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Integration of BIM and Chinese Architectural Heritage: A Bibliometric Analysis Research

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Abstract: The research on the application of BIM technology in architectural heritage is increasing. Building information modeling (BIM) makes the realization of architectural heritage assessment, design, and management systematic and effective. However, little is known about the use of China-based BIM in conjunction with architectural heritage. Therefore, this study conducted a systematic literature analysis to determine the application fields and development trends of BIM and architectural heritage research in China. A total of 186 articles were retrieved from CNKI, of which 167 met the inclusion criteria and formed the basis of this systematic literature analysis. With the aid of the literature research visualization analysis software VOSviewer and SATI, a comprehensive literature visualization analysis was carried out. It was determined that the hot fields of BIM research in architectural heritage in China are mainly focused on (a) the perspective of data acquisition and measurement technology, (b) the perspective of model construction based on point cloud data acquisition, and (c) the perspective of BIM model application. Future research trends may focus on the information research of architectural heritage, combined with the application of BIM technology in the whole life cycle management of architectural heritage and other aspects.

Keywords: building information modeling (BIM); architectural; heritage; bibliometric; VOSviewer

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1. Introduction

Ancient buildings usually carry a great deal of unique, clear, and authentic historical information due to their scale, form, layout, detailing, and spatial relationship with the city. The most substantial task of architectural heritage conservation is to preserve the multifaceted values and information contained in them. How to achieve the development goal of digitalization, informationization, and intelligence of architectural heritage conservation has become an urgent problem in China. As an emerging technology and tool in engineering, building information modeling (BIM) technology provides an effective information means for the realization of the development goal of architectural heritage conservation. The concept of building information modeling (BIM) was first developed by Eastman in *Building Product Models: Computer Environments* [1], which describes the basic concepts, relevant model components, and information exchange of building information models. BIM is an intelligent process based on models, aiming at reducing project costs, improving productivity and quality, and shortening project delivery time [2].

The concept of historical/heritage building information model (HBIM) was generated in 2009, and first defined by Murphy et al. [3]. HBIM as a plug-in for BIM, begins by remotely collecting survey data using ground-based laser scanning or digital photo modeling [4]. The completed BIM helps to characterize the physical and functional features of the existing buildings through reality-based data acquisition and reverse engineering [5]. Due to its ability to store attributes, model objects and interrogate their relationships, BIM technology seems to be applicable to cultural heritage, especially heritage buildings. However, with the emergence of new data collection techniques and their democratization, the application of BIM in cultural heritage received favor [6]. It is expected that HBIM will replace the traditional measurement and restoration processes in the near future [7].

Currently, there are many technologies that can be applied to architectural heritage research together with BIM. In order to create accurate and fast BIM models of existing projects, recent technological advances such as laser scanning, photogrammetry, and drones are helpful [8]. Pocobelli et al. [9] summarized survey techniques for heritage, using different methods ranging from traditional to advanced automated methods such as TLS integrated with GIS, digital photogrammetry, and UAVs. Through these methods, point clouds representing the digital format of real buildings are obtained. Terrestrial laser scanners (TLSs) are increasingly being used as the primary tool to precisely define the basic geometry for three-dimensional modeling of heritage buildings, which will be the starting point for the formation of the final BIM [10]. Compared with traditional measuring tools, 3D laser scanning has high measurement accuracy (millimeter level) and fast measurement speed (100,000 points per second) [11]. Rachmawati [12] summarized a number of articles on the use of UAVs in architectural heritage protection: "The data obtained from UAVs form the basis for building 3D models in BIM to serve the purposes of conservation and restoration" [13–15]. Even three-dimensional models are used to build smart tourism services based on Web/AR/MR technology, where users can obtain information and participate in virtual tours of historic buildings [16]. In addition, Alizadehsalehi et al. [8] suggested that the use of BIM had not yet reached its full potential. This is because the information is not presented in a way that people can fully understand. Extended reality (XR) provides a solution to this problem. XR is an umbrella term for immersive technologies, including virtual reality (VR), augmented reality (AR) and mixed reality (MR) technologies. Mansuri et al. [17] studied and summarized emerging fields of future research on BIM and architectural heritage, including as-built modeling and 3D reconstruction; conservation, preservation and management; documentation; maintenance and restoration; virtual technology and simulation. With the development of BIM technology, it continues to be extended and applied as an important link in architectural heritage conservation.

The BIM technology for architectural heritage has only been studied recently, and its application is not widespread. How BIM supports architectural protection practices needs further study [9]. In particular, the research on BIM in architectural heritage with China as the scope of work is still in its infancy, and few studies have adopted the method of bibliometric analysis to analyze BIM and Chinese architectural heritage. Therefore, it is important to study the development history of "BIM" and "architectural heritage" in China, and to grasp the current research status of "BIM" and "ancient architecture" as a whole, which can lay the foundation for the subsequent exploration of continuous innovation in this field by the academic community. Therefore, the aim of this paper is to systematically analyze the academic research on the integration of BIM and architectural heritage. Based on a general understanding of the current application fields and technical trends of BIM and architectural heritage, this study can be used as a starting point for further research in the future. Specifically, this study attempts to answer the following research questions: (1) In China, which application fields are the main research hotspots of BIM and architectural heritage? (2) What are the technical trends in the integration of BIM and related technologies into architectural heritage? (3) What are the application trends of BIM and architectural heritage research?

2. Materials and Methods

In this paper, the China Knowledge Network (CNKI) academic journal database has been used as the data source, and literature has been searched with "subject = historic building or including architectural heritage, subject = BIM, and time span with all years". All journals were selected as the source category, and the data was retrieved on 15 November 2022. A total of 186 articles were obtained through the search. In the retrieval results, the less relevant papers such as conference information and review reports have been excluded, and we finally obtained 167 valid articles as the sample, including 20 papers with the source categories of SCI, EI, core of Peking University, CSSCI, and CSCD (high-level papers).

Records were extracted from the China National Knowledge Network (CNKI) rather than other databases because (a) within China, CNKI includes a wide range of scientific journal publications, and most records in other databases are also found in CNKI; (b) the CNKI journal data are the most authentic and rapid reflection of research in this field in China; (c) the results extracted from CNKI can be integrated into the VOSviewer software 1.6.18 (Created by Leiden University's Centre for Science and Technology Studies (CWTS), The Netherlands), which enables the construction and visualization of the bibliometric network.

VOSviewer software is a commonly used tool in quantitative scientific analyses [18], which has been widely used in multidisciplinary fields in recent years. It is the most distinctive and influential knowledge graph analysis tool. SATI (Statistical Analysis Toolkit for Informetrics) is a general Statistical Analysis tool for bibliographic information It can analyze the bibliographic information in multiple dimensions in the format of endnotes.

In this paper, the SATI software 4.0 (Created by Liu Qiyuan, Ye Ying, China) is used to analyze the trend of the number of periodicals published, the discipline and subject of the articles, and the cooperation between the authors and their organizations. At the same time, VOSviewer_1.6.18 software is combined to carry out network visualization, and high-frequency keyword analysis, overlay visualization, and research focus analysis. This paper combined the two analysis tools to make a multidimensional comparative analysis of the literature analysis samples, draw the knowledge map of "BIM" and "architectural heritage" research. Grasp the research hotspots and development trends of China's "BIM" and "architectural heritage" academic research field, and provide a comparative role for the regional differences in this research field, and provide a reference for the research and development of this field.

3. Results

3.1. Data Sources

3.1.1. Time-Based Analysis

In the academic field, the number of papers published and time is one of the important indicators to measure the popularity of research in this field. Based on the year distribution of 186 CNKI journals whose subject words are "ancient architecture" or contain "architectural heritage" and whoes theme is "BIM", it is found that the research literature on "BIM" and "architectural heritage" in China started from 2007 and maintained a relatively low number of published articles before 2013. Since 2013, the number of published papers has increased significantly and continued to grow. In 2018 and 2019, the rate of increase is obvious, and it will reach a peak in 2021, as shown in Figure 1. Research in this field has had continuously high popularity. Similarly, from the perspective of the publication of high-level literature, it started in 2012 and formed a peak of high-level journal publication in 2020, basically corresponding to the overall publication volume, as shown in Figure 2.

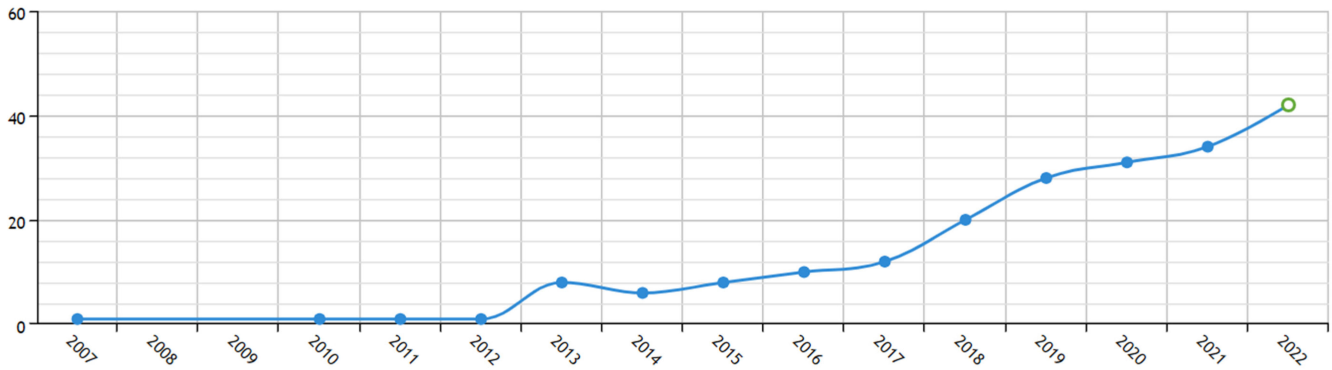


Figure 1. Number of publications (167 papers), October, 2007–2022.

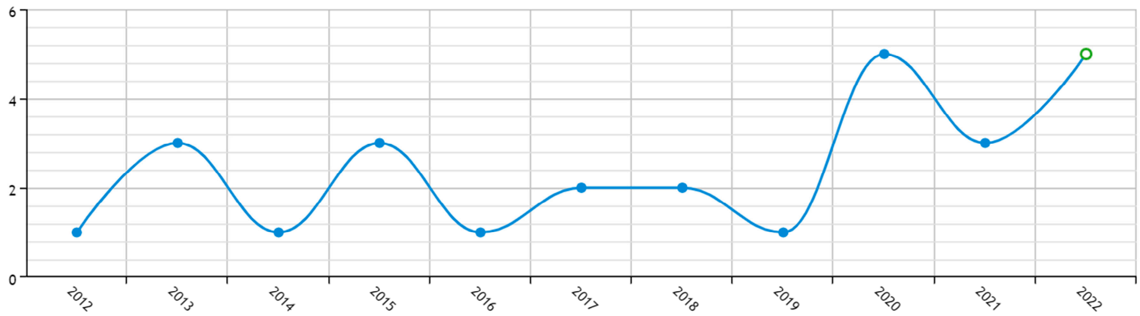


Figure 2. Number of articles published in 2012–2022 (high level papers).

In addition, SATI online analysis software was used to analyze the literature publication year list, and the data was displayed graphically, as shown in Table 1 below. From the trend of publication, it can be seen that Chinese academic research on "BIM" and "architectural heritage" started in 2007, reached the first research peak in 2013, and the annual number of published papers reached six. The number decreased slightly in 2014, and gradually increased from 2015 to 2021, reaching the research peak. The number of annual publications reached 30. The publication of high-level literature only started in 2012, with three in 2013 and five in 2020, forming a peak publication volume. The annual publication volume of high-level literature was low, but also showed an increasing trend year by year. On the whole, the research trend of "BIM" and "architectural heritage" in the academic field is increasing year by year.

Table 1. List of high frequency publication years of "BIM" and "architectural heritage" articles (167 articles listed on the left and 20 high-level articles listed on the right).

Year	Frequency	%
2021	30	17.8571%
2020	29	17.2619%
2019	27	16.0714%
2022	25	14.881%
2018	20	11.9048%
2017	10	5.9524%
2016	8	4.7619%
2013	6	3.5714%
2015	6	3.5714%
2014	5	2.9762%
2007	1	0.5952%
2010	1	0.5952%

Year	Frequency	%
2020	5	25%
2013	3	15%
2015	3	15%
2017	2	10%
2018	2	10%
2021	2	10%
2014	1	5%
2016	1	5%
2019	1	5%

3.1.2. Field Distribution and Research Themes

By analyzing the distribution of the literature by discipline, the distribution of research topics in each discipline can be identified. Since the CNKI database can only help with analyzing the uncensored literature data, the obtained 186 articles suggest that the research disciplines of "architectural heritage" and "BIM" are widely distributed through graphical analysis. The literature distribution is shown in Figure 3. The category of building technology science has the largest number of papers, accounting for 56.86% of all papers, which is related to the disciplinary affiliation of ancient architecture. This is followed by 27.12% of the studies in the category of fine arts. The above two account for more than 80%. Far less than the first two and in the next place are surveying and mapping with 3.27%, computer science with 2.61%, and archaeology with 1.96% in fifth place.

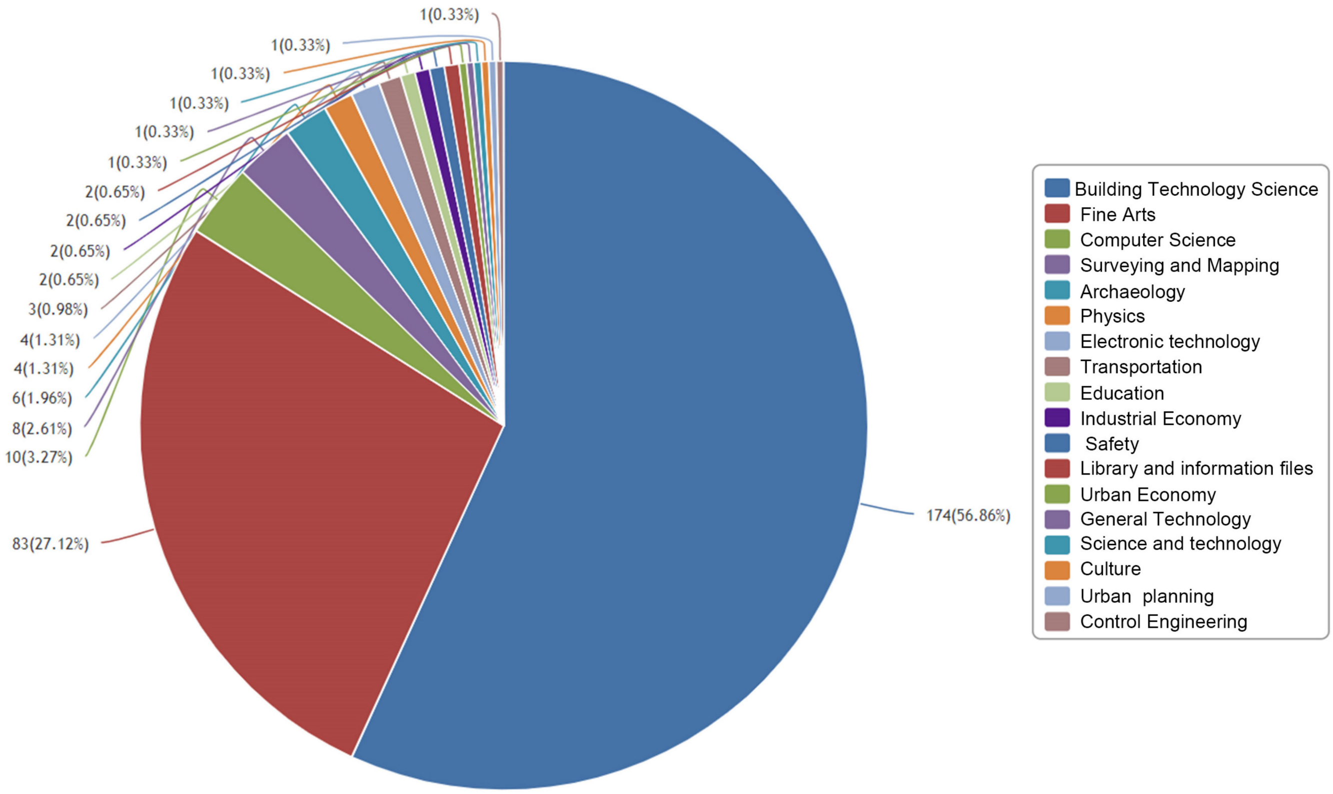


Figure 3. Distribution of the literature in subject areas involved in building information modeling (BIM) and architectural heritage research in China (186 articles).

In this paper, through cross-topic analysis of the 186 articles on the China Knowledge Network, it can be found that the main cross-research areas of "BIM" and "architectural heritage" are: BIM technology research based on ancient architecture, 3D laser scanning research based on BIM and architectural heritage, point cloud/point cloud data research based on ancient architecture, and Revit/3D modeling research based on ancient architecture, as shown in Figure 4.

3.1.3. Statistical Analysis of Literature Journals

By analyzing the number and distribution of published journals, the degree of attention paid to this topic by core journals in the field of "BIM" and "architectural heritage" research in China can be revealed. By analyzing the distribution of the 186 articles on the China Knowledge Network, the most published journal related to the topic of "BIM" and "architectural heritage" from 2007 to 2022 is "*Urbanism and Architecture*", with a total of seven publications, accounting for 7.22%, followed by journals with five publications, which are "*Journal of Information Technology in Civil Engineering and Architecture*", "*House*" and "*Science and Technology Innovation*", each accounting for 5.15%. The number of articles issued was four in seven journals including "*Nature and Cultural Heritage Research*", "*Huazhong Architecture*", and "*Architecture and Culture*", as shown in Figure 5. On the whole, the distribution of BIM and architectural heritage theme research in Chinese domestic journals is relatively scattered, indicating that the distribution of the literature on this research theme has not become focused.

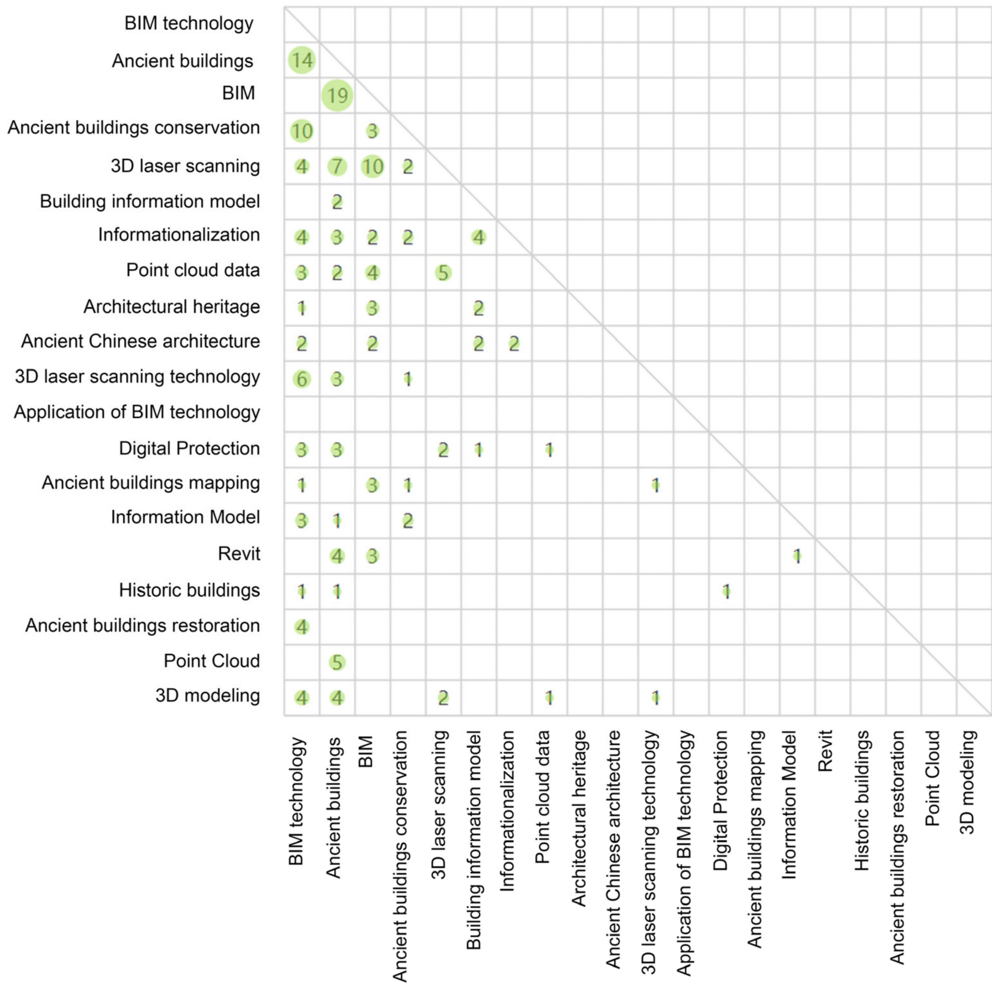


Figure 4. Cross-thematic analysis of "BIM" and "ancient architecture".

The time series analysis of the year of journal publication of the 167 articles through SATI platform analysis is shown in Figure 6, and it is found that the first journal "*Urbanism and Architecture*" and the second journals "*House*" and "*Science and Technology Innovation*", which are tied for the first number of studies published, both entered "BIM" and "architectural heritage". The top ten journals are basically from the top of the list. The top ten journals basically started in 2013, and their annual publication volume was not high, but showed a gradually increasing trend after 2018. Other journals have not shown significant fluctuations in the thematic literature distribution, which suggests that there is a lack of journals that focus on this field consistently.

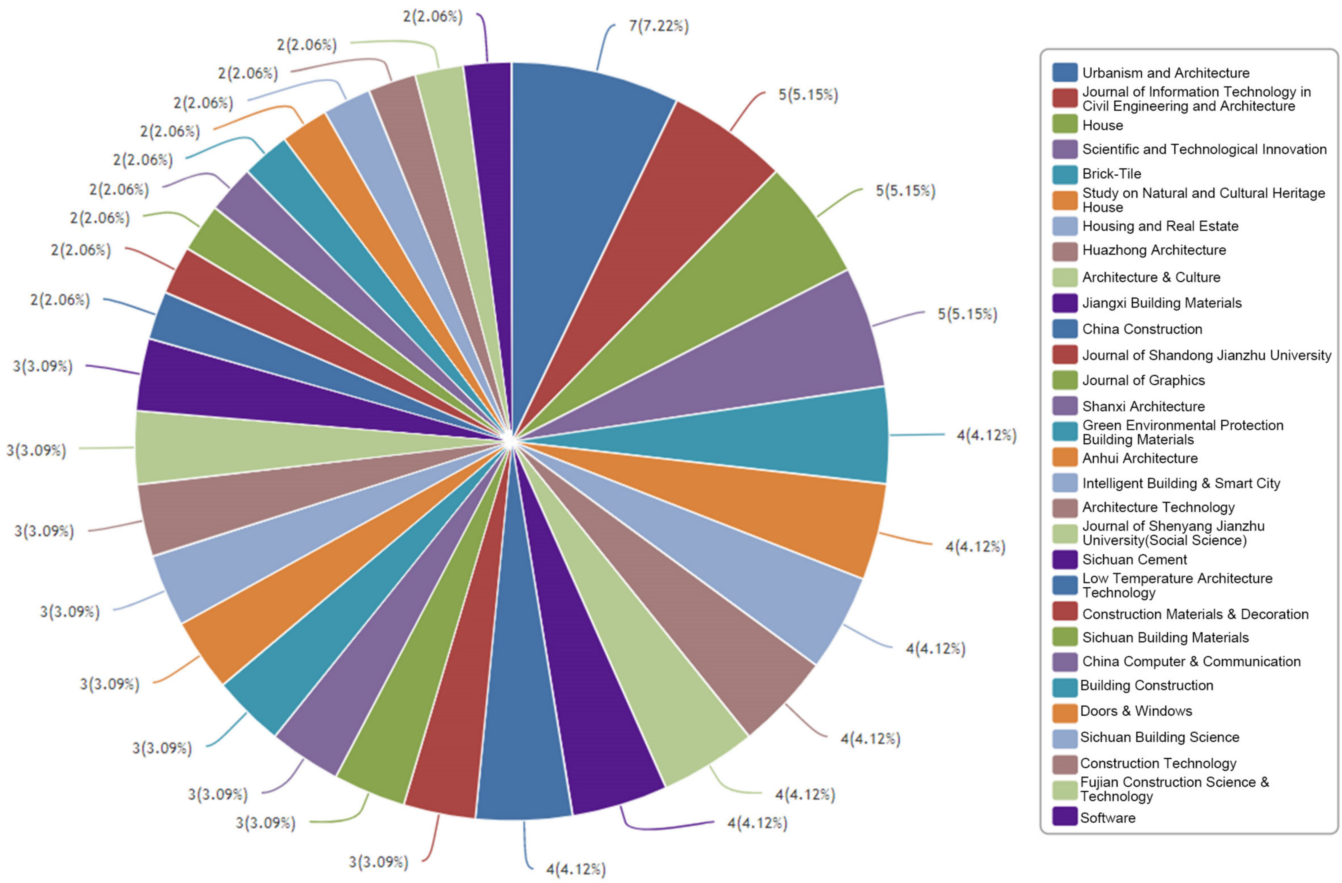


Figure 5. Distribution of journal publications on "BIM" and "architectural heritage" from 2007 to 2022 (186 articles).

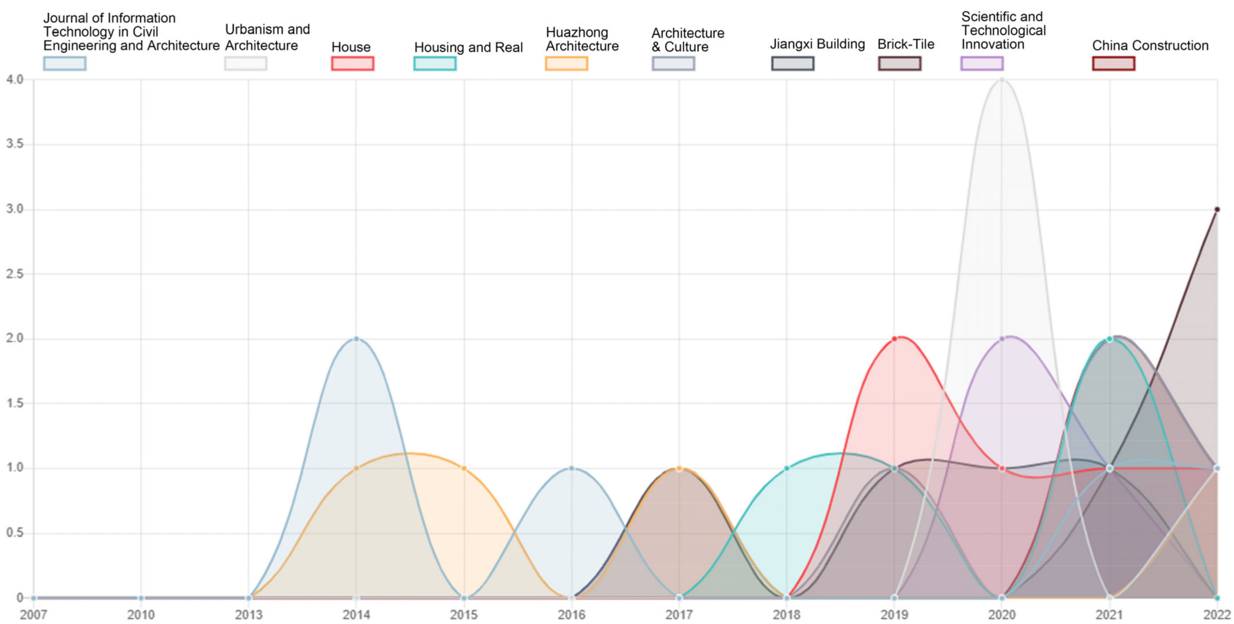


Figure 6. Trend of the number of papers on "BIM" and "architectural heritage" published in various journals from 2007 to 2022 (167 papers).

3.2. *Author & Institutional Analysis*

3.2.1. Author Visualization Mapping

In this paper, the authors of the 167 papers were analyzed by SATI software, and the top 10 authors of "BIM" and "architectural heritage" from 2007 to November 2021 are shown in the Figure 7, namely, Wang Ru published seven articles, Zhang Jian, Yan Zewen, and Xu Dongsheng published four academic articles, and Sun Weixin, Zhang Ailin, Xu Dongsheng, Li Yuan, Wang Yanmin and Han Tingting published three articles, respectively.

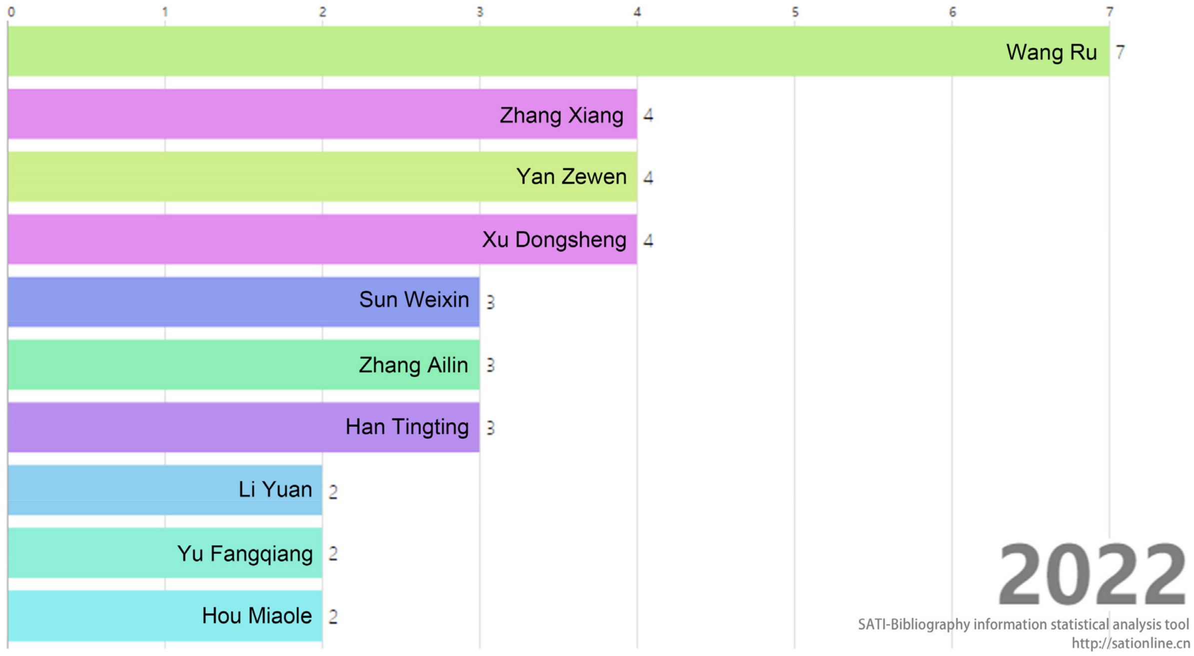


Figure 7. Ranking of core authors' publications on the topic of "BIM" and "architectural heritage" from 2007 to 2022 (167 articles).

The author co-citation analysis mapping by SATI software is shown in Figure 8. The larger the nodes in the figure, the more papers published by the authors; the connecting lines between the nodes represent the cooperation between authors; the thickness of the lines indicates the closeness of the cooperation between the authors.

As Figure 8 analysis, the most of the domestic "BIM" and "architectural heritage" researchers are scattered, althoughthe chart found that the high number of publications of scholars such as Yan Zewen and Zhang Ailin formed a six-member team, whose main research direction is model construction. Wang Ru, Zhang Jian, Sun Weixin, and Han Tingting formed a four-person collaborative team, and their research mainly focused on model standardization and model implementation techniques. Most of the authors of the top ten articles are from the above two teams. On the whole, There is relatively little cooperation among researchers in this field, and the teamwork is mainly composed of two and three people. The cooperation density is not high, and the overall research field has not formed a large disciplinary research team.

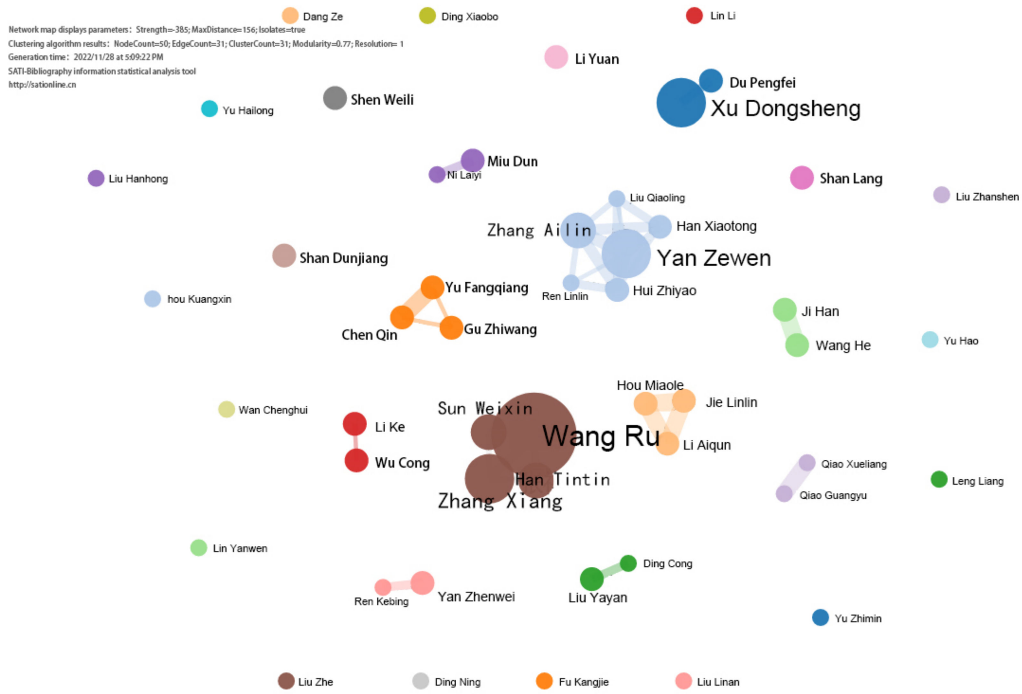


Figure 8. Author Collaboration Atlas of "BIM", "architectural heritage" in China.

3.2.2. Visual Mapping of Research Institutions

Using SATI analysis software, the 167 articles on "BIM" and "architectural heritage" from 2007 to November 2022 have been analyzed for the co-occurrence of cooperative institutions. The larger the node, the more articles published by the research institution in the field, and the larger the line treaty between the nodes, the greater the cooperation intensity between the institutions. The Figure 9 shows that the number of research institutions in "BIM" and "ancient architecture" is large, but the cooperation between institutions is small, mostly scattered, and the cooperation between institutions is not close.

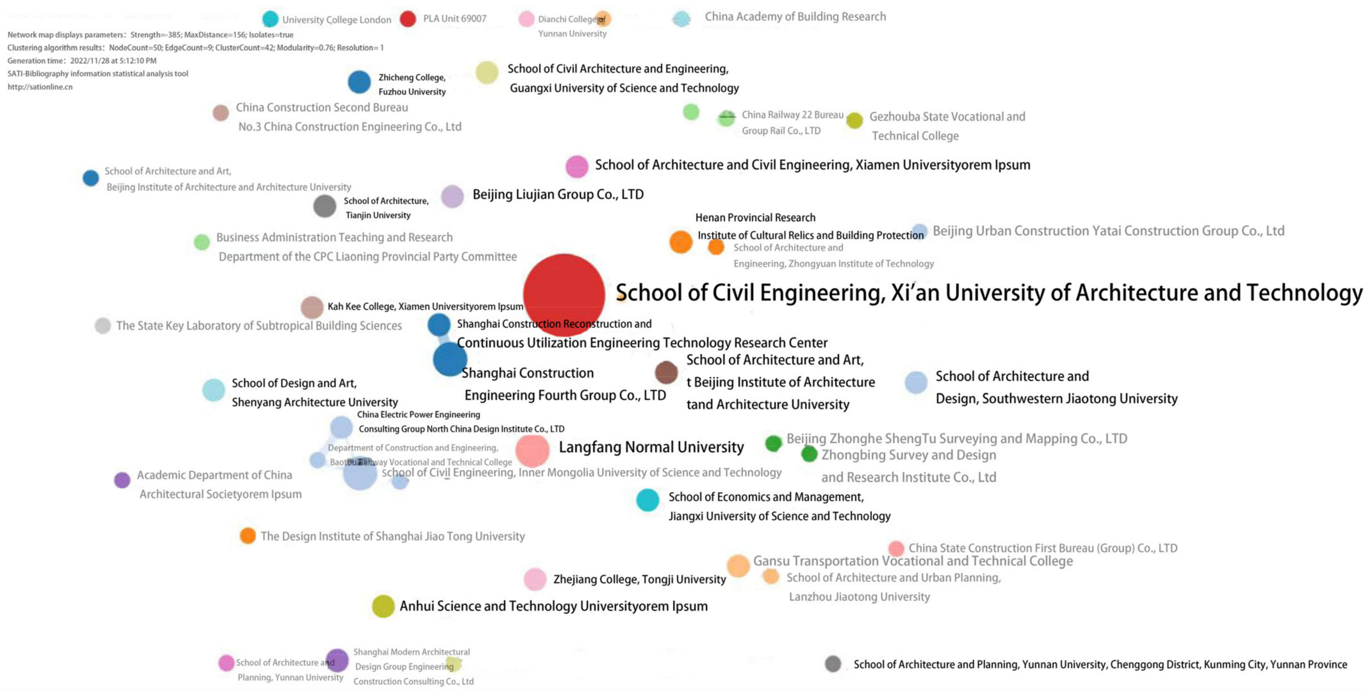


Figure 9. China BIM and architectural heritage research institution cooperation map.

The institutional cooperation network has been analyzed, and the mapping analysis reveals that the highest number of civil engineering articles were published by the Xi'an University of Architecture and Technology, followed by the Shanghai Construction Industry Four Construction Group Co. The College of Civil Engineering of Inner Mongolia University of Science and Technology, and North China Electric Power Design Institute of China Electric Power Engineering Consulting Group, Beijing Tiantuost Technology Co. Ltd., Shanghai Building Alteration and Sustainable Utilization Engineering Technology Research Center, Henan Provincial Institute of Cultural Relics and Building Protection, Zhongyuan Engineering College School of Architecture and Engineering, Beijing Zhonghe Shengtu Surveying and Mapping Co., Ltd., China Bing Survey and Design Research Institute Co., Beijing University of Technology, China Railway 22nd Bureau Group Rail Engineering Co. Ltd., and the China Railway No. 22 Bureau Group Rail Engineering Co., although some universities have published a high number of articles, such as Xi'an University of Architecture and Technology, Langfang Normal University, etc., they all present a state of independent research, and the cooperative research among universities is less.

3.3. Research Hotspots and Frontier Analysis

The 167 sample articles were macroscopic quantitative analysis by using VOSviewer software. Including network visualization and high-frequency keyword analysis, overlay visualization and research focus analysis.

3.3.1. Network Visualization

The 167 sample articles were imported into VOSviewer_1.6.18 software for network visualization keyword co-occurrence analysis. Set the threshold for keyword filtering and synonym merging to 2. The results showed 71 keywords and formed eight different color clusters, namely green, yellow, cyan, purple, orange, brown, blue and red, as shown in Figure 10. The size of the colored circle represents the number of keyword occurrences. The larger the circle, the higher the frequently of the same keyword appears in different articles. The length of the line between two keywords represents the similarity and correlation between the two topics, while the width of the line represents the strength of the connection between them. The keywords "BIM", "BIM technology" occupy the largest node, which is located in the center of Figure 10.

As shown in the Figure 10, the green cluster (cluster 1), presents 14 keywords, including the application of advanced BIM technology in architectural heritage, such as three-dimensional laser scanning technology, oblique photography technology and three-dimensional modeling, point cloud model, digital model, etc. The yellow cluster (cluster 2), includes six keywords related to BIM modeling procedures, including 3D laser scanning, point cloud data, modeling, bucket arches, etc. The sky blue cluster (Cluster 3) and the purple cluster (Cluster 4) contain 12 keywords related to cutting-edge concepts of architectural heritage, including informatization, digital conservation, gis technology, application, component, etc. The orange cluster (cluster 5), which contains five keywords, is associated with the modeling of architectural heritage and focuses on the analysis of modeling methods, such as model construction, ancient architectural components, component libraries, etc., to realize the exploration of three-dimensional models. The brown cluster (cluster 6), presents four keywords, focusing on BIM related technologies, mapping, model reconstruction, etc. The blue cluster (cluster 7), presents ten keywords, focusing on the frontier direction of architectural heritage, such as information mapping, information modeling, parametric modeling. The red cluster (cluster 8), including 20 keywords, reflecting the architectural modular system, full life cycle management, Internet of things. The digital and information transformation of heritage includes the concept of HBIM, including the application of point cloud, Revit and GIS, including information technology, information model, information management, digital standardization, parametric design, VR, etc.

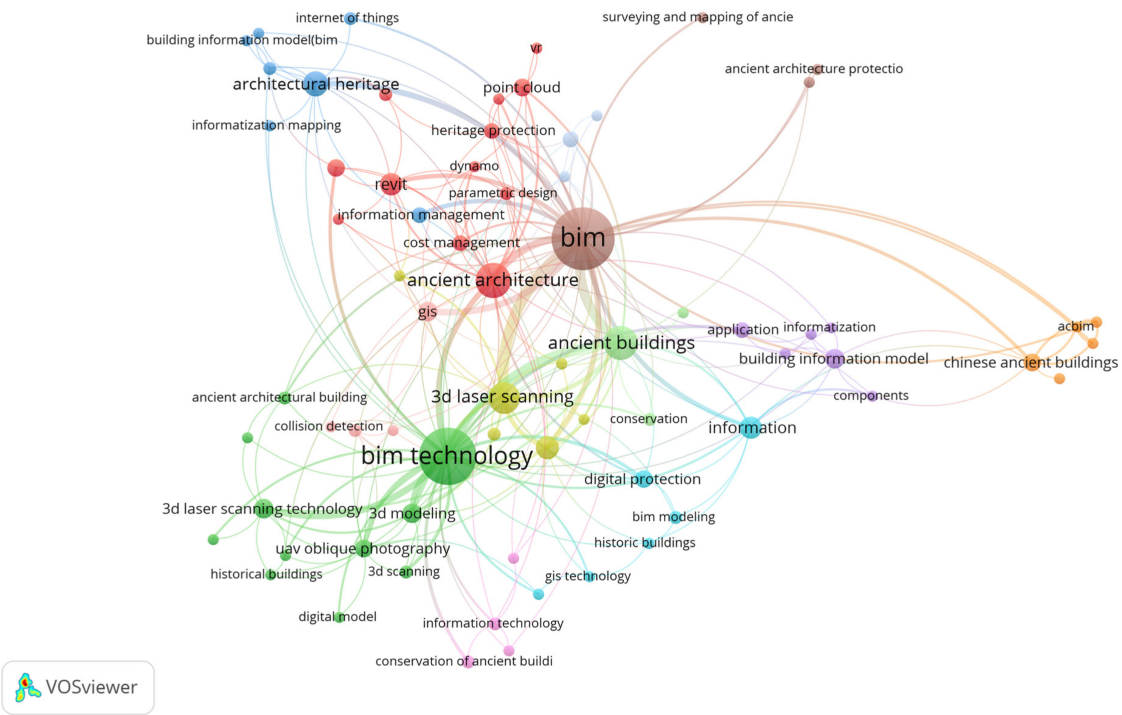


Figure 10. Network visualization of keyword for "BIM" and "architectural heritage" from the 2007 to 2022, created by VOSviewer.

The keyword network visualization of "BIM technology" is selected for analysis. The connection between "BIM technology", and "architectural heritage" is the thickest, showing the highest frequency of occurrence in the same article. Secondly, the connection between "BIM technology", "3D laser scanning", "3D modeling", and " information model" is also thicker, indicating that 3D laser scanning information technology is closely related to BIM technology, and 3D modeling and information model are also hot topics in the discussion of BIM technology, as shown in Figure 11.

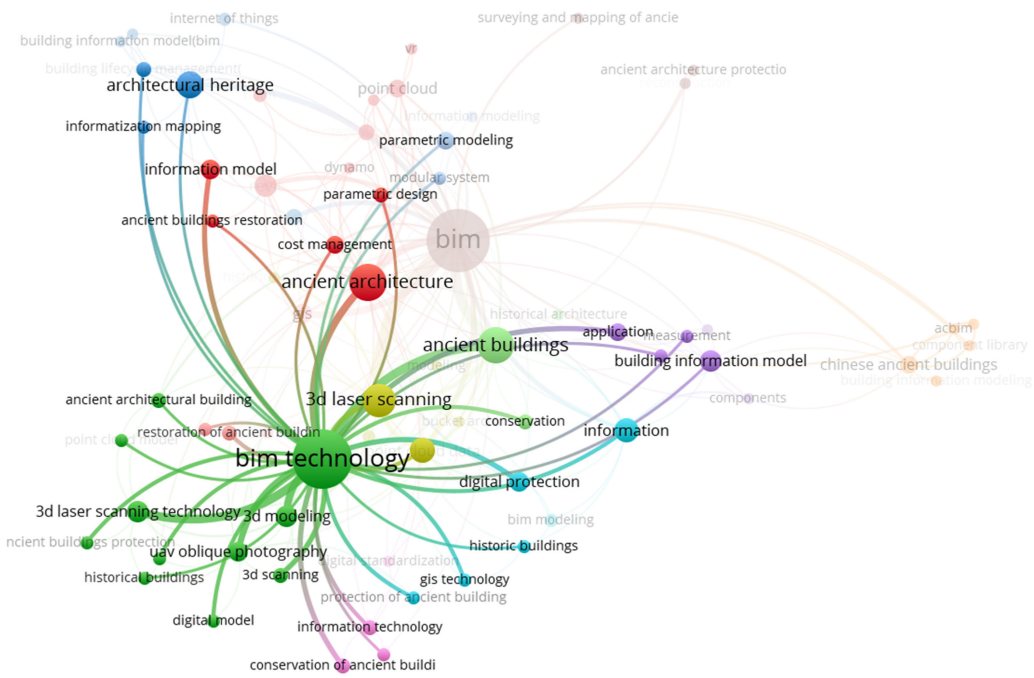


Figure 11. Keyword network visualization of "BIM technology", created by VOSviewer.

The most closely related clustering keywords with BIM and architectural heritage are BIM technology, BIM, ancient architecture, ancient buildings, 3D laser scanning, architecture heritage, point cloud data, information, Revit and 3D laser scanning technology. Table 2 shows the top 10 high-frequency keywords, which were identified by the VOSviewer software keyword co-occurrence analysis. It also displays keyword color clustering, frequency of occurrence and total link strength information.

Table 2. High-frequency keywords about BIM and architectural heritage.

Color [1]	Cluster	Keyword	Occurrences	Total Link Strength
	6	BIM	64	215
	1	BIM technology	52	219
	1	ancient architecture	20	78
	8	ancient buildings	19	96
	2	3D laser scanning	16	74
	7	Architecture heritage	10	37
	2	Point cloud data	9	46
	3	Information	8	40
	8	Revit	8	26
	1	3D laser scanning technology	6	37

[1] The colors in the table are in line with the colors from Figure 10.

3.3.2. Overlay Visualization

The time superposition map can reflect the research hotspot of each year, and also help to reveal future research and development trend of this field. The superimposed network diagram of BIM and architectural heritage keywords generated by VOSviewer software is shown in Figure 12. The period from 2016 to 2021 is shown in dark blue to yellow.

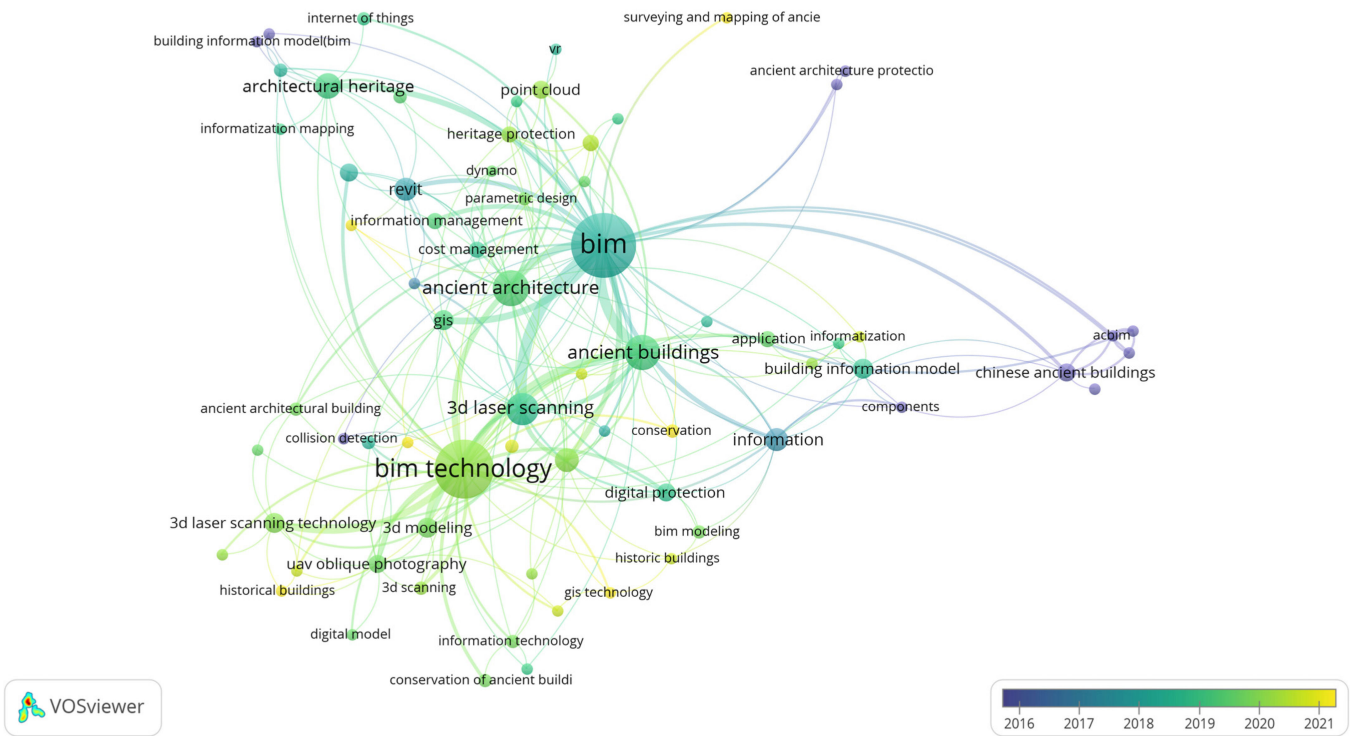


Figure 12. Overlay visualization of the keyword for "BIM" and "architectural heritage" from the 2016 to 2020, created by VOSviewer.

In Figure 12, the main words appearing in the dark blue nodes representing 2016–2017 are "model building", "building library", "data processing", and "point cloud stitching", indicating that the research on BIM and architectural heritage was in its initial stage in these two years, and the pioneers in the intervention field were mapping technology and modeling approaches. In Figure 12, the colors of most nodes are blue-green and green, indicating that most keywords appeared in 2017–2019 on average, which also indicates that these years are a period of rapid development in this field. With the digital development of the architectural heritage conservation industry, 3D laser scanning, point clouds, and BIM are hot topics, and emerging technologies such as 3D laser scanning technology, point cloud data use, and Revit modeling have been widely applied. The yellow nodes in Figure 12 show the latest keywords in 2020 and beyond, with more emphasis on "technology" related keywords, such as "digital technology", "3D scanning technology", "GIS technology", "parametric modeling", "parametric design", and "information management", which shows that BIM technology in the field of architectural heritage research tends to digital and information transformation. Heritage conservation adopts digital twin technology, and BIM technology is still in an important position in the field of architectural heritage.

From 2016 to 2021, the research hotspots of "BIM" and "architectural heritage" in China can be summarized into the following four scenarios, as shown in Table 3.

Table 3. Hot research keywords for"BIM" and"Architectural heritage" are overlaid with visualizations, created by VOSviewer.

Year	Color [1]	Keyword
2016		Restoration, Ancient buildings components, and Components library.
2017		BIM, Revit, Information, and VR.
2018		3D laser scanning, Building lifecycle management (BLM),Digital protection, and Cost management.
2019		Digital protection, Parametric design, Internet of Things.
2020		BIM technology, Digital standardization, Parametric design, Point cloud, Parametric modeling, and Information management.
2021		3D laser scanning technology, UAV oblique photography, and GIS technology.

[1] The colors in the table are in line with the colors from Figure 12.

(1) Frontier concepts: BIM technology, digital conservation, and information management.
(2) Survey techniques: 3D laser scanning technology, UAV oblique photography, and GIS technology.
(3) Modeling and 3D reconstruction: point cloud, parametric design, parametric modeling, modulo-digital system, digital modeling, information models, digital models, and point cloud models.
(4) BIM applications: VR, cost management, schedule management, information management, leveling and topping, and the internet of things.

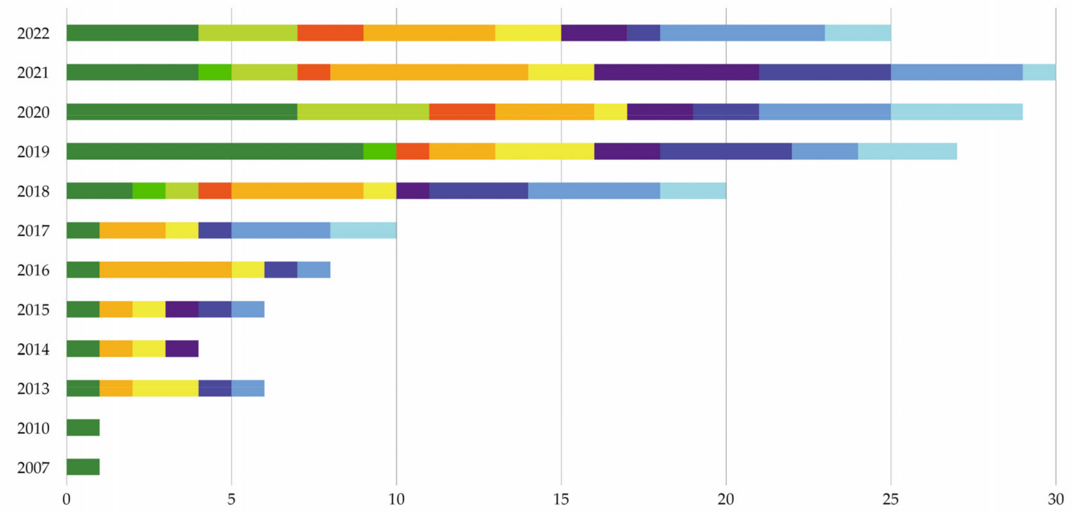
3.4. *Microscopic Qualitative Analysis*

Through the literature analysis, this paper identifies three different application fields of BIM and related technologies in architectural heritage, as shown in Table 4. These application areas represent the authors' interpretation based on 176 studied publications. The three applications include survey techniques, model integration and BIM applications.

Figure 13 shows that most of the three application areas can be subdivided into seven directions. They are 3D laser scanning technology (33 articles), modeling process and method (28 articles), operation and maintenance (25 articles), management and evaluation (18 articles), conservation (14 articles), point cloud post-processing (7 articles), and digital photography/UAV (3 papers). In addition, there are a considerable number of articles whose research direction is not specifically focused, which are listed in the "others". The earliest research in this paper is the 3D laser scanning technology in "Survey techniques ", which has maintained a relatively high number and popularity in recent years. Modeling process and method research is also at an early age and continues to maintain a high research heat. The operation and maintenance of "BIM application" has maintained a high research quantity and popularity since 2017.

Table 4. Application field of BIM in architectural heritage.

Application Area	Examples from Articles	Representative Reference
Survey techniques	3D laser scanning technology.	[19–22]
	Digital photography/UAV.	[23,24]
	Other technologies such as GIS, and LiDAR remote sensing.	[25–27]
Modeling and 3D reconstruction	Point cloud post-processing.	[28–30]
	Modeling process and method. Others such as model platform, component library, and model semantics.	[29,31–33] [34–36]
BIM applications	Conservation.	[37–39]
	Management evaluation.	[40–44]
	Operation and maintenance.	[45–49]
	Others.	[50,51]



Coler	Application Area and direction		2007	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total
	Survey techniques (n=46)	3d laser scanning technology	1	1	1	1	1	1	1	2	9	7	4	4	33
		Digital photography/UAV	0	0	0	0	0	0	0	1	1	0	1	0	3
		Other	0	0	0	0	0	0	0	1	0	4	2	3	10
	Modelling and 3D reconstruction (n=50)	Point cloud post-processing	0	0	0	0	0	0	0	1	1	2	1	2	7
		Modeling process and method	0	0	1	1	1	4	2	4	2	3	6	4	28
		Others	0	0	2	1	1	1	1	1	3	1	2	2	15
	BIM applications (n=71)	Conservation	0	0	0	1	1	0	0	1	2	2	5	2	14
		Management evaluation	0	0	1	0	1	1	1	3	4	2	4	1	18
		Operation and maintenance	0	0	1	0	1	1	3	4	2	4	4	5	25
		Others	0	0	0	0	0	0	2	2	3	4	1	2	14
Total			1	1	6	4	6	8	10	20	27	29	30	25	167

Figure 13. The number of articles published in different years from 2007 to 2022, divided into three subject areas.

3.4.1. Survey Technical Subject Areas

Among the 167 articles evaluated, 46 (28%) focused on the research of survey techniques in architectural heritage. It involves a variety of information technologies, including 3D laser scanning technology [52], digital photography technology [23], UAV technology [24], GIS technology [25], and LiDAR remote sensing technology [26].

According to the current research database, the research on 3D laser scanning technology is the most extensive. The application of 3D laser scanning technology and the collection of architectural heritage information can improve time, accuracy, security, and cost-effectiveness. Ma Hongyu et al. [19] explained the advantages of 3D laser scanning technology in surveying and mapping and heritage conservation by comparing it with traditional surveying and mapping methods. Yang Xin [20] combined this with the case to illustrate the application advantages of 3D laser scanning technology and tilt photography technology of UAVs in the protection and restoration of historical buildings. However, as the literature analysis reveals, the use of laser scanning alone will not be sufficient to produce three-dimensional models. In combination with 3D laser scanning technology, it is the most frequently discussed direction to acquire 3D point cloud data by various means and then construct a 3D BIM model process [21,22].

In addition, for the scanning of complex building types and scenes, Yang Zhenwei [28] proposed the "three-layer measurement wire method" for the three-dimensional laser scanning operation of high-grade ancient buildings and complex surrounding environments. Meanwhile, Yu Fangqiang et al. [53] and Wang Chao [54] believe that the combined 3D laser scanning and tilt photogrammetry technology has more advantages in accuracy and efficiency.

3.4.2. Modeling and Reconstructing Subject Areas

Of the 167 articles evaluated, 50 (30%) focused on the modeling and reconstruction of architectural heritage. This mainly includes the post-processing of point cloud data, modeling processes and modeling method. From the current research database, the largest number of studies focused on modeling methods. For example, research on the BIM modeling method of ancient buildings using 3D laser point cloud [29], research on the parametric modeling method of typical components [31,32], the bucket arches modeling method of integrated BIM-3D scanning technology [33], model reconstruction method of integrated BIM-LiDAR technology [26], and other modeling methods are discussed.

The research on point cloud attaches importance to the processing process and demonstration. For example, a variety of means are used to acquire three-dimensional point cloud data, and then the empirical process of point cloud processing is studied [29]. The method of point cloud data acquisition to model reconstruction [30] and the process of point cloud data acquisition to fine modeling [28] are discussed based on the steps involved in the process from heritage data collection to three-dimensional modeling.

In addition, some articles introduce the concept of HBIM. Zhang Enming et al. [55] take HBIM as a technical means of information management in combination with examples, establish a parametric component library, build a building information model, input survey data, and realize visual management of survey data. Shang Dunjiang et al. [56] combined HBIM technology to classify the types of building components of Shuxi Academy and create a visual model for each component.

3.4.3. BIM Application Subject Areas

Among the 167 articles evaluated, 71 (42%) focused on the application of BIM technology in architectural heritage. The application field of BIM is mainly divided into protection engineering, management, evaluation, operation, and maintenance. According to the current research database, the number of articles in operation and maintenance direction is the largest. For example, the building information model is used to control the whole process cost [45]. In its application in project cost management [46], BIM technology is extended to various fields related to the whole process of construction engineering (construction, management, operation, maintenance, etc.) [47], and it is combined with geographic information system (GIS) technology. Research is being done on whole life cycle management, such as the establishment of the whole life cycle management platform [48] and the construction and evaluation method of the economic index system of protection schemes [49].

In addition, research on the topic of model-based management and evaluation is often involved, for example, using REVIT software to conduct modeling technology and mechanical property analysis of wooden buildings [40], research on the application of BIM technology in the fire safety of ancient buildings [41], construction of an ancient building fire protection system based on spatial information technology [42], seismic performance analysis and research on building heritage [43], and health monitoring system research [44].

The articles on protection direction are based on the application of engineering construction. For example, they are based on the application in the field of building structure reinforcement engineering [37], the application of BIM technology in the translation construction of ancient building reinforcement [38], and the application in translation jacking engineering [39].

4. Discussion

4.1. Current and Future Trends

BIM allows a fully automated process to simulate historic buildings (built heritage). The initial stage of BIM application in conservation projects is the survey and digitization stage [9]. BIM and architectural heritage are studied from the perspective of data collection and measurement technology, which covers the widest range in this research field. Different from "global photogrammetry is the most popular method in heritage modeling" [57], according to the current research database, the research on "BIM" and "architectural heritage" in China pays little attention to photogrammetry modeling. This is related to the fact that China's architectural heritage protection industry mainly uses 3D laser scanning technology for data collection. Chi Mengjie et al. [58] compared the two technologies by taking Guangren Temple in Xi'an as an example and concluded that in terms of applicability, UAV photogrammetry has higher requirements on the surrounding environment and relatively low modeling accuracy, but three-dimensional scanning technology requires a large workload and high cost.

Architectural heritage documents involve 3D modeling of geometry (usually using 3D computer graphics, laser scanning, and photogrammetry) and information management of semantic knowledge (using GIS and ontology tools) [57]. More and more heritage modeling efforts are using laser scanning, GIS and computer science, especially BIM. The results in Section 3.4 show that the process of obtaining 3D modeling from point cloud data is an important part of the current conservation procedures of architectural heritage in China, and is also a hot topic of current research. Many articles around the world focus on the information management of semantic knowledge in 3D modeling [6]. However, from the current research database, it can be seen that the 3D modeling of Chinese architectural heritage pays less attention to the semantic aspect and more attention to the physical restoration.

Murphy expressed the prospect of BIM technology being used in historical scenarios. HBIM of historic buildings can provide: (i) complete measurement and parametric modeling of geometric aspects; (ii) attribute, material, and relationship information of child elements; (iii) possible deformation and change over time [3]. The results in Section 3.4 show that at present, architectural heritage research focuses on 3D laser scanning and 3D modeling, while BIM technology research not only focuses on 3D laser scanning technology and 3D modeling but also focuses on construction period management, cost management, translation, jacking in monitoring, forecasting, and preventive protection. These are consistent with the application prospect of HBIM (iii), indicating that the integration of BIM and architectural heritage is in the upgrading stage at present. In addition, operation and maintenance based on BIM application is also a hot research area. Unlike the research in the field of survey technology and 3D modeling, which is often combined with case studies, the research in the field of operation and maintenance is more based on review and prospect, and lacks the research method to demonstrate by case studies. In the future, the informatization research of architectural heritage combined with the application research of BIM technology in the whole life cycle management of architectural heritage may become a new trend.

4.2. Development and Challenges of Intelligent Models and LCM Research

Modeling is the focus of BIM technology and the climax stage of data acquisition and point cloud processing. Using BIM technology, it is possible to bring together in one file all the information needed during a building project to create a so-called smart model. Building information modeling should be viewed as a process, not a technology [9]. From Section 3.1.2, keywords such as modeling and Revit have a high frequency of occurrence. Most of the research achievements on BIM and architectural heritage in China are mainly the discussion and demonstration of modeling process and method. BIM models contain not only drawings, but also semantic information [59]. So far, obtaining accurate 3D geometric models through laser scanners or image intensive matching methods is no longer a problem. The challenge is to extend these global geometries to semantic models, parametric models, and knowledge models. In terms of parametric modeling, parametric modeling of historical elements in BIM software is often a time-consuming manual concept, and their ability to create complex irregular geometry is limited. In other words, parametric temporal complexity and geometric precision of complex and irregular historical structural elements are major challenges [57].

BIM was initially used to manage the construction process of the whole life cycle of the construction industry. It allows the planning and management of the entire building life cycle. BIM for architectural heritage has recently been studied, but its use is still not widespread [9]. The results of Section 3.4 show that the current research on BIM and architectural heritage tends to solve the problems in the design stage, and the research on the engineering construction stage is also gradually emerging, but few studies pay attention to the operation and maintenance, renovation and demolition and other stages. Due to the multidisciplinary nature and timeliness of information exchange, the application of BIM in the renovation of existing buildings is challenging and requires a wide range of technical components to ensure optimal information exchange [60]. As a result, BIM is not used much in the maintenance, renovation or deconstruction of most existing buildings [61]. There is no doubt that BIM has the potential to be used throughout the entire life cycle of buildings. However, in the early stages of building design, little is known about the use with authorities or the collaborative use of designers and users. The latter is an important challenge if client and user involvement is to be increased in the construction industry as is the case in many other industry examples [62].

5. Conclusions

This paper uses bibliometrics to discuss the research process and development track of BIM and architectural heritage in China. This paper is different from other articles in the following ways. (1) In terms of research methods, this paper attempts for the first time to investigate this interdisciplinary research topic by combining macro-quantitative analysis and micro-qualitative analysis. (2) In terms of research technology, using VOSviewer and SATI visual bibliometric tools, based on macro keyword co-occurrence, this paper reveals for the first time the scheme of BIM and architectural heritage between 2007 and 2022, research hotspots and development trends. The results of this study are expected to provide a comparative role for regional differences in this research field, and it is expected to become a starting point to help architectural heritage researchers and professionals to further promote the integration of BIM and related technologies in the field of heritage protection.

In terms of the number and time of published papers, the research on “BIM” and “architectural heritage” in China started in 2007, reached the first research peak in 2013, and reached the peak in 2021, with the annual number of published papers reaching 30. In general, the research on “BIM” and “architectural heritage” shows an obvious upward trend, and will continue to grow in the future.

From the perspective of discipline fields and published publications, the journals with the theme of "BIM" and "architectural heritage" have obvious interdisciplinary characteristics, involving architectural science, fine arts, surveying and mapping technology, computer software, archaeology, physics, electronic technology, and other disciplines. Among them, architectural science, fine arts, and surveying and mapping technology account for the top three, accounting for 87.25%. The published journals are also scattered due to the interdisciplinary nature of their disciplines. The top ten journals basically started in 2013, and the annual publication volume is not high but shows a gradual upward trend after 2018. The publication volume of other journals does not fluctuate significantly, and there is still a lack of journals that pay continuous attention to this field.

From the distribution of core authors and institutions, most of the researchers on "BIM" and "architectural heritage" in China are independent, and only a small number of them have formed research teams. The majority of research institutions are universities, with few independent research institutions and sparse cooperation networks among them. From the perspective of geographical location, there are few cross-regional and cross-unit cooperation networks, and the overall distribution of scientific research is dispersed.

From the perspective of research hotspots, the research on BIM and architectural heritage based on data collection and measurement technology covers the widest range in this research field. The process of obtaining 3D modeling from point cloud data is an important part of the current conservation process of architectural heritage in China, and is also a hot topic of current research. Some articles focus on surveillance, prediction and preventive protection. In addition, research on model-based management, operation and application is also involved. In the future, the informatization research of architectural heritage combined with the application research of BIM technology in the whole life cycle management of architectural heritage may become a new trend.

In this paper, VOSviewer and SATI bibliometric software are used as analysis tools to carry out a visual analysis of the selected sample of the literature and show the relationship between the studies. However, atlas interpretation is a challenging work, which is prone to misreading, misreading, or selective interpretation, which will affect the results of the literature analysis to some extent.

Most of the existing research focuses on the technical integration of BIM in heritage, especially the application of technology in the design phase. Further research into the non-technical aspects of BIM involvement in legacy is warranted. For example, the qualitative research on the willingness, acceptance, and readiness of stakeholders such as construction and owners to use BIM, as well as the ability to use BIM to participate in heritage protection at the stage of construction, management and maintenance has not been explored. In addition, only one database is used in this paper, namely the China National Knowledge Network database. Some relevant studies can be indexed in other databases, such as Scopus and WoS. Therefore, future follow-up studies may consider using data from multiple databases.

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