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The Application of HBIM in Chinese Architectural Heritage: Sustainability Assessment and Prospects

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Abstract: HBIM is a digital modeling technology applied to cultural heritage buildings. It has achieved remarkable development in data integration and management, digital protection of historical buildings, parametric and semantic modeling, multi-source data fusion, and interdisciplinary cooperation platforms. However, the sustainability of this technology has not been discussed yet. This paper analyzes nearly a hundred relevant research findings from 2010 to 2024 and discovers that not only is there a lack of reviews on the development and application of HBIM technology in China, but also there is a severe shortage of discussions and explorations regarding its sustainability. Therefore, this paper takes the development and application of HBIM technology in China as the research scope, uses relevant practical projects and research results in China, along with a small number of the latest foreign achievements as cases, focuses on the sustainability of HBIM as the research question, and adopts review research and comparative research as methods. It identifies five development directions and dilemmas in the development of HBIM in China and puts forward constructive suggestions for sustainable development. The aim is to provide a reference path for the sustainable development of HBIM technology in China.

Keywords: HBIM; Chinese architectural heritage; sustainability

1. Introduction

The concept of sustainable development was first put forward in 1987 in the report our common future by the World Commission on Environment and Development. It emphasizes the coordinated development of the economic, social, and environmental dimensions, and pursues a development model that can meet the needs of the present generation without compromising the ability of future generations to meet their own needs. This means that when conducting sustainable activities and making decisions, we need to comprehensively consider the factors of these three dimensions to ensure that they promote and support each other rather than conflict with one another. It can be said that there is an interdependent relationship between the economy and heritage, society and heritage, as well as the environment and heritage.

On August 2, 2015, the United Nations also released the Sustainable Development Goals (SDGs), which regulated and defined sustainability from different perspectives and fields. Goal 11 explicitly states "Make cities and human settlements inclusive, safe, resilient and sustainable". Target 11.4 also emphasizes "Strengthen efforts to protect and safeguard the world's cultural and natural heritage". Then, how exactly can the sustainable protection of heritage be achieved？

On June 1, 2012, the Chinese government released "National Report on Sustainable Development of the People's Republic of China", which introduced the overall situation of China's sustainable development. The report elaborated on several aspects, including economic structure, development mode, individual development, social progress, sustainable resource development, ecological environment protection, sustainable development construction, and international cooperation. In the section of "Capacity Building for Sustainable Development", no suggestions or opinions were put forward regarding the "sustainability" of cultural and natural heritage. Relevant protection requirements were only proposed in "Opinions on Strengthening the Protection and Inheritance of History and Culture in Urban and Rural Construction".

Overall, this paper finds that the concept of sustainability was put forward long ago, and it provides important guidance for the sustainable development of cultural and natural heritage. In China's sustainable development, there are no clear regulations and rules regarding the sustainable development of architectural heritage. More often, the concept of green buildings is used as a substitute. This is also the reason why the sustainable development of architectural heritage is often overlooked. In fact, there is a relationship of mutual dependence and promotion among the economy and heritage, society and heritage, and environment and heritage.

For example, in urban renewal, the renovation and upgrading of old buildings not only preserve local historical memories but also play a significant role in the transformation of the contemporary economic society and the creation of local spaces, bringing economic benefits (cultural tourism), local identity, and resource conservation [1–3]. By inference, if we want to achieve the sustainable development of architectural heritage in the economic, social, and environmental aspects, protecting the authenticity and integrity of heritage information is a prerequisite [4,5].

One of the most effective ways to achieve heritage information recording and protection is HBIM technology. Therefore, leveraging this technology can bring benefits to sustainable development. Its emergence has not only introduced new digital, information - based, specialized, and intensive recording methods for conservation teams [6], but also greatly facilitated subsequent sustainable research, management, development, decision - making, monitoring, and display. It also offers diverse means of expression and applications. Particularly in China, which is rich in cultural and natural heritage, HBIM technology undoubtedly serves as a booster to promote the in - depth and practical implementation of the country's sustainable development in heritage conservation.

For example, HBIM plays an important role in the process of sustainable development. For instance, relying on HBIM technology can improve the efficiency of heritage information protection and decision-making, and reduce the potential human and material costs that may be incurred in heritage protection and information recording, as well as the environmental damage that may be caused to the environment of the heritage site.

Another example is that, based on HBIM technology, by developing and introducing advanced BIM modeling software, scanning equipment, and display devices, it is possible to achieve accurate recording and management of heritage information, as well as precise control of heritage protection and restoration, so as to realize the information management of the whole life cycle of architectural heritage, and reduce the consumption brought to the heritage itself by secondary recording and surveying.

Furthermore, in the education and cultivation of postgraduate students in architecture, increasing the relevant courses and practical activities on the sustainable management and protection of HBIM is also conducive to cultivating students' awareness of sustainable development and encouraging them to develop and practice the concept of sustainability in other scientific research fields.

In addition, HBIM can provide scientific basis and practical guidance for the protection of architectural heritage by combining with informatized archives. It can also guide the construction of the disaster prevention and mitigation system and the formulation of emergency plans through this technology, as well as simulate the restoration and the reversible tracking of the restoration process, so as to achieve the sustainable development of architectural heritage protection.

Moreover, HBIM can combine with sensors and collaborative work platforms to achieve the sustainable recording and editing of heritage information, reduce human resource costs, establish a platform for multi-team joint management, and realize sustainable management. Overall, the sustainability of HBIM technology has not received extensive attention, especially in China.

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2. An Overview of the Application of HBIM in the Field of Chinese Architectural Heritage

In 2009, Maurice Murphy from the University of Dublin in Ireland first proposed the concept of HBIM. In the same year, the Design and Research Institute of Tsinghua University and the Institute of Cultural Heritage Conservation in China also put forward the "historic/heritage building information model" (HBIM) technology, defining HBIM as an information management tool in the life cycle of historical buildings with 3D models. Based on cases and practices, Chinese scholar Cong Wu put forward some constructive viewpoints on the development of HBIM. That is, by establishing a cross - platform information surveying and recording system with HBIM as the core technology, it can provide systematic, practical and convenient information services for various aspects of heritage research, protection, management, display and utilization. He also predictively proposed that with the development of the combination of architectural heritage and knowledge base construction, the Internet of Things, big data, 3D printing, digital construction, virtual reality, augmented reality and artificial intelligence, the digital and information development of architectural heritage will move towards the direction of intelligence. Architectural heritage will also become perceptive, responsive and audience - friendly intelligent buildings [6]. These viewpoints more specifically expound the great potential and research value of HBIM technology, and also provide many perspectives for the development of HBIM in China.

At present, some scholars like Jianzhuo Xu have reviewed the frontier developments and applications of foreign HBIM [7]. However, no one has conducted a review study on the development of HBIM in China, and few scholars have approached it from the perspective of sustainable development. This study finds that the development and research of HBIM in China have gone through many twists and turns, but overall, it shows an upward trend. There are still about 20 articles published in 2025 (Figure 1). During the period from 2010 to 2025, Tianjin University conducted in - depth research on HBIM and the heritage - related applications of BIM (Figure 2). In contrast, other schools and institutions are relatively weak in terms of the number of published papers, indicating that the research in this direction in China is still in its infancy.

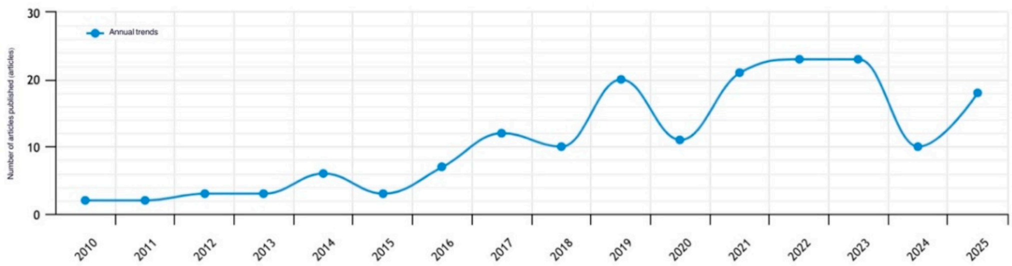

Figure 1. Analysis of the overall trend of HBIM-related research in China Data source: CNKI.

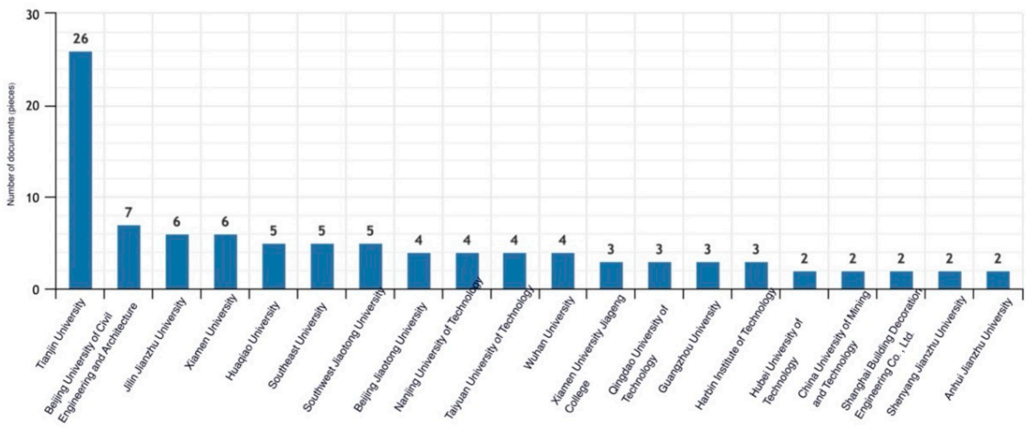

Figure 2. Institutional distribution by number of studies Data source: CNKI.

2.1. Building Heritage Information Models and Visualization Display

Although the start and subsequent development of HBIM research in China lagged behind those in foreign countries, in recent years, numerous Chinese universities and research institutions have actively carried out research on HBIM technology, promoting continuous innovation in its theory and practice. Judging from the journal papers published during the period from 2010 to 2024, the vast majority of HBIM research and development in China is at the stage of model construction and demonstration.

For example, Wang Zhuonan and Gao Min's research focused on the protection and research of Liao - Dynasty brick pagodas based on digital technology. They expounded on the general situation and early research of Liao - Dynasty brick pagodas, and pointed out the advantages of digital technology in the field of ancient architecture protection. Regarding application key points, they emphasized that 3D laser scanning and UAV oblique photogrammetry technology should be selected and reasonably combined as surveying and mapping instruments, while also controlling data accuracy. In specific applications, digital technology can be used for the research of the tower body proportion and the shape of detailed components, and can also be used to observe the mathematical relationships and damage conditions of Wu'anzhou Pagoda [8].

Another example is that Sun Xiangwang, based on HBIM and knowledge ontology technology, proposed the technical route for establishing the HBIM of Zhanyuan Garden. He constructed the knowledge ontology and semantic library framework for garden information preservation and achieved interaction with HBIM. This provided a comprehensive and systematic solution for the information preservation of Jiangnan gardens, standardized the digital modeling process standards, improved the levels of information management and knowledge reuse, and promoted the digital and intelligent development of garden research [9].

Han Sai's research, taking the survey project of the duty rooms in Yangxin Hall of the Forbidden City as an example, explored the expression of architectural heritage survey information results based on HBIM. HBIM technology can effectively integrate, store, and manage survey information to meet the requirements of visualization, specialization, and integration. This research created a damage keyword dictionary and adopted two - parameter control to solve the problems of standardization and automation of survey information expression. Through the application of shadow primitives, the visual expression of the relationships between components, local damage, and overall unit information was achieved. Practice has proved that HBIM technology is feasible in survey work and provides a new technical means for architectural heritage protection work[10,11].

Lai Yujing and Xia Tian's research, taking the Xiangdian Hall in Qufu as an example, explored the construction of an architectural heritage information database based on HBIM. HBIM technology has advantages such as comprehensive and convenient information recording, integrity and authenticity, associated dynamics, and the ability to extend to 5D simulation. In the research of Xiangdian Hall in Qufu, an information database was constructed through data collection, classification, numbering, model creation, and the entry of detailed information. This database contains various types of information, facilitating the research, repair, and protection of architectural heritage [12].

E Guangshu's research, taking the architectural heritage in Taipingjiao, Qingdao as an example, explored the application of HBIM under the concept of preventive protection. The model definition level was clarified, the Revit platform and suitable building types were selected, and the family library and model were constructed. The result expression utilized included thematic drawings and 3D model expressions, which can be used for structural analysis, monitoring, and information management. This research provided a useful reference for the preventive protection of architectural heritage[13].

Zhang Jiahao used informatized surveying and mapping technology, HBIM technology, and software such as Trimble RealWorks, DJI Terra, and RealViewer to process point clouds, and constructed the component family library and HBIM building information models of the architectural heritages of Haicang Juren Di in Xiamen and Anxi Tea Factory in Quanzhou. Based on HBIM, the historical information and current damage information of Juren Di were recorded, managed, and visually analyzed. Its prominent feature is the phased modeling construction by recording the phased information of repair construction based on secondary - developed plugins. The research has an exploratory significance for the technical route of multi - source point cloud data fusion, proposed component information classification and coding methods, and carried out classification planning, naming, coding, and parametric design. It provided a standardized information management method for the digital protection of traditional Minnan large - style houses [14–16]. Scholars with similar research types include Niu Pengtao and Tian Jiang [17], Yang Lin [18], Zhang Jingwei [19], Zhang Enming [20], Li Rui [21]; Li Wenqiang [22], Li Weirong [23]; Chen Ye [24], and so on.

Ji Huanqun, taking the Rouyuan Tower in Jiayuguan, a traditional building in the Hexi Corridor during the Ming and Qing dynasties, as an example, aiming at the problems of low efficiency in most modeling work, illogical model construction operations, and difficult - to - unify work processes, reconstructed the construction knowledge graph, divided the large - scale wooden frame units, analyzed the construction types, and combined theoretical results with modeling development to innovate the research perspective and modeling method, improving the modeling efficiency and quality of the large - scale wooden structure parts [25].

Wang Lingxu et al., taking the restoration project of Jiangsu Road Church in Qingdao as an example, applied BIM technology to the entire process of the church restoration. They proposed the protection idea of tracking the restoration process with a data model, emphasizing the dynamic update and reverse - assisting role of building information in the restoration process, and innovating data translation, integration, and digital model applications, that is, physical models and virtual models. This improved the scientificity and accuracy of ancient building restoration and expanded the application field of digital models[26].

Wang Licai explored the application of HBIM technology in the relocation plan and construction stages of relocated construction projects. In the plan stage, HBIM technology was utilized to build information models, locate components, simulate the environment, and display the plans. In the construction stage, it was applied to construction site layout, quantity calculation, information recording, and later - stage maintenance. Through the analysis of the process and the application of HBIM technology, this paper provided a new approach to solving the problems in the relocated construction of Huizhou traditional dwellings. It also helped relevant practitioners recognize the advantages of HBIM technology and promoted the protection and development of traditional dwellings [27].

In addition, many scholars have made contributions in this regard. For example, Zhang Wenjing [28], Zhu Ning [29], Zhu Lei [30], Shi Yue [31], Shi Ruoming [32], Li Shujing [33], Li Lijuan [34], Du Xin [35], Zhou Chengchuanqi [36], Xing Liang [37], Tong Qiaohui [38–40], Liu Yingxiang [41], Guan Xian [42], Chang Lei [43], Wang Zhixin [44], Shi Liwen [45], Meng Hui [46], Xun Haowei [47], Ma Weikang [48], Fu Jinyu [49], Wang Hechi [50], Du Shihu [51], Wang He [52], Liang Yi[53], Jia Zheng [54], Gui Yuhuan [55], Jing Songfeng [56], Tao Ye [57], etc. These scholars have carried out work similar to that of the previously mentioned scholars, so it is not necessary to elaborate on each of them here.

2.2. Four Practical Directions of HBIM - Current Trends

In addition to the above - mentioned scholars and experts conducting HBIM practices on different types of architectural heritage, many Chinese teams have carried out in - depth research and practice based on these efforts. This includes several major directions such as BIM automatic modeling algorithms and automated routes, parametric and procedural modeling, multi - dimensional extended applications of HBIM, and the construction and management of collaborative platforms.

2.2.1. In the Aspect of Automatic Modeling Algorithms and Automated Routes

First, in terms of HBIM automatic modeling algorithms and automated routes, several scholars are the most representative. For example, Sun Zhuqing, Zhang Dabao and others took the main hall of a temple in Guangdong Province as the research object to explore a new practice of automatically converting point - cloud data into BIM models. They proposed an automatic BIM modeling algorithm based on architectural grammar and an automated roadmap, and verified the feasibility of the algorithm. This research improved the modeling efficiency of historical buildings, provided new technical means for digital protection, clarified the development direction and stage goals of automatic BIM modeling, and promoted its application in the construction industry [58].

Another example is Huo Pengpeng. For the roof decorative components of Ming and Qing official - style buildings (such as the Qianqing Palace and the Jiaotai Hall in the Forbidden City), she used Context Capture to automatically generate a rough model of the decorative components. Then, she applied the 3DS Max 3D modeling software and referred to the design details listed in books and manuscripts of roof decorative components of Ming and Qing official - style buildings to refine the rough 3D model. Finally, she reconstructed decorative components with good - detailed expressions, established a template library of roof decorative components by building 3D models, and achieved high - efficiency and high - precision 3D reconstruction of Ming and Qing official - style buildings. She also proposed a registration method based on image and point - cloud data to realize the automatic invocation of the template library [59].

Moreover, Wu Rui and others took the large - wooden structure of the Holy Mother Hall in Jinci Temple, Shanxi Province as the main experimental object to study the processing of its 3D point - cloud data, the construction and reasoning of knowledge graphs. They proposed an automatic HBIM generation method based on knowledge - graph construction and reasoning technology, which enabled the rapid and accurate construction of historical building models. Additionally, they solved the problems of data missing, uneven density, and data anomalies when obtaining 3D point - cloud data of historical buildings using lidar and oblique photogrammetry technology, as well as the problem that the 3D models generated by point - cloud fitting were non - disassemblable [60].

2.2.2. In the Aspect of Automatic Modeling Algorithms and Automated Routes

Secondly, in terms of parametric and procedural modeling of HBIM. For example, Feng Xu proposed a new method for modeling the wooden frames of historical buildings in HBIM based on carpenter's architectural rules. Through the research on the drum towers in the Pingtan River Basin of Hunan, the carpenter's building rules were obtained, and the rapid generation of wooden frame models was achieved by using procedural modeling. This method can generate models similar to actual buildings according to simple constraints, reducing the workload of manual modeling and improving the modeling efficiency. Although there are some differences in model accuracy, it can generally meet the requirements of HBIM [61].

Another example is that Yang Hongji and others proposed an innovative parametric and computational modeling method based on the HBIM technical process for the large - wooden frames of traditional Minnan residences. They innovated the geometric description of components and built a cloud - based display platform, which improved the efficiency and accuracy of modeling and provided a new path for the informatized protection of traditional residences [62].

Wang Xi is a scholar who has conducted in - depth research in this field. He proposed a method for generating regular axes from irregular column grids through a genetic algorithm and a method for realizing the synergy between metadata and meta - models through algorithmic modeling. That is, he reconstructed the tile model in Grasshopper, generated IFC models and Cypher statements through algorithm clusters, and constructed a graph database [63–65].

2.2.3. In the Aspect of Multi-dimensional Extended Applications

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Thirdly, in terms of the multi - dimensional extended applications of HBIM. Currently, the more mainstream cross - platform displays and applications mainly involve combinations such as HBIM + GIS, HBIM + VR, HBIM + 3D, and HBIM + Dynamo. For example, Fang Dongya took the main building of Tianjin Foreign Studies University as an example to explore the applicability of BIM technology, elaborated on the process of constructing an information model, and analyzed the cooperation methods with other technologies, such as BIM + GIS, BIM + VR, and BIM + 3D scanning [66].

Shi Yilin explored the advantages of the BIM + VR technology in response to the problems faced by the renovation of China's current industrial heritage, such as chaotic data management, lack of visual expression, and difficulties in collaborative design. He established an information model platform and applied it to the renovation project of the Traditional Architecture Museum at Inner Mongolia University of Technology. Additionally, during the stages of scheme design, construction drawing design, and optimization and adjustment, the BIM + VR technology achieved the informatization of data, the high efficiency of collaborative design, and the instant synchronization of information. This has improved the overall design level and the advancement efficiency of the project, providing a new technical path and practical reference for the renovation of industrial heritage [67]. The article mentions the viewpoints that collaborative design and information synchronization are significant for sustainable development, yet it does not conduct in-depth discussions and research on these two aspects. Shang Dunjiang [68,69]also adopted the BIM + VR technology. Moreover, he explored the combinations of BIM with the Internet and BIM + MR.

Li Yuan's research analyzed the protection of architectural cultural heritage based on the BIM + concept, mainly including data collection of HBIM, integration with GIS, and construction of virtual scenes with VR. Valuable perspectives on the future development directions of HBIM were put forward, including user behavior analysis, monitoring of changes in the building environment, engineering construction management, and operation of intelligent museums [70].

Liu Niancheng took the corners of Song - Dynasty official - style buildings as the research object. Based on the Yingzao Fashi (Treatise on Architectural Methods), the parametric logic of its large - wooden structure system was sorted out. The Revit - Dynamo platform was used to create a component family library. Not only was parametric modeling achieved and numerical control construction explored, but also a digital chain system from the parametric system to parametric modeling was established [71].

2.2.4. In the Aspect of Construction and Management of Collaborative Platforms

Finally, in terms of the construction and management of collaborative platforms. For example, Zhang Kehan et al. analyzed the application status of the HBIM concept in architectural heritage protection projects. They pointed out that it has rich applications in information collection, integration, and collaborative cooperation, but relatively fewer applications in design, management, construction, and other aspects. Taking the Gulangyu Island Bagua Tower protection project as a case, this study constructed an application strategy framework for the HBIM concept, covering a basic data platform, a design management platform, a construction management platform, and a result display platform, and sorted out the application strategies and work functions of each participating team at different stages [72]. It can be said that such a platform has a certain sense of sustainability, reducing the consumption of human and material resources and improving the efficiency of heritage protection and renewal.

Another example is that Li Ling proposed an HBIM system architecture suitable for ancient buildings and built a health monitoring platform for ancient buildings based on this. On the basis of the HBIM 3D model, an IFC model of the structural damage of ancient buildings was constructed, and the overall health status of ancient buildings was evaluated through the data fusion technology of multi - source sensors [73]. Scholar Xu Mu [74]also achieved preventive monitoring and protection based on the BIM platform, just like others.

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Xu Chaoran explored the sustainable recording and protection of the Zangniang Pagoda and Sangzhou Temple in China using HBIM technology. Requirements for HBIM sustainable recording methods and the functional framework of the HBIM + Bentley + NAS sustainable information recording and management platform were proposed [75], enabling a way for multiple teams or types of work to update the information model in real - time. Xu Jianzhuo proposed constructing an accessible resource database based on HBIM to promote public participation, and combining digital twins and deep learning with HBIM to improve the accuracy and efficiency of modeling [7].

Overall, most domestic experts and scholars in China are discussing issues at the levels of model construction and display, automated modeling routes, parametric modeling, multi - dimensional extended applications, and information model management. There has been no in - depth discussion on the sustainability of HBIM. Only a few scholars such as Zhang Kehan, Li Ling, Xu Chaoran, and Xu Jianzhuo have put forward some insights on the construction of collaborative platforms.

3. Problems of HBIM Technology in China in Terms of "Sustainability"

The sustainability is not prominent before and after the construction process of HBIM. The pre - model - building stage is generally divided into phases such as model planning, data collection, geometric measurement, semantic segmentation, and modeling. It does not reflect the sustainability of the entire construction process. Instead, problems like secondary supplementary survey and information loss may occur. If there are problems in any of these links, it will inevitably cause waste of manpower, funds, and time, thus affecting the delivery and use of subsequent results. However, sustainable development emphasizes the efficient use and recycling of resources. The post - model - building stage is generally limited to three aspects: heritage visualization, heritage monitoring and analysis, and archive integration and management. That is, it is presented through the use of WEB platforms and media or software platforms and plugins such as PointKit, ReCap, Dynamo, Pyrevit, and Model Checker. But there is no exploration and demonstration of how to achieve sustainable update, management, or "intelligence" in the follow - up.

In addition, most of the latest foreign research on HBIM technology focuses on architectural structure analysis [76], model accuracy control [77], semantic segmentation, BIM software plugins [78], and HBIM customization strategies [79]. However, a small number of scholars have established remote access methods by updating customized repositories to sustainably record the historical evolution of heritage, update its preservation status and decay process [80], and integrate multi - source information of historical buildings [81], thus supporting decision - making in the protection, restoration, and management of architectural heritage. Some scholars have also built HBIM cross - cycle management platforms to manage the geometric data, decay degree, and material loss of architectural heritage structures in different time cycles [82]. Meanwhile, some students use HBIM to analyze and visually display the collected data. They use the real - time data view function of the platform to display sensor positions and the latest readings, generate interactive charts through the data navigator and provide operations such as data browsing and export. They also use the analysis module to analyze the building's energy performance and generate reports to visually present the changing trends and characteristics of the building's energy performance, providing a basis for the building's energy management and optimization [83]. This is also the strategy closest to the sustainable monitoring and analysis of heritage.

Overall, the HBIM technology research carried out in China tends to focus more on the realization and completion of model construction and digital display. The research achievements also show a fragmented and unsystematic state. Unlike some foreign scholars, Chinese researchers have not conducted explorations and studies with sustainable potential, such as remote access to databases, construction of cross-cycle management platforms, display of interactive icons, and continuous detection and analysis of heritage structures. Zhang Yunan also pointed out this issue in his discussion on the HBIM management platform and the extension of its later-stage operation in China[84]. However, judging from the above-mentioned research, many scholars have not discussed or explored the sustainability of HBIM technology.

4. Exploration of How to Carry out "Sustainable" Work of HBIM in China

The sustainability of HBIM technology is essential and conducive to promoting the harmonious development of the economy and heritage, society and heritage, as well as the environment and heritage. It is necessary to control implementation costs and improve work efficiency, while also providing assistance and approaches for the sustainable protection and renewal of heritage in the future. This includes that HBIM should meet the needs of a series of activities such as tourism, education, popular science, and promotion in the future, bringing sustainable impetus to society and the economy. It should meet the requirement of minimal interference with the heritage itself and its environment, avoiding the impacts caused by activities such as inspections, scientific research, and surveying and mapping. It should achieve the sustainable monitoring and analysis of heritage, and make the protection plans and strategies economical, effective, and environmentally friendly. It should strive to meet the sustainability throughout the whole process of technical practice, rather than just the sustainability during the application process after the model and platform are constructed. Based on the above literature review, this paper takes the sustainable path of HBIM technology as the theme and puts forward sustainable ideas and suggestions for the two major stages of the technical practice respectively.

1. Sustainability in the Model Construction Stage: Currently, there are many software programs available for implementing HBIM models (Table 1). By utilizing these platforms, we can use NAS cloud servers in the pre - model - construction stage to exchange and update BIM software model files, enabling cross - time - space, cross - specialty, and cross - platform collaborative work among different model and data entry teams, thus achieving sustainability in the model construction stage. In addition, through the division of labor and cooperation among different teams, mutual review and communication can be carried out, further improving the accuracy and integrity of the model. For example, ArchiCAD (Graphisoft), Tekla Structures, Bentley System, Revit Autodesk, and AccaSoftware Edificius (the component family libraries of the above software that are adapted to traditional Chinese architecture need to be built separately, which is also a relatively long process) can all achieve the exchange of model files. In China, Revit Autodesk and Bentley System are the main ones. They can not only be adapted to the construction of HBIM models for ancient buildings but also have the stability to meet the IFC data exchange (under the condition of compatibility between versions). Currently, the HBIM workflow proposed by Xu Chaoran and Wu Cong from Tianjin University in China can basically achieve sustainability [75]. In addition, Liu Huiyuan[85] , Di Yajing[86]from this team also put forward the concepts of the whole life cycle and comprehensive sharing. Although Chang Zilu[87] proposed the ideas of real-time monitoring, data sharing, and sustainable updating, she did not present specific implementation plans.

Table 1. HBIM modeling software Data source: Author's summary.

HBIM modeling software classification		
BIM platform name	**Main functions**	**Remark**
Autodesk Revit Architecture	Architectural modeling and parametric design	Dynamo (suitable for NAS file exchange)
Autodesk Revit Structure	Structural modeling and parametric design	Dynamo (suitable for NAS file exchange)
Bentley Architecture	BIM modeling	(Suitable for NAS file exchange)
AccaSoftware Edificius	CADBuilding information modeling design and 3D CAD	Professionally developed software (suitable for NAS file exchange)
Vico Office Vico Software	Five-dimensional conceptual modeling	
Trelligence Affinity	Concept design modeling	Early design stage

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Graphisoft ArchiCAD	Architectural Concept Modeling	(Suitable for NAS file exchange)
Tekla TeklaStructures	Architectural Concept Modeling	
Nemetschek Vectorworks Designer	Architectural Concept Modeling	

2. Sustainability in the Model Application Stage: This stage mainly relies on the HBIM platform, and its sustainable design involves several aspects such as model access, display, monitoring, analysis, interaction, and research. For example, through customizing the HBIM repository and platform, the sustainable management and remote access of architectural heritage can be achieved. By using software and approaches such as Navisworks Freedom, Tekla BIMsight, Open BIM xBIMXplorer, VR, and AR, sustainable education, interaction, and research can be realized. By using software such as Ecotect Analysis, DAYSIM, and Energy Plus (Table 2), as well as remote detection instruments (PIR, LUX level sensor, VOC and dB sensor, CO2 level sensor, etc.), the sustainable monitoring, diagnosis, and energy conservation of the structure and space of architectural heritage can be achieved.

Table 2. HBIM functional analysis software Data source: Author's summary.

HBIM functional analysis software		
BIM platform name	**Main functions**	**Remark**
Autodesk Robot	Building structure analysis	Bidirectional link to Autodesk Revit Structure
Autodesk Ecotect	Building energy analysis	Weather, energy, water, carbon emissions analysis
Autodesk Green Building Studio	Building energy analysis	Measure energy use and carbon footprint
Bentley Systems Structural Analysis Design Detailing, Building Performance	Structural analysis, detailing, earthwork calculations, building performance	Measure, evaluate and report building performance
Beck Technology DProfiler	Cost estimate	With real-time cost estimation function
Vico Software Vico Office	Cost and schedule estimates	
Autodesk Robot	Building structure analysis	Bidirectional link to Autodesk Revit Structure

In addition to the above-mentioned methods for achieving the sustainability of HBIM, the current combination of HBIM with artificial intelligence, the Internet of Things and Digital Twins (IoT & Digital Twins), Mixed Reality, machine learning, and other means can offer more approaches and models for sustainability. For instance, it can realize aspects such as the Automated Scan-to-BIM workflow, Auto-classification and data enrichment of heritage information, Predictive maintenance, and Preventive conservation. This will be the main development direction of HBIM technology in China, as well as the major direction for the future protection, update, and application of architectural heritage information. It is also a convenient way to achieve sustainability.

Certainly, the sustainability of HBIM technology in China still confronts numerous problems and external irresistible factors:

- The research outcomes are rather fragmented, and a great deal of research lacks systematicness. It is merely aimed at completing different stages of model construction. Hence, there is still a long journey ahead to achieve sustainability.
- The current issues of software updates and compatibility also give rise to difficulties in realizing the sustainability of HBIM. Take, for instance, the compatibility and update problems between

HBIM software versions and IFC versions. The conversion of data between different versions directly impacts the sustainable development of HBIM technology.

- At present, the implementation of HBIM technology still requires a substantial amount of capital and human resources, and it demands an even longer process for research. This remains a challenge for smaller teams.

Overall, the sustainability of HBIM technology needs to be established at the application levels such as sustainable management, sustainable education, sustainable monitoring, sustainable display, and sustainable energy conservation. This is also in line with the three dimensions of economy, society, and environment in the concept of sustainable development. Currently, the development of HBIM technology in China not only needs to break away from the work logic and mindset of merely focusing on completing model construction and digital display, but also should carry out explorations and research in aspects such as remote access to databases, construction of cross-cycle management platforms, display of interactive icons, and continuous detection and analysis of heritage structures.

5. Results

This paper focuses on the development and application status of HBIM in the protection of Chinese architectural heritage, as well as the evaluation and prospects of the sustainability of HBIM technology. This research explores the relationship between HBIM and sustainability, reviews the current development stage and status of HBIM in China, and sorts out five aspects of the current development of HBIM, including building heritage information models and visualization display, automatic modeling algorithms and automated routes, parametric and procedural modeling, multi - dimensional extended applications, and the construction and management of collaborative platforms. It is found that the current development and research of HBIM in China are still at the two levels of exploring model - building methods and model visualization display, and there is a tendency to be "fragmented". Only a few scholars have carried out research in the other four aspects, but still have not conducted in - depth exploration from the perspective of sustainability. In contrast, foreign scholars have carried out a large number of studies by updating and customizing HBIM repositories, establishing remote access methods, sustainably recording multi - source information of heritage, building HBIM cross - cycle management platforms, and sustainably collecting building energy performance. Finally, based on the above analysis and research, this paper puts forward ideas and suggestions regarding the sustainability of HBIM technology in China. It also summarizes the possible dilemmas that HBIM may encounter during the process of sustainable development, encompassing multiple aspects such as funds, teams, software, and data conversion.

Overall, the research findings of this paper offer a perspective for the future research and development of HBIM in China. They demonstrate the possibility of HBIM achieving sustainable development in the three dimensions of economy, society, and environment, and summarize the potential in application aspects such as sustainable management, sustainable education, sustainable monitoring, sustainable display, and sustainable energy conservation. As such, this paper holds certain reference value and research significance.

6. Discussion

First, this paper only focuses on the research achievements of domestic Chinese scholars and foreign research papers on HBIM in China. The sources include databases such as CNKI, Web of Science, Elsevier ScienceDirect, IEEE/IET Electronic Library, and Wiley. However, this cannot fully cover all academic achievements. In the future, this paper will continuously increase the research samples and conduct further in-depth research and discussion on the sustainability of HBIM technology.

Second, the articles actually selected in this paper span from 2010 to 2025, and high-quality articles included in the Peking University Core Journals, CSSCI, SCI, and SSCI have been emphasized as references. Other articles are only reviewed and discussed as references. In the future, this paper will screen and study more articles to ensure the rigor and rationality of the research conclusions.

Third, the theme explored in this paper still poses certain challenges, which have been pointed out in the discussion of the last subsection of this paper. It can be said that various variables such as software, technology, platforms, funds, and time will all affect the sustainability of HBIM technology. However, this does not deny the value and significance of the research theme of this paper. The purpose of this literature review is to provide a perspective for the future research and development of HBIM and to attract the attention of more scholars.

Fourth, the viewpoints in this paper are possible and constructive viewpoints proposed based on the current domestic research achievements of HBIM in China, the development stage of this technology in China, its research highlights and deficiencies, as well as the latest foreign research achievements. This paper will focus on these viewpoints and directions and carry out applied research based on the current scientific research teams and platforms.

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