such as Sustainability [6], Journal of Civil Engineering and Management [7] and European Journal of Operational Research [8]. In addition, this methodology can not only be used in journals, but also be suitable to evaluate the performance of different research fields. Gema et al. [9] conducted a bibliometric analysis on green innovation for the 1971-2015 period, Keivan et al. [10] investigated green supply chain from 1995 to 2017, Liao et al. [11] presented a bibliometric analysis on medical big data.

The existing literatures illustrate that the bibliometric analysis is valuable in finding out more information, but research on BIM pays less attention to this kind of method. This paper aims to carry out an analysis for BIM studies in the perspective of bibliometrics. The remainder of this paper is organized as follows: Section 2 introduces the data source and methods used in this study. Section 3 conducts the results in detail, including publications and citation structure, the network of co-authorship



in countries/regions and institutes, the network of co-citation in cited references and keywords co-occurrence analysis for hot topics. The concluding remarks are showed in Section 4.

## 2. Data and Methods

This study collects data from the Web of Science(WoS) which is considered to be one of the most prestigious databases. The search term used is “Building information modeling”. To be more specific, we constraint the search range only in titles. There are 1247 publications in total from 1981 until now (20 August 2020). The numbers and proportions of various document types are listed in Table 1, article(604) and proceedings paper(514) are the most frequent document types, accounting for 48.44% and 41.22% respectively. VOS viewer software is then adopted to conduct analyses of co-authorship, co-citation and keywords co-occurrence. Eck and Waltman [12] developed this software which is free to get access. It provides a user interface to easily produce many quantitative results, especially in visualising mapping.

Table 1. Retrieved document types.

Document types	Frequency	Propotion
Article	604	48.44%
Proceedings paper	514	41.22%
Review	58	4.65%
Editorial material	30	2.41%
Early access	20	1.60%
Meeting abstract	7	0.56%
News item	7	0.56%
Correction	5	0.40%
Book review	2	0.16%
Total	1247	

## 3. Results

### 3.1. Publications and citation structure on BIM

The amount of scientific knowledge can be reflected by the change of literature quantity in this field. Here, we take the number of publications, citations, and H-index as indicators to measure productivity and influential of BIM [13]. From 1981 to 2020, there are 1247 publications on BIM. The overall publications are shown in Figure 1. Before 2005, there were basically no related publications to BIM. After 2005, the number of publications started to grow gradually. After 2016, the number of publications increased significantly. 167 and 176 papers were published in 2017 and 2018 respectively, indicating that BIM has attracted more and more attention from scholars.

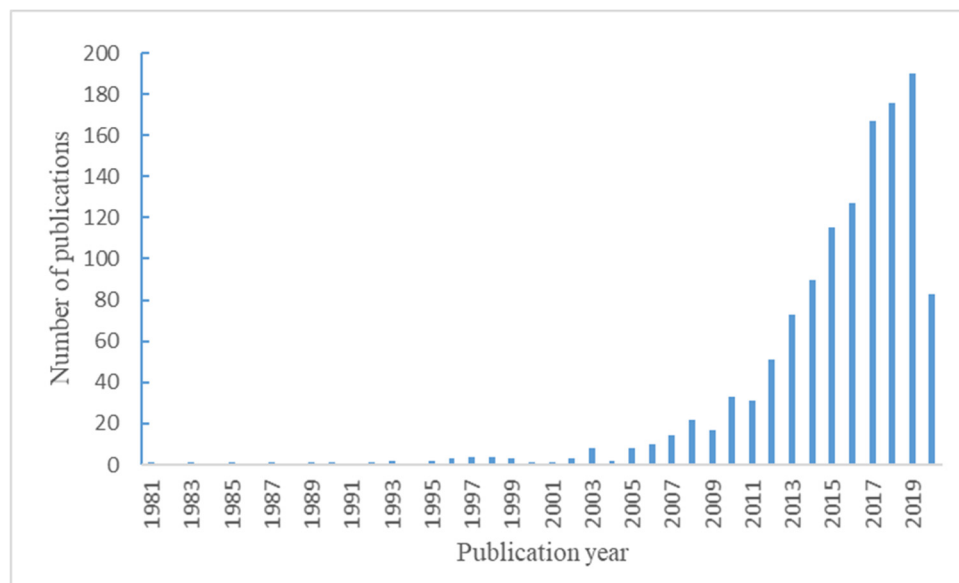


Figure 1. Annual publications on BIM from 1981 to 2020

Table 2 shows the number of papers published on BIM and the total number of citations for the past 10 years. In addition, by defining some thresholds, the cited papers are divided into five grades according to the number of citations. We can see that 14 papers have surpassed 100 citations. In addition, 4.79% of the papers were cited over 50 citations, 34.51% and 64.23% of the papers were cited over 5 citations and 1 citation, which means that most BIM publications have attracted the attention of scholars. From 2011 to 2020, Both the citations and H-index increased first but decreased after a period of time. The number of citations reached a peak of 2227 citations in 2013. The H-index was the largest in 2015, reaching 26. Understandably, the impact of publications from 2011 to 2015 has increased almost every year. But new publications requires more time to receive attention from scholars, so the H-index will naturally decline in recent years.

Table 2. Citation structure of BIM publications from 2011 to 2020.

Year	TP <sup>a</sup>	TC <sup>b</sup>	≥100	≥50	≥20	≥10	≥5	≥1	H-index
2011	31	750	3	5	8	8	12	20	8
2012	51	592	1	3	10	14	18	37	12
2013	73	2227	5	14	26	35	38	55	25
2014	90	2035	4	10	22	34	43	67	21
2015	115	1556	1	9	27	42	53	84	26
2016	127	993	0	2	14	35	52	90	17
2017	167	1670	0	10	24	46	73	114	21
2018	176	923	0	0	12	36	56	118	18
2019	190	488	0	0	2	13	37	108	10
2020	87	23	0	0	0	0	0	18	2
Total	1107	11257	14	53	145	263	382	711	
Percentage	100%	100%	1.26%	4.79%	13.10%	23.76%	34.51%	64.23%	

<sup>a</sup>Total publications.

<sup>b</sup>Total citations.

### 3.2. Network of co-authorship countries/regions and institutes

With the rapid development of communication technology, co-authorship is taken as one of the most popular ways to cooperation both in domestic and abroad, and international co-authorship is an essential form of co-authorship. It can be figured out which are active countries/regions and institutes by

analysing its network. Additionally, international co-authored papers normally gain a good performance in numbers as well as citations [14].

As shown in Figure 2, different nodes represent different countries/regions, and their sizes mean the activity of the country/region. The bigger the node is, the more publications the country/region has. A line is drawn if two countries/regions have a cooperation relationship, and with more cooperation relationship, the line will become thicker. We set the minimum number of documents at 5, then there are 46 countries/regions meeting the threshold. these 46 nodes are divided into 7 clusters by VOSviewer software. One color denotes one cluster. As we can observe, Nodes including the USA, China, England, and Australia are the biggest. Portugal and Finland are in the red cluster. Australia and Brazil are in the yellow cluster. Therefore, geographical distance is not an obvious barrier for researchers and international cooperation becomes wider. Furthermore, China is strongly connected with Australia as well as England. It uncovers that academic communications have been strengthened by increasing international exchanges nowadays. There are more opportunities for scholars in the field of BIM to pursue further studies and make academic visits at abroad.

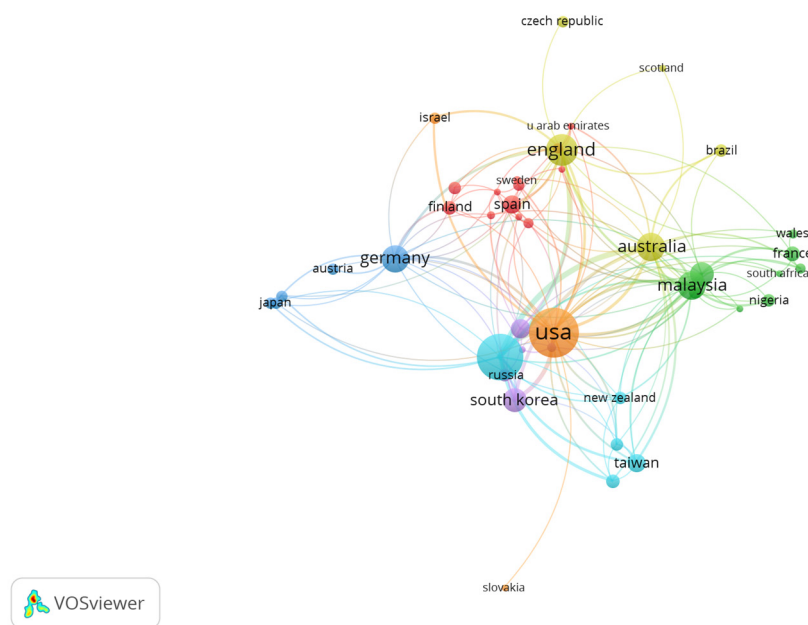


Figure 2. Network of co-authorship countries/regions on BIM.

At the same time, we illustrate the network of co-authorship institutes in Figure 3. There are 1054 institutes with publications on BIM. After setting the minimum publications at 8, 32 related institutes cross the threshold. They are divided into 7 clusters by Vosviewer software. Nodes including The Hong Kong Polytechnic University, Curtin University, Universiti Teknologi Malaysia and Georgia Institute of Technology are the four largest. University of Florida, Hanyang University and Georgia Institute of Technology belong to the red cluster. Chongqing University and The Hong Kong University of Science and Technology belong to the purple cluster. It is indicated that geographical proximity and language are essential factors in the cooperation of institutes.

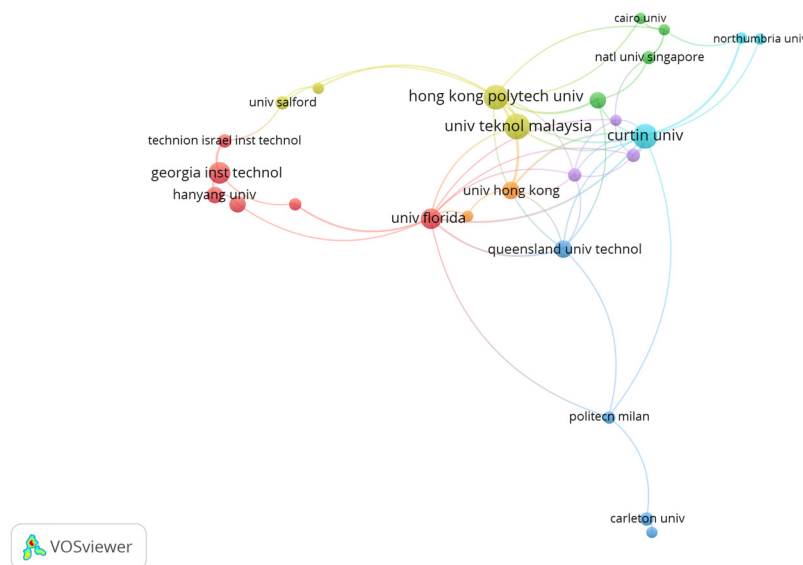


Figure 3. Network of co-authorship institutes on BIM.

### 3.3. Network of co-citation references on BIM

Small [15] proposed co-citation analysis at first. If two papers appear in the references of the third paper at the same time, a co-citation relationship is established. Co-citation analysis uses some representative literature as the analysis targets, and divides them into several clusters by network analysis method. In this way, we can get the structural features of a specific field. We present network of co-citation of local cited references in Figure 4. We set the minimum documents number at 40 and a total of 23 papers met the criteria. A color represents a cluster. These 23 references are divided into 3 clusters by Vosviewer software. It is noteworthy that Eastman C, Succar B, Azhar S and Volk R are the main authors of BIM publications. To see more details in Figure 4, we present the top 10 highly total link strength references in Table 3. Total link strength is the counted frequency of co-citation relationship. As we can see, Eastman C takes the lead in the list with 217 local citations and 883 total link strength, followed by Succar B and Azhar S whose local citations are 138 and 133, respectively. It's interesting to find that not all of the references with higher local citations perform better in total link strength, such as Gu N and Volk R, indicating that some references can be cited alone.

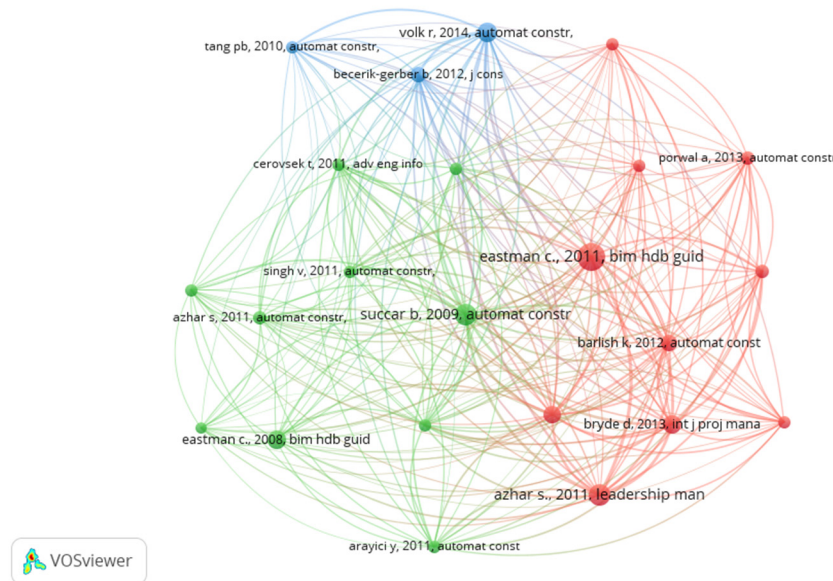


Figure 4. Network of co-citation references on BIM.

Table 3. Top 10 highly link strength references of BIM publications.

Rank	Author	Local Citations	Year	Total Link Strength
1	Eastman C	217	2011	883
2	Succar B	138	2009	828
3	Azhar S	133	2011	758
4	Bryde D	101	2013	705
5	Gu N	89	2010	691
6	Volk R	114	2014	624
7	Barlish K	77	2012	532
8	Becerik-gerber B	70	2012	442
9	Jung Y	48	2011	406
10	Cerovsek T	47	2011	395

### 3.4. Network of keywords occurrence on BIM

The network of keywords occurrence reveals the main theme of the literature so as to summarize the research trends and hot topics [16]. We look into used keywords with highly frequency to determine the hot topics of BIM research. To avoid unnecessary information, we only use the keywords provided by authors. According to VOSviewer's results, there are 2595 key words, and we set the threshold of the minimum number of co-occurrence words at 10, then 97 items are selected out of them. And these 97 key words belong to 13 clusters. The biggest nodes, as we expect, are bim, building information modeling, building information modelling and building information modelling(bim). Some other obvious keywords are construction, industry foundation classes, project management, interoperability, sustainability, laser scanning, facility management etc. Keywords given above denote the heat topics of research on BIM. Additionally, we can observe some thick links in the network, for instance, the links in bim and facility management, bim and interoperability, sustainability and facility management, revealing that these key words have been highly connected in the same paper.

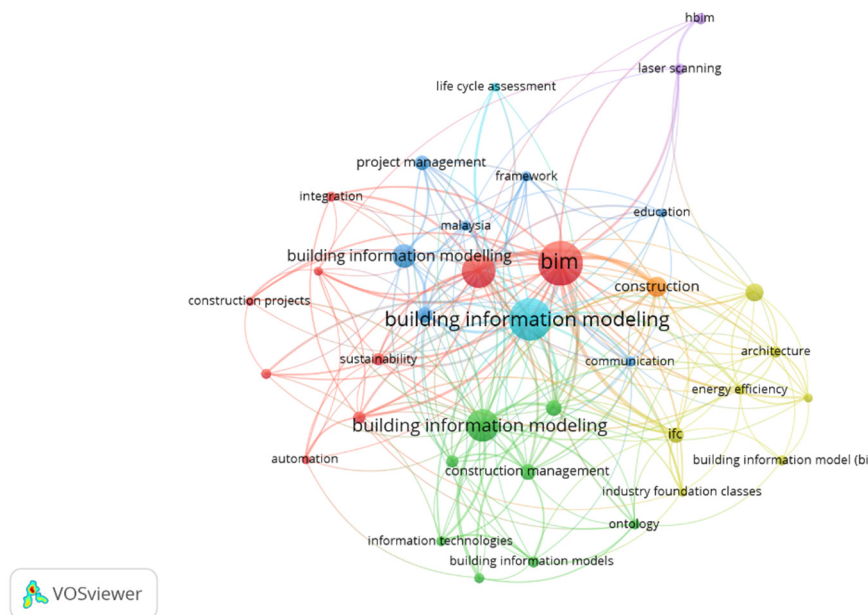


Figure 5. Network of keywords co-occurrence on BIM.

#### 4. Concluding remarks

In this paper, a bibliometric review of BIM publications is presented. And the data was collected from WoS database. The results including four aspects of analysis: publications and citation structures on BIM, network of co-authorship, network of co-citation and keywords co-occurrence. A few counterpart insights can be summarized from the analysis results:

- Compared to decades ago, BIM publications have grown drastically in past 10 years, especially after 2016, reflecting an impressive productivity in this domain. But The citations of BIM publications in recent 2 years still need more time to expand their influence.

- The most active countries are The USA, China, England, and Australia. The Hong Kong Polytechnic University, Curtin University, Universiti Teknologi Malaysia and Georgia Institute of Technology are the most influential institutes. International cooperation becomes wider and wider, though language and geographical proximity are still factors affecting cooperation among institutes.

- Eastman C, Succar B, Azhar S and Volk R are the main authors of BIM publications, but not all of those references with higher local citations perform better in total link strength, indicating that some references can be cited alone.

- Construction, industry foundation classes, project management, interoperability, sustainability are the highly used key words in BIM publications. Further research may study deeper in these topics.

This paper aims to analyse the status quo and future trend of BIM publications in the perspective of bibliometric analysis, so comprehensive understanding towards BIM can be improved. Nevertheless, there are limitations in this work. This research collected data from WoS database, there are still many studies related to BIM which are stored in other databases. And the results regarding to the publications in the past 2 years may change over time, which requires bibliometric analysis to be updated timely.

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